

The tutorial contains educational materials intended for Master's students majoring in metallurgy and PhD students enrolled in degree programmes related to materials science and metallurgy. It comprises texts, exercises with supporting data, and a Ukrainian-English dictionary of professional terms that help to learn basic industry-specific terminology used in mechanical engineering, material properties, metalforming processes, and rolling technologies and machines.



FOR METAL FORMING ENGINEERING AND RESEARCH IN METALLURGY AND MATERIAL SCIENCE

Iryna NIKITINA
Tamara KYRPYTA
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Volodymyr KUKHAR
Khrystyna MALII
Olena KHOROSHAILO

Tutorial



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TECHNICAL UNIVERSITY “METINVEST POLYTECHNIC”

ENGLISH
FOR METAL FORMING ENGINEERING
AND RESEARCH IN METALLURGY
AND MATERIAL SCIENCE

Tutorial

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ТОВ «ТЕХНІЧНИЙ УНІВЕРСИТЕТ “МЕТІНВЕСТ ПОЛІТЕХНІКА”»

АНГЛІЙСЬКА
ДЛЯ ФАХІВЦІВ У ГАЛУЗІ ОБРОБКИ МЕТАЛІВ
ТИСКОМ І ДОСЛІДЖЕНЬ У МЕТАЛУРГІЇ
ТА МАТЕРІАЛОЗНАВСТВІ

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Англійська для фахівців у галузі обробки металів тиском
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Посібник містить навчальні матеріали для здобувачів вищої освіти, які навчаються за магістерськими освітніми програмами металургійного спрямування, та здобувачів рівня доктор філософії, які навчаються за освітніми програмами, пов'язаними з матеріалознавством та металургією. Представлені тексти, вправи з ілюстративним матеріалом та українсько-англійський словник професійних термінів, що допомагають засвоїти базову спеціальну термінологію в області механічної інженерії, властивостей матеріалів, процесів обробки матеріалів тиском, технологій та машин прокатного виробництва.

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ВСТУП

Навчальний посібник “English for Metal Forming Engineering and Research in Metallurgy and Material Science” є доповненим та розширеним варіантом попереднього видання “English for Metal Forming Engineering” [1]. Посібник укладено з метою поглиблення знань здобувачів вищої освіти з фахової іноземної (англійської) мови, а також із лексики та граматики. Навчальні матеріали побудовано на основі автентичних текстів із професійної тематики із проставленням посилань на першоджерела. Розроблена методологія викладання сприятиме розвитку соціолінгвістичної та лінгвістичної компетенцій здобувачів закладів вищої освіти, покращуючи досвід засвоєння ними наукових і технічних текстів англійською, навички наукової комунікації та професійних ділових переговорів.

Навчальний посібник складено з чотирнадцяти змістових частин, перші тринадцять із яких містять необхідний лексичний мінімум, лексико-граматичні вправи, автентичні тексти з професійної тематики, комунікативні вправи, спрямовані на розвиток усного та писемного мовлення і закріплення знань із лексики і, частково, з граматики. У якості чотирнадцятої частини подано технічний україно-англійський словник спеціальної термінології, що стосується механічної інженерії (матеріалознавства і металургії), а саме прокатного виробництва.

Матеріал посібника дозволяє поступово й цілеспрямовано формувати мовні навички та вміння студентів завдяки системі завдань і вправ для професійного іншомовного читання. До кожної теми входять завдання та вправи на ознайомлення та тренування активного словникового запасу, а також розмовні та письмові вправи. Посібник “English for Metal Forming Engineering and Research in Metallurgy and Material Science” містить значну кількість ілюстрацій, таблиць і схем, що підвищує пізнавальну діяльність і якість знань студентів, сприяє кращому засвоєнню та закріпленню вивченого матеріалу.

Посібник складено на основі сучасних принципів вивчення іноземної мови та враховує потреби майбутніх фахівців і практиків, які бажають удосконалити свої навички іноземної мови.

Словникові вправи побудовані так, щоб студенти могли розширити, а також активізувати словниковий запас для подолання труднощів перекладу.

CHAPTER 1

ENGINEERING — WHAT'S IT ALL ABOUT?

1.1 List the main branches of engineering

Combine your list with others in your group. Then read this text to find out how many of the branches listed are mentioned.

Engineering is largely a practical activity. It is about putting ideas into action. Civil engineering is concerned with making bridges, roads, airports, etc. Mechanical engineering deals with the design and manufacture of tools and machines. Electrical engineering is about the generation and distribution of electricity and its many applications. Electronic engineering is concerned with components and equipment for communications, computing, and so on.

Mechanical engineering includes marine, automobile, aeronautical, heating and ventilating, and others. Electrical engineering includes electricity generating, electrical installation, lighting, etc. Mining and medical engineering belong partly to mechanical and partly to electrical [1, 2].

1.2 Study these illustrations (see Fig. 1.1, p. 8)

They show some of the areas in which engineers work. What kinds of engineers are concerned with these areas?

Transport. Cars, trains, ships, and planes are all products of mechanical engineering. Mechanical engineers are also involved in support services such as roads, rail track, harbours, and bridges.

Food processing. Mechanical engineers design, develop and make the machines and processing equipment for harvesting, preparing and preserving the foods and drinks that fill the supermarkets.

Medical engineering. Body scanners, X-ray machines, life-support systems, and other high-tech equipment result from mechanical and electrical engineers combining with medical experts to convert ideas into life-saving and preserving products.

Building services. Electrical engineers provide all the services we need in our homes and places of work, including lighting, heating, ventilation, air-conditioning, refrigeration, and lifts [1, 2].

Energy and power. Electrical engineers are concerned with the production and distribution of electricity to homes, offices,

industry, hospitals, colleges and schools, and the installation and maintenance of the equipment involved in these processes.

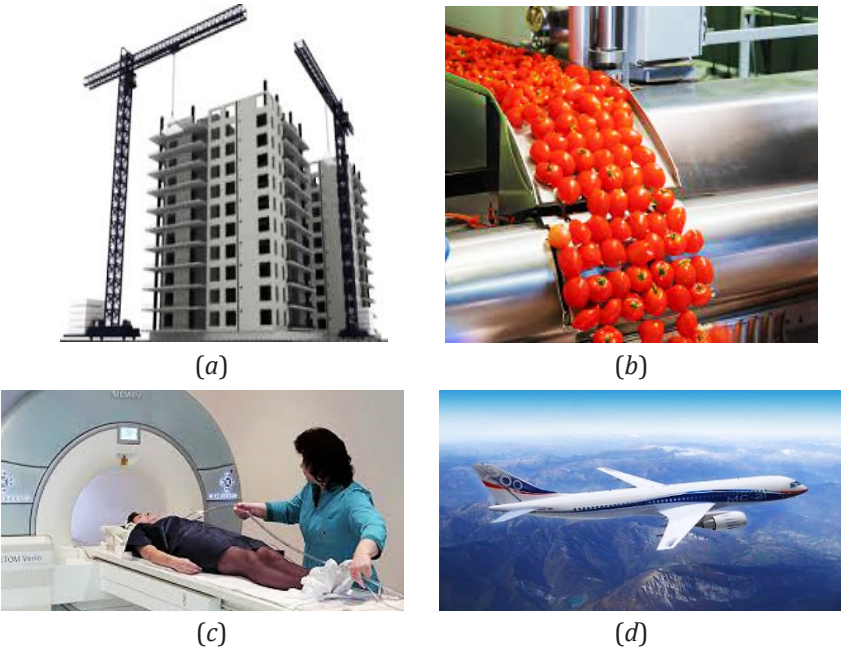


Figure 1.1 — Illustrations to point 1.2 [1]

TASKS

1.3 Language study *deals with/is concerned with*

What is the link between columns (see Table 1.1)?

Table 1.1 — Task to point 1.3 [1, 2]

mechanical electrical	machines electricity
--------------------------	-------------------------

1.4 Matching

In the Table 1.2 (see p. 9) left column lists a branch of engineering or a type of engineer. Right column lists things they are concerned with. We can show the link between them in a number of ways [1, 2]:

1. Mechanical engineering **deals with** machines.
2. Mechanical engineers **deal with** machines.
3. Mechanical engineering **is concerned with** machines.
4. Mechanical engineers **are concerned with** machines.
5. Machines **are concerned with** mechanical engineers.

Match each item in left column with an appropriate item from right column and link the two in a sentence.

Table 1.2 — Task to point 1.4 [1, 2]

1) marine	a) air-conditioning
2) aeronautical	b) roads and bridges
3) heating and ventilating	c) body scanners
4) electricity generating	d) cables and switchgear
5) automobile	e) communications and equipment
6) civil	f) ships
7) electronic	g) planes
8) electrical installation	h) cars and trucks
9) medical	i) power stations

Over to you

Fill in the gaps in the following description of the different branches of engineering using information and language you have studied in this chapter.

The main branches of engineering are civil, _____, _____ and electronic. Mechanical engineering is _____ machinery of all kinds. This ranch of engineering includes _____, automobile, _____, and heating and ventilating. The first three are concerned with transport: _____, _____, cars and planes. The last _____ with air-conditioning, refrigeration, etc. [1, 2].

Electrical engineering deals with _____ from generation to use. Electricity generating is concerned with _____ stations. Electrical installation deals _____ cables, switchgear, and connecting up electrical equipment.

Two branches of engineering include both _____ and _____ engineers. These are mining and _____ engineering. The former deals with mines and mining equipment, the latter with hospital _____ of all kinds [1, 2].

CHAPTER 2

FORMING, WORKING AND HEAT-TREATING METAL

2.1 Casting, sintering and extruding metal

Metal can be **formed** into shapes using heat and pressure. **Casting** involves heating metal until it becomes **molten** (liquid) and pouring it, or forcing it under pressure, into a mould called a **die**. Instead of being **cast**, metal components can be formed by **sintering**. This is done by using metal powder instead of molten metal. The powder is placed in a die and compressed into a solid mass. It is then heated (though not melted) until it becomes sintered that is, the powder particles join together structurally, due to the heat [1, 3–9].

Metal can also be shaped by **extruding** it into long lengths. **Extrusion** involves heating metal until it is molten, then forcing it at high pressure through a shaping tool also called a die to form bars or tubes, for example. At the same time, the metal cools and becomes solid [1, 3–9].

2.2 Working metal

Traditionally, many metal tools were made by heating iron bars in a fire, called a **forge**, until they were **red hot** or (hotter still) **white hot**. The metal was then worked — in other words, shaped by hammering it. **Working metal** using pressure (for example, hammering) is also called **forging**. The same basic technique is still in use today, especially with steel. However, large, automated machines are now used. Metal is often worked (or **forged**) when hot (**hot forged**), but may also be worked when it is cold (**cold forged**).

A common forging technique is **drop forging**, where a heavy hammer is dropped onto a piece of metal. A die fixed to the hammer compresses the metal into the required shape (see Fig. 2.1). Rollers can also be used to apply compression, with or without heat, to produce **hot rolled** or **cold rolled** metal.



Figure 2.1 — Drop forged steel (to point 2.2) [1]

Forging also increases the hardness of metal. This is called **work hardening**. Metal becomes **work hardened** because its structure is changed by compression. The same result can be achieved without hammering or rolling and therefore without changing the component's shape — by **shot-peening**. This involves firing small metal balls (metal shot) at the surface of components (when cold), at high speed. After components have been shot-peened, their surface is significantly harder [1, 3].

2.3 Heat treating metal

The properties of a metal can be changed by **heat treating** it – that is, heating and cooling the metal. The table below (see Table 2.1), from the technical information section of a steel supplier's website, summarizes the main types of **heat treatment** [1, 3].

Table 2.1 — The main types of heat treatment (to point 2.3) [1, 3]

Type of heat treatment	Description of process	Properties of treated metal
Quenching	Metal is heated, and then dipped in water or oil to cool it rapidly.	Quenched metal is harder, but tends to be more brittle.
Annealing	Metal is heated, and then allowed to cool slowly.	Annealed metal is generally softer and more elastic.
Tempering	Metal is heated and kept at a high temperature for a period of time.	Tempered metal possesses a balance between hardness and elasticity.
Precipitation hardening (also called age hardening)	A process similar to tempering, but heat is maintained for longer.	Precipitation-hardened metal is harder than tempered metal.
Case hardening (also called surface hardening)	Metal is heated in specific types of gas (not in air), causing its surface to absorb elements such as carbon.	Only the outer surface of case-hardened metal becomes harder.

TASKS

2.4 Tick what is usually required in the metal forming processes (1–3), Table 2.2. Look at point 2.1 to help you [1, 3]

Table 2.2 — Task to point 2.4 [1, 3]

Processes	Molten metal	Metal powder	Heat	Pressure	A die
1. Casting	☐	☐	☐	☐	☐
2. Sintering	☐	☐	☐	☐	☐
3. Extrusion	☐	☐	☐	☐	☐

2.5 Decide whether the sentences below are true or false, and correct the false sentences. Look at point 2.2 to help you [1, 3]

1. Metal must always be heated before it can be forged.
2. When referring to metals, the terms working and forging mean the same.
3. A common reason for forging metal is to increase its hardness.
4. One way of forging metal is by heating it and then rolling it.
5. Metal can only be rolled after it has been heated to a high temperature.
6. When metal is drop forged, it is subjected to compression.
7. Metal can only be work hardened by the process of hot forging.
8. Shot-peening is a hot forging technique used to work hardened metal.

2.6 Make correct sentences using one part from each column (see Table 2.3). Look at point 2.3 to help you [1, 3]

Table 2.3 — Task to point 2.6 [1, 3]

1	2	3
1. If a metal is precipitation hardened,	it is held at a high temperature for a time,	making it harder, but more brittle.
2. When metal is annealed,	it is heated within a gas	to improve its hardness without reducing its elasticity too much.

End of Table 2.3

1	2	3
3. If metal is quenched, this means	it can also be described as age hardened,	to harden only the metal near the surface.
4. When a metal is tempered,	its temperature is allowed to decrease gradually	because it is heated for a long time.
5. If a metal case is hardened,	its temperature is reduced rapidly	in order to make it more elastic and less brittle.

2.7 Replace the underlined expressions in the report extract with alternative words and expressions from point 2.1, 2.2 and 2.3. Sometimes there is more than one possible answer [1, 3]

The first stage in manufacturing the blades for the cutting tools is to form them into an approximate shape by (1) a process of squeezing molten metal through a die. Before the blades have cooled, they are then (2) hammered while still at a high temperature — a process which not only flattens them into their final shape, but also ensures the metal becomes (3) harder as a result of the hammering action. The blades are then (4) cooled quickly in water. Finally, they are (5) bombarded with small metal balls in order to further increase their surface hardness [1, 3].

Over to you

Think of a type of steel component that needs to have specific properties. Suggest different ways of obtaining these properties by forging or heat treating the steel.

CHAPTER 3

LOAD, STRESS AND STRAIN

3.1 Load (Force)

When engineers design a machine or structure, they need to know what forces will ***be exerted on*** it (put pressure on it). In engineering, forces are called ***loads***. Usually, several different loads (see Table 3.1) will ***act on*** — apply force to — the components in a machine, or the members (parts) of a structure [1, 3].

Table 3.1 — Types of load (to point 3.1) [1, 3]

Type of load	Description	Examples
dead load	a load that never changes, such as the <i>self-weight of a structure</i> (its own weight)	the weight of the concrete from which a bridge is built
live load	a load whose magnitude can be different at different times — usually imposed on (put on) a machine or structure by something that is not part of the machine or structure	cargo carried by a truck — different weights of cargo may be carried on different trips
static load	a load that remains still (does not move)	the dead load of a building, or a live load which remains still, such as snow lying on a roof
dynamic load	a moving load, such as one which produces a sudden shock but lasts for only a brief moment (an impulse)	aircraft wheels hitting the runway on landing
point load	a load which is concentrated – that is, one which acts on a small area	the end of a set screw pressing on a shaft
uniformly distributed load (UDL)	a load which is spread evenly over a reasonably large area	the weight of water acting on the bottom of a swimming pool

A component or member which is designed to ***carry*** (or ***bear***) a ***load*** is called a ***load-bearing*** component or member.

To predict what will happen when components are ***loaded***, engineers calculate the ***magnitude*** (size) of each load, and also work out the direction of the load — for example, vertically downwards. Load is therefore a ***vector quantity*** (or vector) — that is, a measurement with both a magnitude and a direction. This is different to a scalar quantity, which has a magnitude only.

3.2 Stress and strain

The information below is intended to give you an understanding of the application of the terminology of “strength of materials” in the English language. The information is taken mainly from sources [10, 11].

Stress And Strain. You may have noticed that certain objects stretch easily, but stretching objects such as an iron rod sounds impossible, right? In this article, we will help you understand why a few objects are more malleable than others. Mainly, we will discuss Stress-Strain Curve because it helps us know the amount of load or stress that a material can handle before it stretches and breaks.

What is Stress? Stress is defined as force per unit area within materials that arises from externally applied forces, uneven heating, or permanent deformation and that permits an accurate description and prediction of elastic, plastic, and fluid behaviour.

Stress is given by the following formula [10, 11]:

$$\sigma = \text{Stress} = \frac{\text{Force}}{\text{Area}} = \frac{F}{A},$$

where σ is the stress applied, F is the force applied and A is the area of the force application (see Fig. 3.1).

The unit of stress is N/m^2 .

Types of Stress. Stress applied to a material can be of two types as follows:

Tensile Stress. The external force per unit area of the material resulting in the stretch of the material is known as tensile stress.

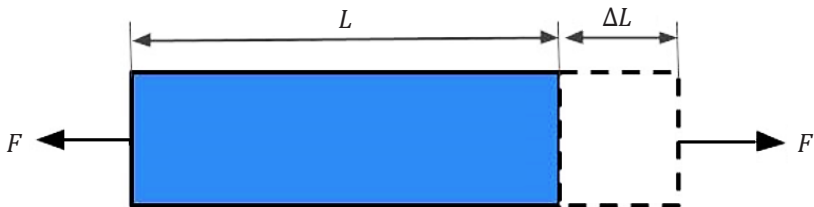


Figure 3.1 — Elongation of a sample under load
(to point 3.2) [11]

Compressive Stress. Compressive stress is the force that is responsible for the deformation of the material, such that the volume of the material reduces.

What is Strain? Strain is the amount of deformation experienced by the body in the direction of force applied, divided by the initial dimensions of the body.

The following equation gives the relation for deformation in terms of the length of a solid [10, 11]:

$$\varepsilon = \text{Strain} = \frac{\text{Change in Length}}{\text{Original Length}} = \frac{\Delta L}{L},$$

where ε is the strain due to the stress applied, ΔL is the change in length and L is the original length of the material (see Fig. 3.1).

The strain is a dimensionless quantity as it just defines the relative change in shape.

Types of Strain. Strain experienced by a body can be of two types depending on stress application as follows:

Tensile Strain. The deformation or elongation of a solid body due to applying a tensile force or stress is known as Tensile strain. In other words, tensile strain is produced when a body increases in length as applied forces try to stretch it.

Compressive Strain. Compressive strain is the deformation in a solid due to the application of compressive stress. In other words, compressive strain is produced when a body decreases in length when equal and opposite forces try to compress it.

Stress-Strain Curve. When we study solids and their mechanical properties, information regarding their elastic properties is most important. We can learn about the elastic properties of materials by studying the stress-strain relationships, under different loads, in these materials.

The material's stress-strain curve (see Fig. 3.2, p. 17) gives its stress-strain relationship. In a stress-strain curve, the stress and its corresponding strain values are plotted. An example of a stress-strain curve is given below.

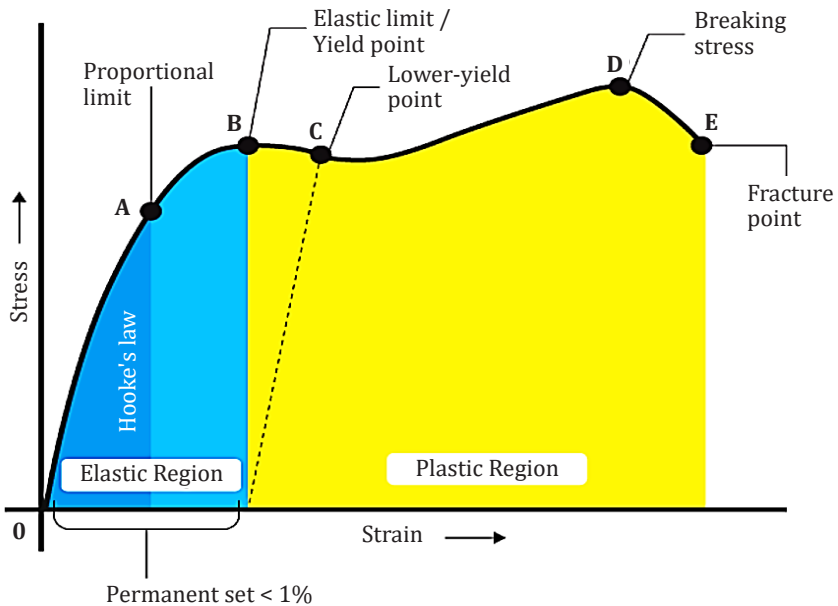


Figure 3.2 — Generalized view of the stress-strain curve
(to point 3.2) [10]

How is Stress-Strain Graph Plotted? We need to perform material tensile testing on the standard specimen to plot the Engineering and True Stress-Strain Curves using Universal Testing Machine (see Fig. 3.3, p. 18).

Universal Testing Machine (UTM) consists of two claws. These claws hold and pull the extreme ends of the test specimen at a uniform rate.

During tensile testing, you need to record any change in the length of the test specimen for applied load at various time stamps until the test sample fractures. These values determine variation in stress acting on the test sample for strain value.

Afterward, we can plot the stress-strain graph keeping mechanical stress values on the vertical axis and strain on the horizontal axis.

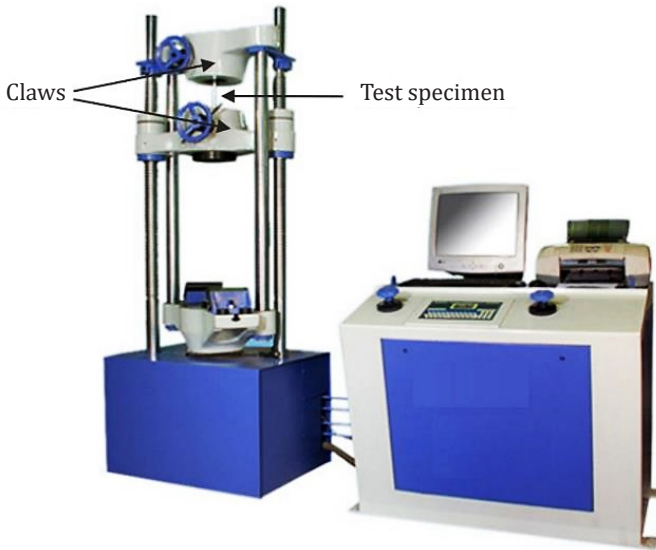


Figure 3.3 — Universal Testing Machine (UTM) (to point 3.2) [11]

Explaining Stress-Strain Graph. The different regions in the stress-strain diagram are [11]:

Proportional Limit. It is the region in the stress-strain curve that obeys Hooke's Law. In this limit, the stress-strain ratio gives us a proportionality constant known as Young's modulus. The point OA in the graph represents the proportional limit.

Elastic Limit. It is the point in the graph up to which the material returns to its original position when the load acting on it is completely removed. Beyond this limit, the material doesn't return to its original position, and a plastic deformation starts to appear in it.

Yield Point. The yield point is defined as the point at which the material starts to deform plastically. After the yield point is passed, permanent plastic deformation occurs. There are two yield points (i) upper yield point (ii) lower yield point.

Ultimate Stress Point. It is a point that represents the maximum stress that a material can endure before failure. Beyond this point, failure occurs.

Fracture or Breaking Point. It is the point in the stress-strain curve at which the failure of the material takes place.

3.3 Application

The extract below is from sources [1, 3].

In a test, a thick cable is used to pick up a heavy object. The cable stretches slightly, but lifts the weight. A second test is done using a thinner cable — one with only half the cross-sectional area of the thick cable. This time, the cable stretches, and then breaks.

Why did the thinner cable **fail**? Not due to a higher load, as the weight was the same. The **failure** was due to **stress**. Stress is force per unit of area, and is measured in newtons per square metre, or Pascals ($1\text{ N/m}^2 = 1\text{ Pa}$). The thinner cable was therefore **stressed** twice as much as the thick cable, as the same load was **concentrated** into a cross-sectional area that was 50% smaller.

Why did the thick cable stretch but not break? When objects are stressed, they **deform** — that is, they change size (if only slightly). In the tests, the cable **extended** — it increased in length. **Extension** can be measured as a change in an object's length compared with its **original length** before stress was applied. This measurement is called **strain**. According to a law called Young's Modulus of Elasticity, stress is **proportional** to strain. In other words, a percentage increase in stress will cause the same percentage increase in strain. However, this is only true up to a point called the **limit of proportionality**. If a material is **overstressed** — beyond this limit — it will start to become **strained by** a higher proportion. Stress and strain will therefore become **disproportional** [1, 3].

TASKS

3.4 Replace the underlined words and expressions with alternative words and expressions from point 3.1 and Table 3.1

If you look at the objects around you, it's difficult to find something that couldn't be smashed with a hammer. But if you laid a hammer down carefully on any of those objects, the (1) force which it (2) put

on them wouldn't be sufficient to cause even the slightest damage. This comparison illustrates the difference between [1, 3]:

- a (3) moving force, which combines mass and movement to apply (4) a shock;
- a (5) still force, which consists only of an object's (6) own mass.

Between the two situations, the (7) size of the load (8) placed on the surface is dramatically different.

The above comparison illustrates another difference in the way surfaces are (9) pressured. When a hammer is laid horizontally on a surface, its weight is spread over a relatively large area. It therefore applies a (10) spread out force. By contrast, when a hammer hits something, only the edge of the hammer head comes into contact with the surface. The force is therefore (11) focused in a small area, applying a (12) localized pressure [1, 3].

3.5 Complete the technical checklist (1-7) based on the questions (A-G), using words from point 3.1 and 3.2 and Table 3.1. The first one has been done for you

- A. Which components need to carry load?
- B. What types of load will be carried by each part? Which loads will remain constant, and which will differ depending on use and circumstances?
- C. What amount of load will be exerted, in newtons?
- D. In what directions will the loads act?
- E. For the materials used, how concentrated can maximum loads be without putting the component under too much pressure?
- F. How much deformation can be expected?
- G. If something breaks, will the assembly collapse dangerously, or in a controlled, relatively safe way?
1. Determine which components are load-bearing.
 2. Analyze the types of load that will _____ on each part. Assess _____ loads and _____ loads.
 3. Calculate the _____ of loads as _____ quantities.
 4. Evaluate loads as _____ quantities.
 5. Determine the maximum level of _____ that can be carried by materials without causing them to be _____.

6. Calculate percentages of _____.
7. Assess the consequences if a component _____ determining the potential dangers of the _____.

Over to you

Think about a machine or structure you're familiar with. Give examples of types of load which act on specific components or members. Say which components are stressed the most and explain why.

CHAPTER 4

FORCE, DEFORMATION AND FAILURE

4.1 Types of force and deformation (see Table 4.1 and Fig. 4.1)
Basic information in this chapter is taken from the source [12].

Table 4.1 — Types of force and deformation (to point 4.1) [1, 3]

Non-technical word	Technical term (noun)	Adjective used with the nouns <i>stress</i> , <i>load</i> and <i>force</i>	Initial deformation of component or member
stretching	<i>tension</i>	<i>tensile stress</i>	It will <i>extend</i> (lengthen).
squashing	<i>compression</i>	<i>compressive stress</i>	It will <i>compress</i> (shorten).
bending	<i>bending</i>	<i>bending stress</i>	It will <i>bend</i> — we can also say it will <i>deflect</i> or <i>flex</i> . Beams usually <i>sag</i> , deflecting downwards. In some cases, <i>deflection</i> or <i>flexure</i> is upward — the beam <i>hogs</i> .
scissoring	<i>shear or shearing</i>	<i>shear stress</i>	It will deform very little, failing suddenly.
twisting	<i>torsion or torque</i>	<i>torsion al stress</i>	It will <i>twist</i> .

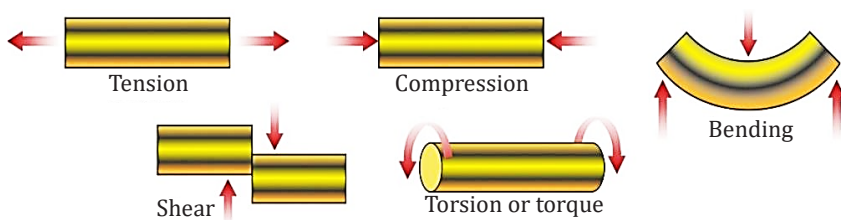


Figure 4.1 — Types of force deformation (to point 4.1) [1]

Bending comprises two opposite stresses: tension and compression. This is shown in the diagram of a *simply supported beam* (see Fig. 4.2, p. 23). As a result of the bending force, the lower half of the beam is in *tension* and the upper half is in *compression*. These opposite stresses reach their maximum at the upper and lower surfaces of the beam, and progressively decrease to zero at the *neutral axis* — an imaginary line along the centre of the beam which is free from stress [1, 3].

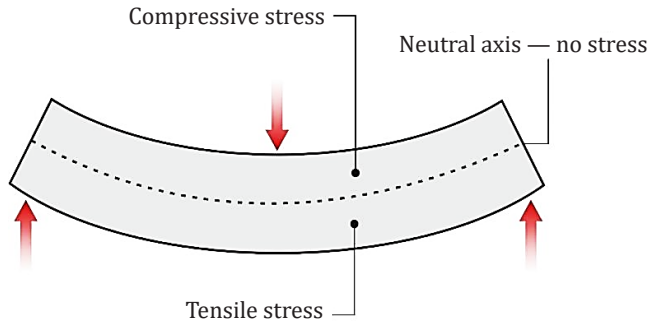


Figure 4.2 — A simply supported beam — three-point bending (to point 4.1) [1]

4.2 Types of failure

The ultimate failure of a component or *structural member* depends on the type of force [1, 3]:

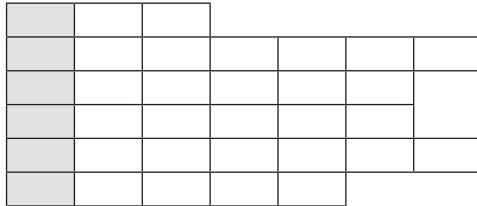
- in tension — it will **fracture**;
- in compression — if it is thick, it will **crush** (squash); if it is **slender** (long and thin), it will **buckle**, bending out of shape;
- in **bending** — it will fracture on the side of the component which is in tension, or crush on the side which is in compression — or fail due to a combination of both;
- in **shear** — it will shear (break due to shear force);
- in **torsion** — it will fracture or shear.

When vertical members can no longer resist a load they either crush or buckle.

TASKS

4.3 Complete the word puzzle and find the word going down the page. Look at point 4.1 and 4.2 to help you [1, 3]

- 1) bend downwards
- 2) a twisting force
- 3) take a force without breaking
- 4) increase in length, due to tension
- 5) long and thin, likely to buckle rather than crush
- 6) a scissoring force



4.4 The question below, which was posted on a forum on a construction website, contains a mistake about a technical fact. Can you find the mistake? Look at point 4.1 opposite to help you [1, 3]

Post 1:

I was under the impression that concrete and steel bars were used together in reinforced concrete (RC) because concrete is good at resisting compression and poor at resisting tension, whereas steel is strong in tension. I also thought the steel always went at the bottom of an RC beam because that's the part that's in tension, whereas the top of the beam is free from stress. But if that's the case, when you see reinforcement being fixed in big RC beams, why are there bars both at the bottom and at the top? [1, 3]

4.5 Now complete a structural engineer's answer to the question in point 4.4 using the words in the box (see Table 4.2). Look at point 4.1 and 4.2 opposite and point 4.4 above to help you [1, 3]

Table 4.2 — Task to point 4.5 [1, 3]

bending compression	compressive crushing	deflect deflection	fracturing hog	neutral sag	tensile tension
------------------------	-------------------------	-----------------------	-------------------	----------------	--------------------

Replies to post 1 (see point 4.4) [1, 3]:

Let me start by clarifying something. When a beam is subjected to (1) stress, the bottom part is generally in tension, as you rightly say. But the top part is not 'free from stress', as you suggest. It's in (2) Only the horizontal centerline of the beam — a zone called the (3) axis — is not stressed. It's also important to be clear about the strengths of concrete and steel. You're right that concrete is poor at resisting (4) stress as it's prone to failure by (5) suddenly. It's also true that concrete is good at resisting (6) stress. But steel is much stronger than concrete, not just in (7) as you point out, but also when it's compressed. So steel is often put in the tops of beams in cases where the beam is subjected to high levels of compression, meaning that the concrete requires reinforcing to prevent it from (8) and failing.

Another possible reason for a beam having steel in the top is to take tension. Why would you get tension in the top of a beam? It's true that most beams want to (9) downwards because gravity causes them to (10), putting only the bottom of the beam in tension. But in some structures, there are beams or parts of beams that want to (11) — being forced into upward (12)

Over to you

Think about the different forces acting on a machine or structure you're familiar with.

How would the different components or members deform or fail if they were not adequately designed, or if they were overstressed?

CHAPTER 5

METAL FORMING PROCESSES

Basic information in this chapter is taken from the sources [1, 3, 13–15].

5.1 Introduction

Metal forming is a very important manufacturing operation. It enjoys industrial importance among various production operations due to its advantages such as cost effectiveness, enhanced mechanical properties, flexible operations, higher productivity, considerable material saving.

The objects and articles that we use in our daily life are man-made, engineered parts, which are obtained from some raw material through some **manufacturing process**. All these objects are made of a number of small components assembled into finished product. The pen that we use for writing, for example is made of several small parts, assembled together. An automobile is supposed to be an assembly of more than 15 000 parts, produced through various manufacturing operations.

Manufacturing of **finished parts** and **components** from raw materials is one of the most important steps in production.

Production encompasses all types of manufacturing processes. Manufacturing refers to the conversion of raw materials into finished products employing suitable techniques.

There are several methods of manufacturing such as **metal casting, metal forming, metal machining, metal joining** and **finishing**. Some of the modern methods of manufacturing include micromachining, nanofabrication, ultraprecision manufacturing etc.

In order to fulfill the requirements of the ever-increasing demands of various types of industries, the manufacturing engineer has to choose the right type of material and the right type of equipment for manufacture so that the cost of production and the energy consumption are minimal.

The selection of suitable manufacturing process should also include concerns for environmental impacts such as air pollution, waste disposal etc.

Modern concepts such as lean manufacturing, adaptive control, agile manufacturing, group technology etc. have considerable influence on cost reduction and quality improvements of products. Computers and robots play important role in modern manufacturing techniques, today. Modeling and simulation of the process prior to mass production helps the manufacturing engineer fix up the best operating parameters and hence achieve the finished product to the utmost level of quality and cost-effectiveness.

5.2 Metal forming — definition

Materials are converted into finished products though different manufacturing processes. Manufacturing processes are classified into **shaping** (casting), **forming**, **joining**, and **coating**, **dividing**, **machining** and **modifying** material property (see Fig. 5.1).

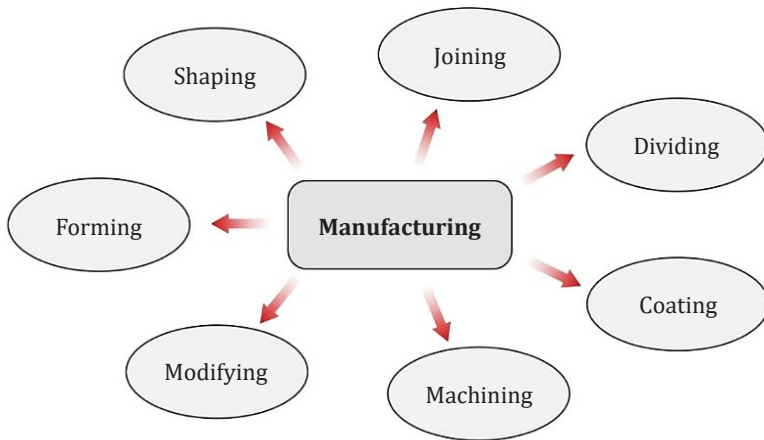


Figure 5.1 — Various operations on materials (to point 5.2)

Of these manufacturing processes, forming is a widely used process which finds applications in automotive, aerospace, defense and other industries.

Wrought forms of materials are produced through bulk or sheet forming operations. Cast products are made through shaping — molding and casting.

A typical automobile uses formed parts such as wheel rims, car body, valves, rolled shapes for chassis, stamped oil pan, etc.

In our daily life we use innumerable formed products e.g. cooking vessels, tooth paste containers, bicycle body, chains, tube fitting, fan blades etc.

Forming is the process of obtaining the required shape and size on the raw material by subjecting the material to plastic deformation through the application of tensile force, compressive force, bending or shear force or combinations of these forces.

TASKS

5.3 Answer the following questions

1. Why is metal forming important? What are its advantages?
2. What are the objects and articles that we use in our daily life obtained from?
3. What does manufacturing refer to?
4. Who has to choose the right type of material and the right type of equipment for manufacture?
5. Are computers and robots a part of modern manufacturing techniques?
6. How are manufacturing processes classified?
7. In what industries does forming find application?
8. How are wrought forms of materials produced?
9. What formed products do we use in our everyday life?
10. How do you define forming?

5.4 Match words or word combinations with their definitions (see Table 5.1)

Table 5.1 — Task to point 5.4 [1]

1) manufacturing engineer	a) a strategy that allows a company to be extremely flexible toward customers' needs and demands
2) manufacturing process	b) a person who focuses on the design, development and operation of integrated systems of production to obtain high quality & economically competitive products

End of Table 5.1

3) article	c) made or caused by human beings
4) finished product	d) the steps through which raw materials are transformed into a final product
5) man-made	e) a particular thing or item
6) agile manufacturing	f) the product that emerges at the end of a manufacturing process

5.5 Complete the following statements by choosing the answer which you think fits best. Are the other answers unsuitable? Why?

1. Manufacturing of finished parts and components from raw materials is one of the most important steps in production because:
 - a) the objects we use are obtained from some raw material;
 - b) all the articles we use in everyday life are made of a number of small components assembled into finished product;
 - c) it is very hard to produce automobiles.
2. The selection of suitable manufacturing process should also include:
 - a) the right type of material and right type of equipment for manufacture, as well as concerns for environmental impacts such as air pollution, waste disposal etc;
 - b) the requirements of the ever-increasing demands of various types of industries;
 - c) the modern methods of manufacturing.
3. Wrought forms of materials are produced through:
 - a) shaping — molding and casting;
 - b) shaping (casting), forming, joining, and coating, dividing, machining and modifying material property;
 - c) bulk or sheet forming operations.
4. Wheel rims, car body, valves, rolled shapes for chassis, stamped oil pan, etc:
 - a) are formed parts used in a typical automobile;
 - b) are formed products we use in our daily life;
 - c) are wrought forms of materials.

5. According to point 5.1, modern concepts such as lean manufacturing, adaptive control, agile manufacturing, group technology etc:
- have considerable influence on cost reduction and quality improvements of products;
 - play important role in modern manufacturing techniques;
 - include micro machining, nano-fabrication, ultra precision manufacturing etc.

5.6 Insert the missing words using the Table 5.2 below

Table 5.2 — Task to point 5.6 [1]

a) engineer	b) efficiency	c) engineering	d) manufacture	e) forged parts
-------------	---------------	----------------	----------------	-----------------

It cannot escape the attention of the cost and quality-conscious manufacturing (1) ____ that the number of forming processes in the (2) ____ of serial parts is increasing. Besides the classic advantages — e.g. the extraordinary properties of (3) ____ — it is the thinking in manufacturing sequences and substitution possibilities above all that reveals the chances within forming (4) ____ of accelerating or improving the (5) ____ of the finishing process and of using forming for property improvement.

5.7 Change the underlined words using their equivalents given in the Table 5.3

Table 5.3 — Task to point 5.7 [1]

fatigue	development	accuracy	favorable	manifold
---------	-------------	----------	-----------	----------

Increasing (1) veracity of cold massive forming and forging technology enables the production of ready-to-install parts. Such a process substitution has often not only cost advantages, but also leads to product advantages. The (2) acceptable structure alignment and resultantly higher (3) weariness strength of the workpieces permit smaller dimensioning without reducing the load capacity. In automotive engineering, this (4) new method has found use

in the lightweight construction of axes, gear shafts and hubs. Massive forming offers (5) multiple possibilities of component formation for a variety of applications.

Over to you

Think of one of manufacturing methods such as metal casting, metal forming, metal machining, metal joining and finishing you are familiar with. Describe specific aspects of it — the type of material and the type of equipment they use.

CHAPTER 6

CLASSIFICATION

OF METAL FORMING OPERATIONS

Basic information in this chapter is taken from the sources [1, 3, 13–15].

6.1 Classification of forming (Fig. 6.1)

Typically, metal forming processes can be classified into two broad groups.

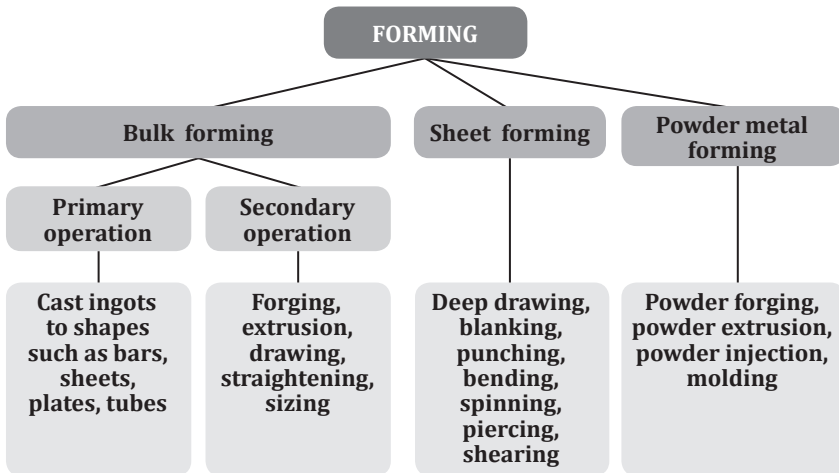


Figure 6.1 — Classification of metal forming processes (to point 6.1)

One is ***bulk forming*** and the other is ***sheet metal forming***.

6.2 Bulk forming processes

Bulk deformation (see Fig. 6.2, p. 33) refers to the use of raw materials for forming which have low surface area to volume ratio. ***Rolling, forging, extrusion*** and ***drawing*** are bulk forming processes. In bulk deformation processing methods, the nature of force applied may be compressive, compressive and tensile, shear or a combination of these forces.

Bulk forming is accomplished in forming presses with the help of a set of tool and die. Examples for products produced by bulk

forming are: gears, bushed, valves, engine parts such as valves, connecting rods, hydraulic valves, etc. Sheet metals forming involves application of tensile or shear forces predominantly.

6.3 Sheet Metalworking Processes

Sheet metal forming (see Fig. 6.3, p. 34) involves the application of tensile or shear forces predominantly. Working upon **sheets**, **plates** and **strips** mainly constitutes sheet forming. Sheet metal operations are mostly carried out in presses — hydraulic or pneumatic. A set of tools called die and punch are used for the sheet working operations. Bending, drawing, shearing, blanking, punching are some of the sheet metal operations.

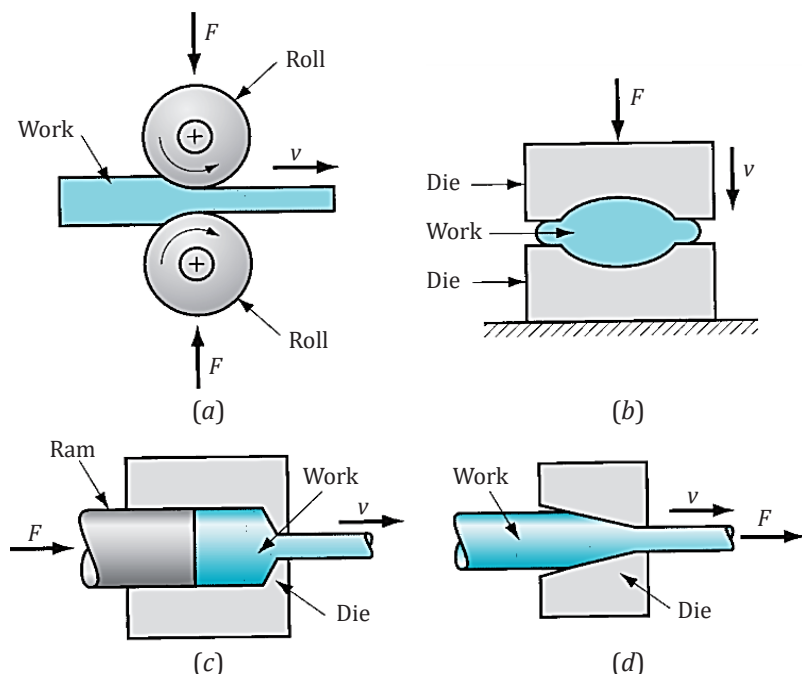


Figure 6.2 — Main bulk forming processes: rolling (a), forging (b), extrusion (c), drawing (d); relative motion in the operations is indicated by v ; forces are indicated by F [14] (to point 6.2)

6.4 Powder Metal Forming

A new class of forming process called powder forming is gaining importance due to its unique capabilities. The manufacturing process of iron and steel powders, as well as the forming of products from them, is shown in Fig. 6.4 (see p. 35).

One of the important merits of powder forming is its ability to produce parts very near to final dimensions with minimum material wastage. It is called near-net-shape forming. Material compositions can be adjusted to suit the desirable mechanical properties. The formability of sintered metals is greater than conventional wrought materials. However, the challenge in powder forming continues to be the complete elimination or near-complete

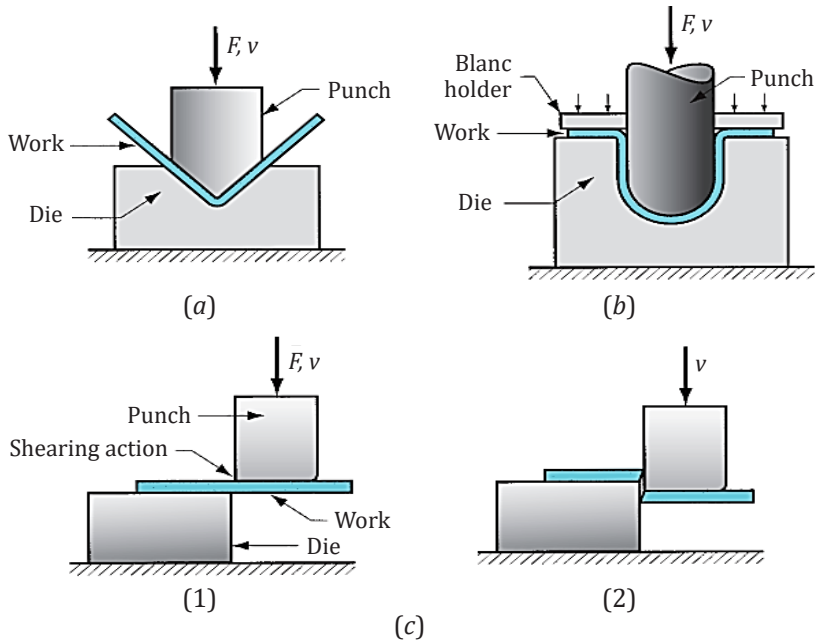


Figure 6.3 — Basic sheet metalworking operations: (a) bending, (b) drawing, and (c) shearing: (1) as punch first contacts sheet, and (2) after cutting; force and relative motion in these operations are indicated by F and v [14] (to point 6.3)

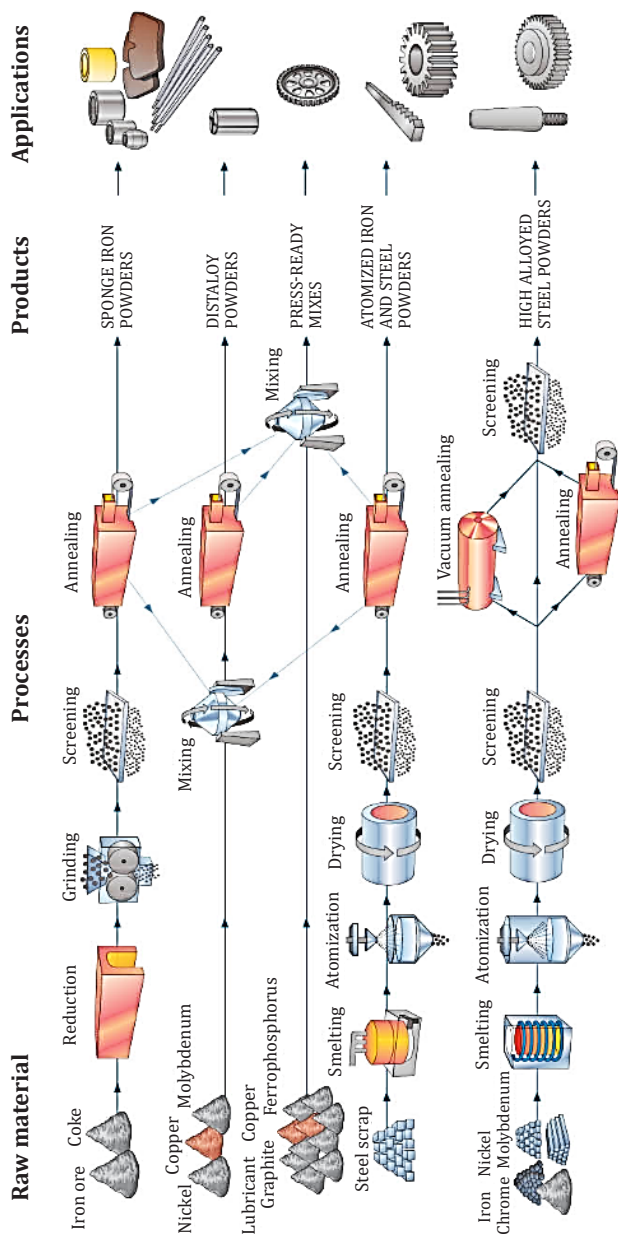


Figure 6.4 — Manufacturing process of iron and steel powders [16] (to point 6.4)

elimination of porosity. Porosity reduces the strength, ductility and corrosion resistance and enhances the risk of premature failure of components.

6.5 Based on the nature of deformation force applied on the material, during forming, metal forming processes are also classified into several types as shown in the Table 6.1 below.

Table 6.1 — Classification based on the deformation force
(to point 6.5) [1]

Forming by compressive stress	Tensile and compressive stresses	Forming under tensile stress	Bending and shearing stresses
• open die forging • closed die forging • rolling • coining • extrusion	• deep drawing • spinning • stripping • wrinkle bulging	• stretch forming • stretching • expanding	• bending • shearing • punching • blanking

Forming is also classified as cold forming, hot forming or warm forming. Hot forming is the deformation carried out at temperatures above recrystallization temperatures.

Typically, recrystallization temperatures for materials range from $0.5 T_m$ to $0.8 T_m$, where T_m is melting temperature of material.

TASKS

6.6 Answer the following questions

1. Into how many broad groups can metal processes be classified? Name these groups.
2. In what processing methods, the nature of force applied may be compressive, compressive and tensile, shear or a combination of these forces?
3. What is bulk forming in forming presses accomplished with?
4. What forces are involved in sheet metal forming?
5. Why is powder forming gaining importance?
6. What still prevents powder forming from being widely used?

7. How does porosity affect metal properties?
8. What are types of metal forming processes based on the nature of deformation force applied on the material during forming?
9. How can forming be classified according to the temperature at what the process is carried out?
10. What is the typical recrystallization temperatures range?

6.7 Match words or word combinations with their definitions
(see Table 6.2)

Table 6.2 — Task to point 6.4 [1]

1) recrystallization	a) a measure of the void (i.e. “empty”) spaces in a material
2) bulk forming	b) a solid product made through the process of powder metallurgy from different types of metals and alloys
3) sheet metal forming	c) a punch press used for forming (as metal parts)
4) forming press	d) the process in which deformed grains of the crystal structure are replaced by a new set of stress-free grains that nucleate and grow until all the original grains have been consumed
5) hydraulic press	e) a press operated by air pressure
6) pneumatic press	f) process in which force is applied to a piece of sheet metal to modify its geometry rather than remove any material
7) powder forming	g) a press operated with the help of water or other liquid
8) porosity	h) a process for forming metal parts by heating compacted metal powders to just below their melting points
9) sintered metal	i) forming of a bulk metal at room temperature without initial or interstage heating

6.8 Complete the following statements by choosing the answer which you think fits best. Are the other answers unsuitable? Why?

1. Bulk deformation refers to the use of:
 - a) sintered metal;
 - b) raw materials;
 - c) prepared metal.

2. Working upon sheets, plates and strips mainly constitutes:
 - a) sheet forming;
 - b) powder forming;
 - c) bulk forming.
3. Material compositions can be adjusted to suit the desirable:
 - a) recrystallization temperature;
 - b) hot and cold conditions;
 - c) mechanical properties.
4. The complete elimination or near-complete elimination of porosity:
 - a) continues to be the challenge in powder forming;
 - b) is sensitive to hydrostatic pressure;
 - c) leads to increased susceptibility to fatigue and stress-corrosion cracking.
5. Hot forming is the deformation carried out at temperatures:
 - a) below recrystallization temperatures;
 - b) at recrystallization temperatures;
 - c) above recrystallization temperatures.

6.9 Insert the missing words using the Table 6.3 below

Table 6.3 — Task to point 6.6 [1]

a) presses	b) deep drawing	c) drawing	d) ingot steel	e) sheet forming
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The rolling of thin iron sheets in the 18th century formed the basis for a broad application of (1) _____.

Hollow parts, which were already being manufactured in the Middle Ages by “thimbles” and “bell makers”, were increasingly produced by means of (2) _____ with the help of devices from which the 19th century drawing (3) _____ originated.

This created, together with the development of (4) _____, the foundation for the major industrial use of the processes of sheet forming, especially that of (5) _____, which in the 1920s obtained a decisive impulse by the rising demands of the automobile industry.

6.10 Change the underlined words using their equivalents given in the Table 6.4

Table 6.4 — Task to point 6.7 [1]

transformed	restored	misplacements	strain	faults
-------------	----------	---------------	--------	--------

The energy applied in plastic forming is (1) converted for the most part into heat. The rest remains stored in the lattice as internal energy, as potential energy of elastic deformation. Of interest for forming are twins and (2) dislocations as well as lattice vacancies and interstitial atoms. The largest amount of elastic (3) deformation energy can be attributed to dislocations, the number of which is significantly increased in the case of cold forming. When the activation energy is exceeded, the lattice (4) defects are (5) recovered and rearranged.

Over to you

Think about the specific types of forming processes that are used in your industry, or industry you're familiar with. How are they used?

Give examples of types of loads which act on specific components or members. What forces are applied on the material used?

CHAPTER 7

BRIEF DESCRIPTION OF METAL FORMING OPERATIONS

7.1 Bulk forming processes

Rolling is a compressive deformation process (see Fig. 7.1), which is used for producing semi-finished products such as **bars**, **sheets**, **plates** and **finished products** such as **angles**, **channels**, **sections**. Rolling can be carried out both in hot and cold conditions [1, 14, 17].

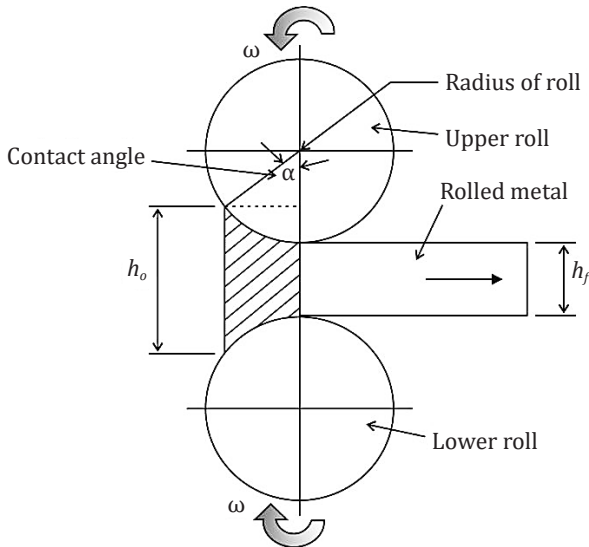


Figure 7.1 — Rolling process (to point 7.1) [14, 17]

Forging is a bulk forming process in which the **work piece** or **billet** is shaped into finished part by the application of compressive and tensile forces with the help of a pair of tools called die and punch. Forging can be done in **open dies** or **closed dies** (see Fig. 7.2, p. 41). Open die forging is usually used for preliminary shaping of raw materials into a form suitable for subsequent forming or machining [14].

Open die forging is done using a pair of flat faced dies for operations such as drawing out, thinning, etc.

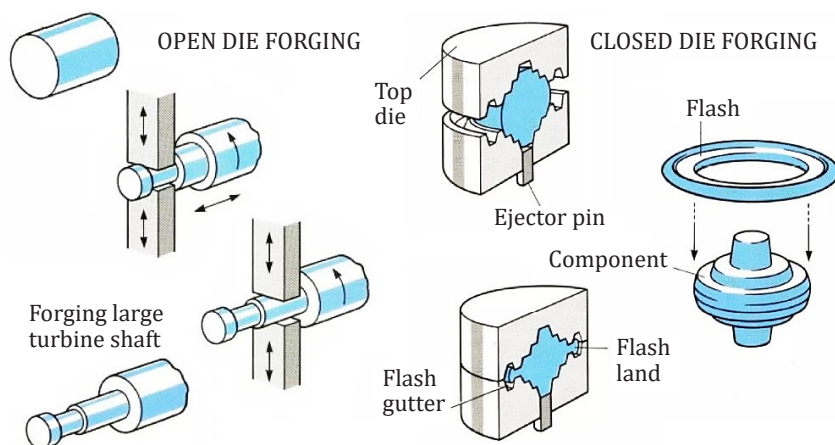


Figure 7.2 — Closed die and open die forging [14, 18] (to point 7.1)

Closed die forging is performed by **squeezing** the raw material called billet inside the cavity formed between a pair of shaped dies. Formed products attain the shape of the die cavity. Valve parts, pump parts, small gears, connecting rods, spanners, etc. are produced by closed die forging.

Coining is the process of applying compressive stress on surface of the raw material in order to impart special shapes on to the surface from the embossing punch — e.g. coins, medallions.

Extrusion involves forcing the raw material through a narrow opening of constant cross-section or varying cross-section in order to reduce the diameter and increase the length. Extrusion can be done hot or cold. Extruded products include shafts, tubes, cans, cups, gears [14].

Basically, there are two methods of extrusion, direct and indirect extrusions (see Fig. 7.3, p. 42). In direct extrusion the work and the extrusion punch move along the same direction. In indirect extrusion the punch moves opposite to the direction of movement of the work piece.

Wire drawing process is used for producing small diameter wires from rods by reducing their diameter and stretching their length

through the application of tensile force (see Fig. 7.4) [14]. Musical strings are produced by wire drawing process. Seamless tubes can be produced by tube drawing process.

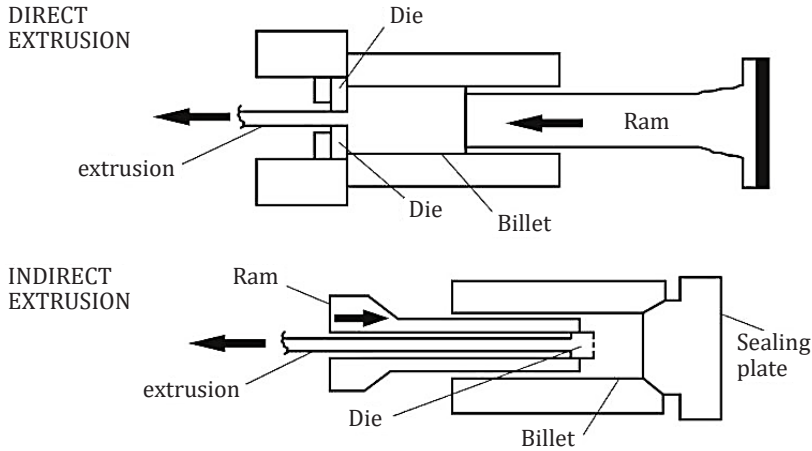


Figure 7.3 — Direct and indirect extrusion (to point 7.1) [14, 17]

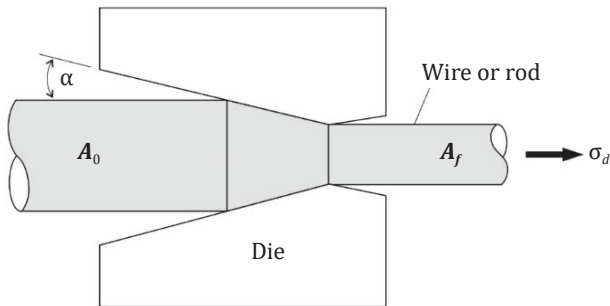


Figure 7.4 — Wire drawing (to point 7.1) [14, 17]

7.2 Sheet metal operations

Deep drawing is a **sheet metal process**; the process in which a sheet metal is forced into cup of hollow shape without altering its thickness — using tensile and compressive forces. Complex shapes can be produced by deep drawing of blanks in stages — redrawing, multiple draw deep drawing etc. [14].

Hydro mechanical deep drawing uses both punch force and hydrostatic force of a pressurized fluid for achieving the shape (see Fig. 7.5).

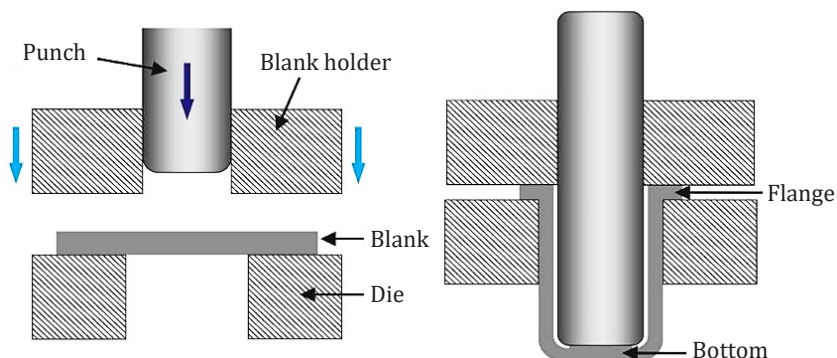


Figure 7.5 — Deep drawing [1, 8] (to point 7.2)

Flanges and collars are formed by flanging process (Fig. 7.6)

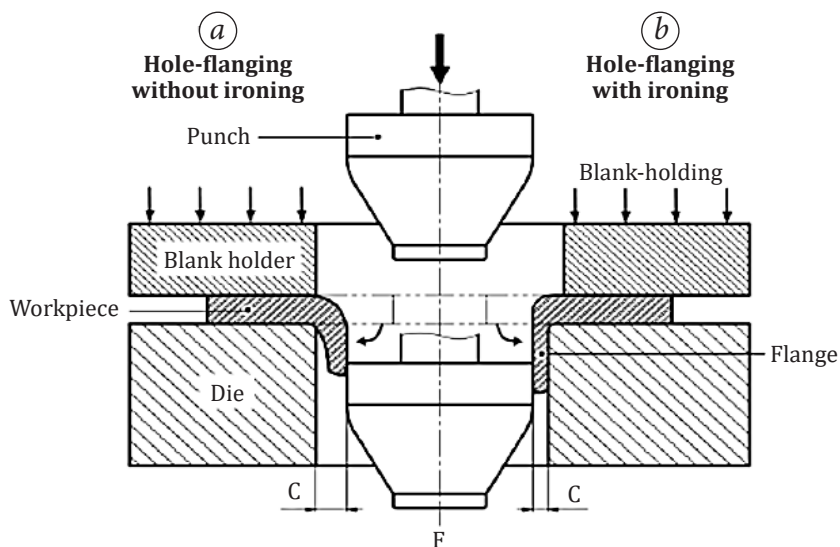


Figure 7.6 — Flanging process [19] (to point 7.2)

Spinning (see Fig. 7.7) transforms a sheet metal into a hollow shape by compressive and tensile stresses. Spinning mandrel of given shape is used against a roll head.

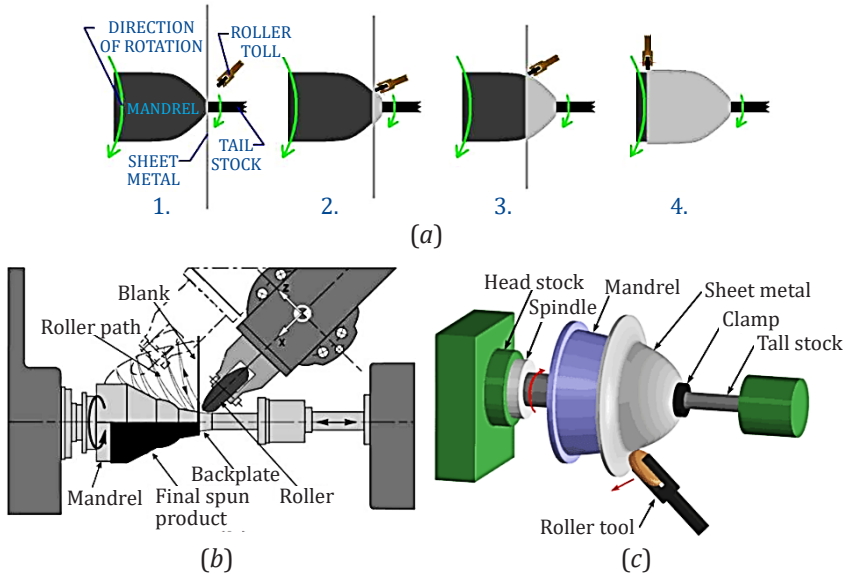


Figure 7.7 — Spinning: by stages (a) [20], general diagram with tool (b) [21], 3D visualization (c) [22] (to point 7.2)

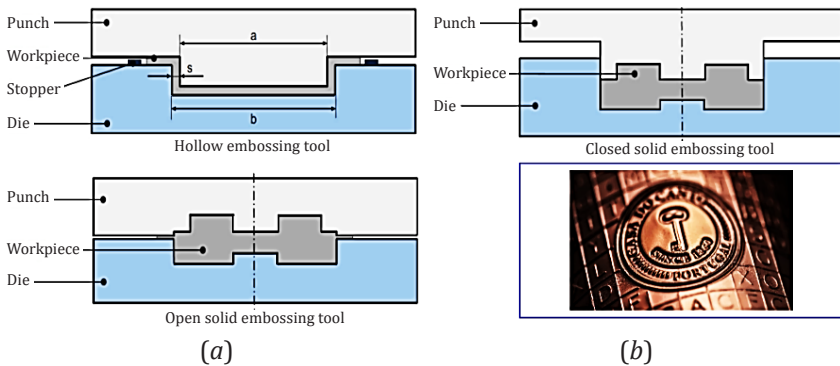


Figure 7.8 — Embossing: types and die designs (a) [23] and product (b) [24] (to point 7.2)

Embossing (see Fig. 7.8, p. 44) imparts an impression on the work piece by means of an embossing punch.

Bending of sheets includes rotary bending, swivel bending, roll bending using rotary die (see Fig. 7.9).

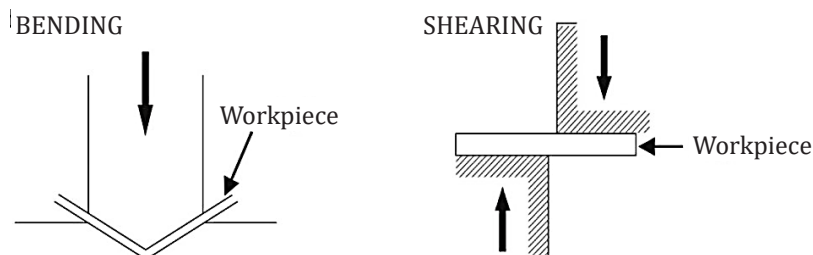


Figure 7.9 — Bending and shearing [1] (to point 7.2)

Die bending using flat die or shaped die is used for bending of sheets, or die coining of sheets.

TASKS

7.3 Answer the following questions

1. How do you define rolling?
2. Can rolling be carried out in hot or cold conditions?
3. Is the work piece or billet shaped into finished part in forging?
4. What is the difference between rolling and forging?
5. What process uses a pair of flat faced dies for operations such as drawing out, thinning, etc?
6. What articles are produced by closed die forming?
7. For what purpose is compressive stress on surface of the raw material applied in coining?
8. What is the essence of extrusion?
9. What are the two methods of extrusion?
10. What happens while deep drawing?

7.4 Match words or word combinations with their definitions in the Table 7.1

Table 7.1 — Task to point 7.4 [1]

1	2
1) deep drawing	a) forcing heated alloy billet through a die by pressure
2) rolling	b) the process of applying compressive stress on surface of the raw material
3) forging	c) a metal block used in forming materials
4) coining	d) a metal forming process in which metal stock is passed through one or more pairs of rolls to reduce the thickness and to make the thickness uniform
5) die	e) the fabrication process of flat rolled steel to make drawn parts
6) workpiece	f) the moveable die in a press or forging machine
7) punch	g) a piece of stock (also call a slug or multiple) from which a forging is to be made
8) extrusion process	h) a piece of work in process of manufacture
9) wire drawing	i) producing wires from rods
10) blank	

7.5 Complete the following statements by choosing the answer which you think fits best. Are the other answers unsuitable? Why? [1]

- In forging the work piece or billet is shaped into:
 - finished part;
 - semi-finished part;
 - blank.
- Open die forging is usually used for:
 - producing parts very near to final dimensions with minimum material wastage;
 - preliminary shaping of raw materials into a form suitable for subsequent forming or machining;
 - forming which have low surface area to volume ratio.
- Valve parts, pump parts, small gears etc. can be produced by:
 - closed die forging;
 - open die forging;
 - coining.

4. The work and the extrusion punch move along the same direction in:
 - a) wire drawing;
 - b) indirect extrusion;
 - c) direct extrusion.
5. When we need complex shapes we use:
 - a) deep drawing;
 - b) direct extrusion;
 - c) open die forging.

7.6 Insert the missing words using the Table 7.2 below

Table 7.2 — Task to point 7.6 [1]

forming	flow	drawing	blank	blank dimensions
---------	------	---------	-------	------------------

The essential prerequisites for achieving optimal work results in deep (1) ____ are the correct control of the material (2) ____, the determination of the (3) ____, the knowledge of the limits to which the (4) ____ can be driven within a single operation and the estimation of the force required to shape the (5) ____.

7.7 Change the underlined words using their equivalents given in the Table 7.3

Table 7.3 — Task to point 7.7 [1]

induce	collapse	produced	coarseness	worked
--------	----------	----------	------------	--------

If the surface of the workpiece to be (1) processed exhibits marked pores or high (2) roughness heights, such as those found in cast iron, a lubricant may not be used, as the lubricant entering the pores can (3) cause changes to the loading condition of the workpiece possibly leading to (4) failure as a result of the hydrostatic pressure (5) generated during rolling.

7.8 Match words from two columns in the Table 7.4 to form a term or word combination used in points 7.1 and 7.2

Table 7.4 — Task to point 7.8 [1]

1) sheet	a) extrusion
2) deep	b) drawing
3) indirect	c) shape
4) tensile	d) forging
5) hollow	e) metal
6) open die	f) force

Over to you

Think of an enterprise you are familiar with. Describe specific aspects of it: the type of equipment it uses, the forming operations used for producing specific shapes, the finished products it produces.

CHAPTER 8

TERMINOLOGY

FOR BASIC CONCEPTS OF ROLLING

Basic information in this chapter is taken from the sources [25].

8.1 Rolling definition

Rolling (Fig. 8.1) is the process of plastically deforming metal by passing it between the rolls. The rolling process is basically used for reducing the cross-sectional area of the metal stock (the width is the same but there is a significant reduction of thickness). It is the most widely used forming process and it provides high production with very close control of the final product. The squeezing action between the rolls results in the metal is subjected to high compressive stress. The frictional process is responsible for drawing the metal into rolls. At the exit from the rolls, the speed of the metal is higher than at the entrance to the rolls and higher than the linear speed of the rolls.

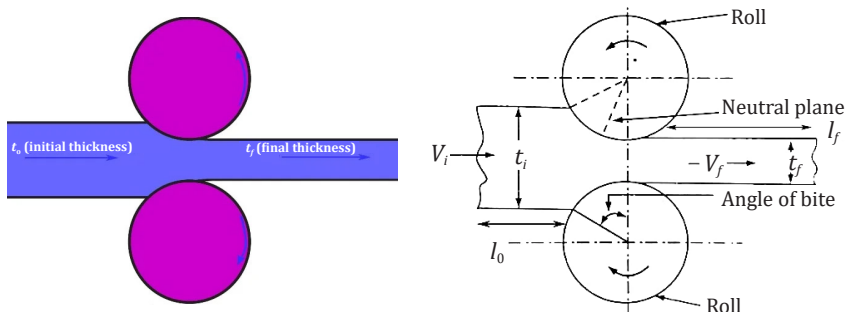


Figure 8.1 — Diagram and terminology for the rolling process [25]
(to point 8.1)

For Fig. 8.1:

$W_0 = W_f$, where W_0 — initial width, and W_f — final width, width is always constant when ever rolling is carried out but there is a significant reduction of thickness;

$l_0 < l_f$, where l_0 — initial length and l_f — final length;

$t_0 > t_f$, where t_0 — initial thickness and t_f — final thickness;

V_i is the initial force and the V_f is the final force.

8.2 Rolling ratios

Angle of bite. The *angle of bite* (see Fig. 8.1) determines the extent of thickness reduction which will be taken place. The angle of the bite also depends upon the condition in which the rolling is being carried out, which means it is hot or cold or the surface roughness or smoothness of the rollers. For the smoother surface low angle of bite is used while for the rough surface high angle of bite is used.

The large diameter of the rollers is used for the low angle of the bite while the small diameter rollers are used for the high angle of bite. The cold-rolling angle of the bite is very low (like 3–4 degrees) but for hot rolling, it is very high (like 24–32 degrees).

Draft (draught). The difference between the thickness of initial and rolled metal piece is called **draft (draught)**. Thus if t_i is initial thickness and t_f is final thickness, then the draught d is given by:

$$d = t_i - t_f.$$

The **maximum draft** that can be achieved via rollers of radius R with coefficient of static friction f between the roller and the metal surface is given by:

$$d_{\max} = f^2 R.$$

This is the case when the frictional force on the metal from inlet contact matches the negative force from the exit contact.

The coefficient of the friction f between the metal and the roller surface:

- for cold working condition $f=0.1$;
- for warm working condition $f=0.2$;
- for cold working condition $f=0.4-1.0$;

R is the radius of the roller.

If the surface roughness is more than more draft is possible and if the roller diameter is more than more draft is possible.

Reduction. Reduction r is defined as the per-unit change in thickness with respect to the entry thickness t_i :

$$r = \frac{t_i - t_f}{t_i} = \frac{d}{t_i},$$

where t_f is the exit thickness (see Fig. 8.1).

As the material is reduced, its length becomes proportionately longer.

Elongation. Elongation e is defined as the per-unit increase in length due to a decrease in area with respect to the entry, regardless of shape.

Given an entry length ℓ , then:

$$e = \frac{L - \ell}{\ell},$$

where L is the final length (Fig. 8.2).

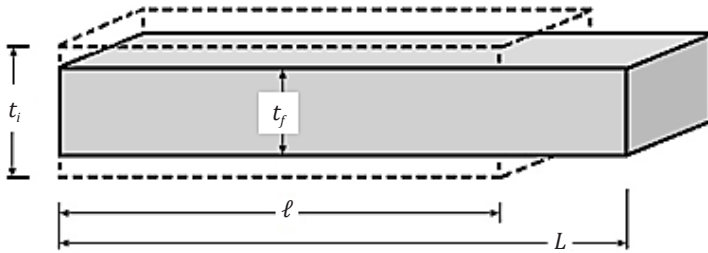


Figure 8.2 — Changes in length during rolling (to point 8.2)

8.3 Rolling terminology for work pieces and products

Bloom — it is the product of the first breakdown of ingots, generally hot working (the cross-sectional area is 150×150 cm).

Billet — product obtained from further reduction by hot rolling (the cross-sectional area is 40×40 mm²).

Slab is any hot rolled ingot with a cross-sectional area is 100 cm² and width is > or equal to 2 × thickness.

Plate is a product with a thickness > 6 mm.

Sheet — product with thickness < 6 mm and width > 600 mm.

Strip is the product with thickness < 6 mm and width < 600 mm.

Blooms, billets, and slabs are also known as semi-finished products. It may be further reduced.

The rolling sequence for the production of rods, profiles and flat products from blooms, billets and slabs is shown in Fig. 8.3 (see p. 52).

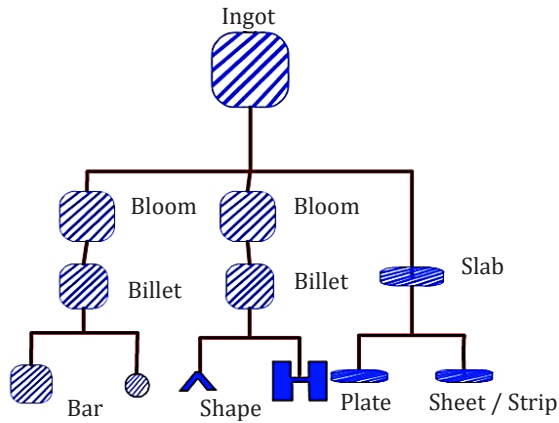


Figure 8.3 — Flow diagram showing rolling of different products [26] (to point 8.3)

8.4 Recrystallization. Hot rolling and cold rolling

There are two types of the rolling process: hot rolling and cold rolling (see Fig. 8.4).

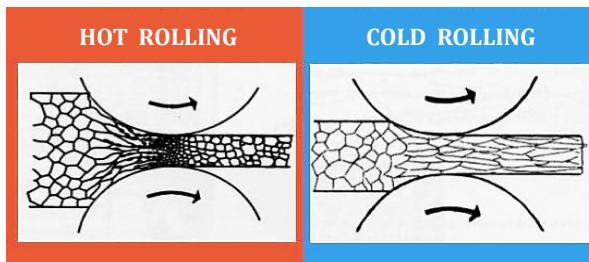


Figure 8.4 — Difference in the formation of metal grains during hot and cold rolling [27] (to point 8.4)

Recrystallization and the metal forming process.

Recrystallization is an important phenomenon in metallurgy. It occurs when metal atoms are energized to a point at which new crystals start to form. Just like water changes phases to steam and ice, metal has its own phase changes. Every metal has a unique recrystallization point.

The technical definitions of both hot and cold work refer to the recrystallization temperature of the metal. Hot working occurs when metal is deformed above its recrystallization temperature. In contrast, cold working occurs when metal is deformed below the recrystallization temperature. A third metal forming process, warm forming, sits between the two [27].

Hot rolling is a metalworking process that occurs above the recrystallization temperature (below the melting temperature) of the metal, see Fig. 8.5. It requires low pressure. The initial breakdown of ingots in blooms and billets is generally done by hot rolling. Further hot rolling is carried out to obtain products in the form of plates, sheets, rods, bars, etc. It has a poor surface finish [25].

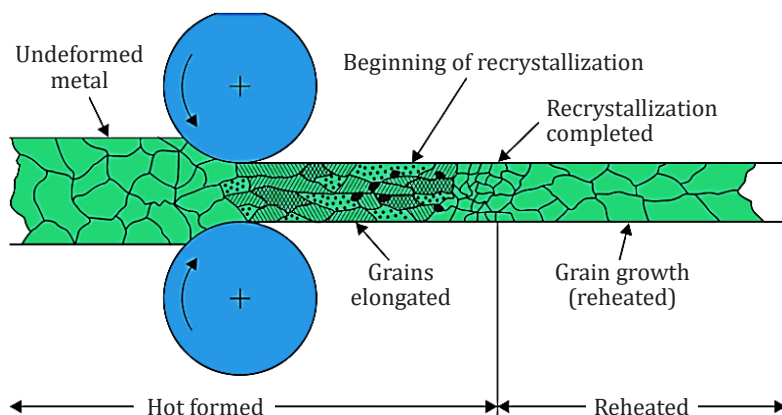


Figure 8.5 — Effect of hot working on the microstructure of metal [28] (to point 8.4)

Specific features of hot rolling are:

- the first hot working operation is done using a roughing mill (blooming, slabbing or cogging);
- these mills are designated based on the roll diameter;
- initially, scale removal is done;
- breakdown of cast ingots / blooms / slabs / for subsequent reductions;

- the ingots are turned 90° between subsequent passes;
- generally, they are two high reversing mills (24–54-inch (610–1372 mm) diameter rolls);
- for high production rates, universal mills are used to take care of edging (two vertical rolls to control the edge);
- high-pressure water jets remove scales;
- subsequent to the last finishing stand, strips are sheared to the required size or coiled to obtain continuous sheets.

Cold rolling occurs with the metal below its recrystallization temperature. It requires more pressure than a hot rolling mill (Fig. 8.6). Cold rolling is carried out by industries to obtain sheets, strips, foils, bars, etc. [25].

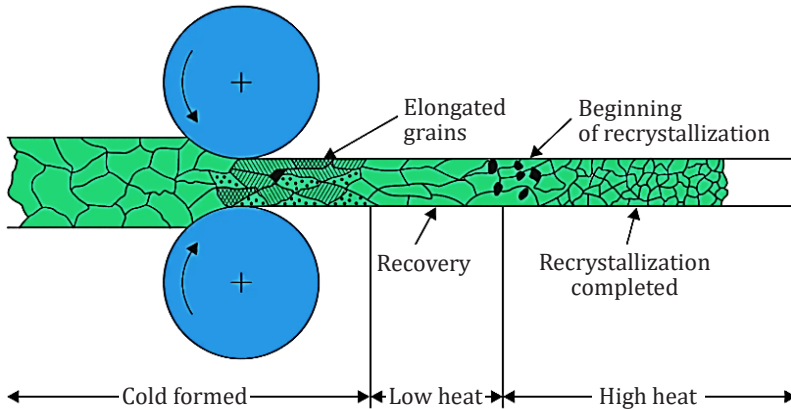


Figure 8.6 — Effect of hot working on the microstructure of metal [28]
(to point 8.4)

Advantages of cold rolling mills are:

- good surface finish;
- close control to product dimensions;
- increase mechanical properties;
- used to obtain high strength;
- a large number of non-ferrous sheets are produced by cold rolling;
- total reduction varies from about 50% to 90%;

- the rolling is carried out using 3–6 strands;
- high speed for high mills is generally used;
- in the finishing strand, minimum reduction occurs so as to obtain a good surface finish and uniform thickness;
- annealed steels are given skin pass or temper rolling to eliminate the yield point phenomenon.

The **actual process** employed in the industry for the production of small gauge material is hot rolling to slightly above the finished size required, cleaning/removing the oxidised surface by machining pickling or some other suitable process and finally using cold-rolling of work material to finished sizes [28].

TASKS

8.5 Match the following terms with their definitions in the Table 8.1

Table 8.1 — Task to point 8.5 [1]

1) angle of bite	a) the extent of thickness reduction determined by the rolling process
2) recrystallization	b) the per-unit increase in length due to a decrease in area with respect to the entry, regardless of shape
3) draft	c) the process when new crystals start to form due to energized metal atoms
4) billet	d) product obtained from further reduction by hot rolling
5) elongation	e) the angle that determines the thickness reduction based on conditions like surface roughness and temperature

8.6 Insert the appropriate term for each definition, look at Chapter 8 to help you

1. The process of plastically deforming metal by passing it between the rolls is known as _____.
2. The angle of bite determines the extent of _____ reduction.
3. Draft (d) is calculated as _____.
4. Blooms are the product of the first breakdown of _____.
5. Cold rolling occurs with the metal below its _____ temperature.

8.7 Answer the following questions

1. What is the significance of the angle of bite in rolling?
2. Explain the concept of draft value in rolling.
3. Define “blooms”, “billets” and “slabs”.
4. What is the difference between hot rolling and cold rolling in terms of recrystallization?

8.8 By filling out the table, determine the word that combines the meaning of a class of chemical elements or a chemically simple substance with high strength, malleability (forgeability), good thermal and electrical conductivity

1. Product of the first breakdown of ingots, generally hot worked.
2. Product obtained from further reduction by hot rolling.
3. Product with thickness <6 mm and width >600 mm.
4. Any hot rolled ingot with a cross-sectional area of 100 cm^2 .
5. Product with a thickness >6 mm.

1.								
2.								
3.								
4.								
5.								

Over to you

Consider a situation in the metalworking industry where achieving high mechanical properties in the final product is critical. Give examples of single and combined processing operations aimed at increasing the strength of rolled products. Discuss the steps involved in the production processes for hot rolling and cold rolling. Compare the advantages and disadvantages for cold and hot rolling in terms of energy costs, surface cleanliness of rolled products, and product range by thickness.

CHAPTER 9

ROLLING PROCESSES TERMINOLOGY

9.1 Rolling processes

Rolling processes by intended purpose can be divided according to Fig. 9.1.

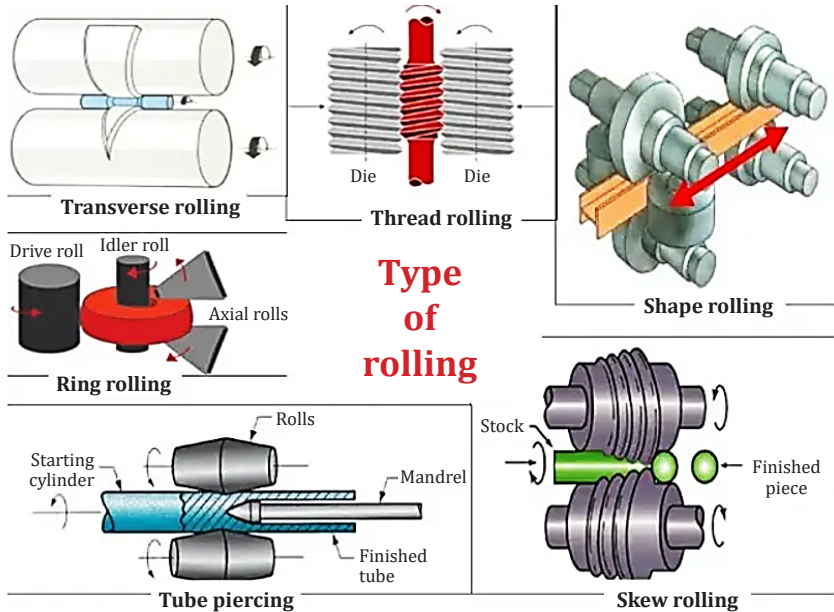


Figure 9.1 — Types of rolling by intended purpose [29] (to point 9.1)

9.2 Powder rolling

Powder rolling — metal powder is introduced between rolls and compacted into a green strip which is subsequently sintered and subjected to hot or cold working followed by annealing (see Fig. 9.2, p. 58).

Advantages of powder rolling:

- a high-density sheet can be obtained;
- elimination of initial hot-ingot breakdown process;
- minimum contaminants which otherwise would form during hot working;
- reduction in initial huge capital investment;

- very fine-grained material with a drastic reduction of preferred orientation of grains.

9.3 Shaped rolling

Shaped rolling or section rolling:

- a special type of cold rolling in which a flat slab is progressively bent into complex shapes by passing it through a series of driven rolls;
- no appreciable change in the thickness of the metal during the process;
- suitable for producing molded sections such as irregularly shaped channels.

Explanations for section (shape) rolling are given in Fig. 9.3.

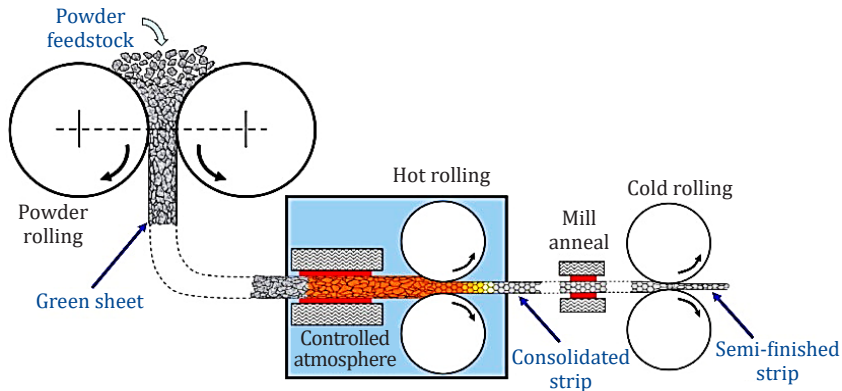


Figure 9.2 — Schematic diagram of powder rolling (CSIRO process) for producing strip from Ti-based metal powder [30, 31] (to point 9.2)

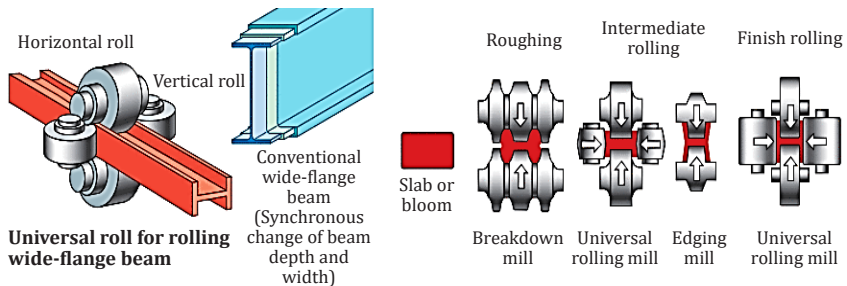


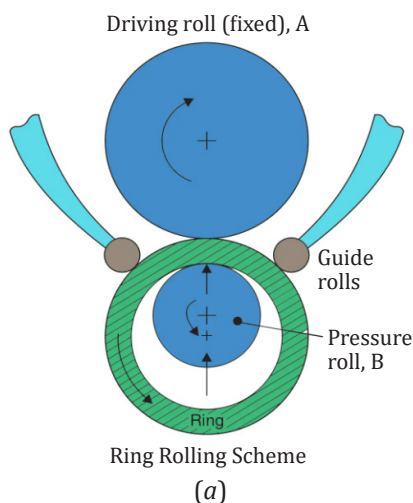
Figure 9.3 — Stages in the H-section shape rolling [32] (to point 9.3)

9.4 Ring rolling

Smaller diameter, thicker ring can be enlarged to larger diameter, thinner section by ring rolling. In this process, two circular rolls, one of which is idler roll and the other is driven roll are used. A pair of edging rollers are used for maintaining the height constant. The ring is rotated and the rings are moved closer to each other, thereby reducing the thickness of ring and increasing its diameter. Rings of different cross-sections can be produced. The major merits of this process are high productivity, material saving, dimensional accuracy and grain flow which is advantageous [26].

The inner and outer races of the ball and roller bearings, steel tires for railway wheels, large rings for turbines, flanges and rings for pipes are produced by the **ring rolling process** (Fig. 9.4).

Ring Rolling Procedure. The starting workpiece is a thick-walled circular piece of metal in whose centre a hole has been made by drifting and piercing. The workpiece is heated until it becomes red hot and then placed between two rolls A and B (see Fig. 9.4) which rotate in opposite directions. The arrangement of the rolls and



Ring Rolling from a manufacturing plant

(b)

Figure 9.4 — Ring rolling scheme (a) and ring rolling mill (b) [28]
(to point 9.4)

the ring is shown in the below schematic representation. The pressure roll B exerts pressure on the material from inside. Caught between rolls A and B, the ring rotates. At the same time, the inside and outside diameter of the ring progressively increase and the wall thickness keeps on reducing. In order to ensure that the ring is circular, two guide rolls are suitably placed on the outer surface of the ring. When the outer and inner diameter of the ring increase to the size required, the rolling is stopped [28].

9.5 Tube piercing

Rotary tube piercing is used for producing long thick-walled tubes (Fig. 9.5). Cavity forms at the center due to tensile stress, in a round rod when subjected to external compressive stress — especially cyclic compressive stress.

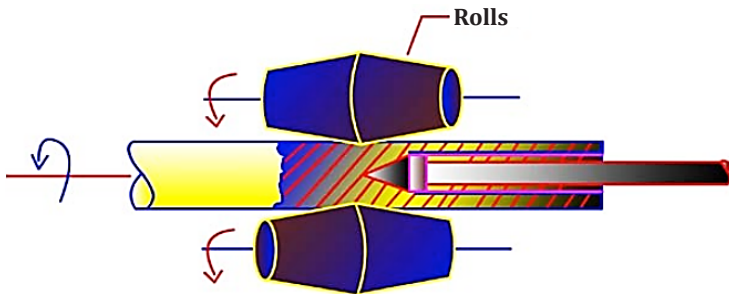


Figure 9.5 — Mannesmann process [26] (to point 9.5)

The Mannesmann process makes use of a tube piercing in rotary mode. A pair of skewed rolls are used for drawing the work piece inside the rolls. The roll axes are oriented at 6 degrees with reference to axis of work piece. A mandrel is used for expanding the central hole, and sizing the inner diameter. Pilger mill uses reciprocating motion of both work and mandrel to produce tubes. Work is periodically rotated additionally [26].

TASKS

9.6 Read the text and fill in the gaps with missing words

One specialized rolling process is (1) _____ where metal powder is introduced between rolls and compacted into a green strip. This strip is subsequently sintered and subjected to hot or cold working followed by annealing. This process has several advantages, including the ability to obtain a high-density sheet and the elimination of the initial hot-ingot breakdown process.

Another important type is (2) _____ or section rolling. This involves passing a flat slab through a series of driven rolls to create complex shapes. Interestingly, there is no appreciable change in the thickness of the metal during this process. It is particularly suitable for producing molded sections such as irregularly shaped (3) _____.

(4) _____ is a process where a smaller diameter, thicker ring is enlarged to a larger diameter, thinner section. This is achieved using two circular rolls, one of which is an idler roll, and the other is a driven roll. A pair of edging rollers are used to maintain the height constant. Rings of different cross-sections can be produced. This process is highly productive and ensures dimensional accuracy.

Finally, (5) _____ is a technique used for producing long thick-walled tubes. It involves the formation of a cavity at the center of a round rod when subjected to external compressive stress. The Mannesmann process employs a tube piercing in rotary mode, using a pair of skewed rolls to draw the workpiece inside.

9.7 Critical analysis

The statement below, taken from a technical discussion on a materials engineering forum, discusses a misconception about a specific rolling process. Can you identify the mistake? Refer to Chapter 9 for assistance.

Post 1:

"I heard that powder rolling is only used for small-scale productions. The process is limited in terms of scale and can't be applied to industrial-level manufacturing". Is this true?

9.8 Explanation

Describe under what circumstances it is advisable to use powder rolling and provide examples of products that can be obtained using this method.

9.9 Application scenario

Imagine you are a materials engineer working for a company that specializes in the production of custom-shaped metal components. A client approaches you with a project to create a unique metal component with irregularly shaped channels for their machinery. Based on your knowledge of rolling processes from Chapter 9, explain which rolling process would be most suitable for this project and why. Provide details about the advantages and characteristics of the chosen rolling process for producing these irregularly shaped channels.

Over to you

If you were to create a new rolling process for a unique material or application, what would it be? Provide a brief overview of this novel process and explain how it could revolutionize manufacturing.

CHAPTER 10

ROLLING MILLS TERMINOLOGY

10.1 Types of rolling mills

Rolling mill consists of rolls, bearings, structure, or housing for rigidly supporting these parts, power drive, power transmission system, speed control, roll gap adjusting set up, etc. The force for rolling generally is very high. The power requirements are very high. Hence initial capital investment is high. Rolling mills are generally classified with respect to the number and arrangement of the roll [25].

In the **two high pull over rolling mill** the stock is returned to the entrance for further reduction (see Fig. 10.1). It consist of two rollers. Both rollers are rotate in opposite direction.

In the **two high reversing rolling mills** the work can be passed back and forth through the rolls by reversing their direction of rotation (see Fig. 10.2).

Three high rolling mills consist of upper and lower driven rolls and a middle roll, which rotate by friction (see Fig. 10.3, p. 64). Three high rolling mills reduced the material handling which is needed for rolling.

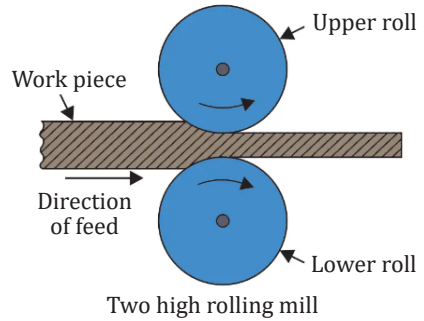


Figure 10.1 —
The two high rolling mill [28]
(to point 10.1)

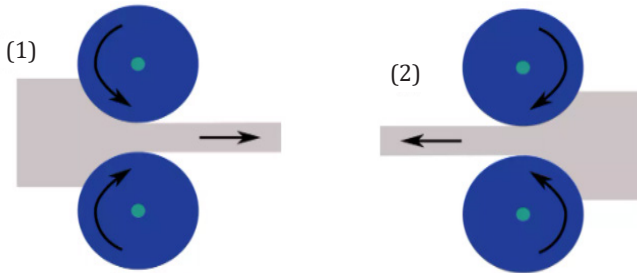


Figure 10.2 — The two high reversing rolling mill: forward (1) and backward (2) feeds of the workpiece [28] (to point 10.1)

It consists of three rollers. The first and third roller rotate in the same direction while the mid roller rotates in opposite direction. This requires less costly motive power. It has higher output.

In the **four high rolling mills** small diameter rolls (less strength and rigidity) supported by larger diameter backup rolls (see Fig. 10.4). It consists of four rollers. This process is used for both cold and hot rolling [28].

In the **cluster rolling mill** or **Sendzimir rolling mill** each of the working rolls is supported by two backing rolls (Fig. 10.5). Here rigidity is well maintained. Cluster rolling mills are used for the high draft.

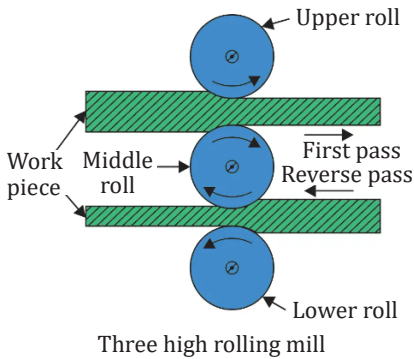


Figure 10.3 — The three high rolling mill [28] (to point 10.1)

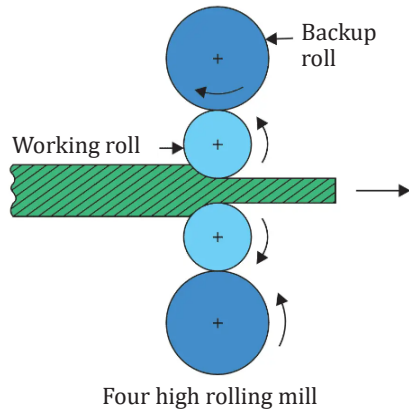


Figure 10.4 — The four high rolling mill [28] (to point 10.1)

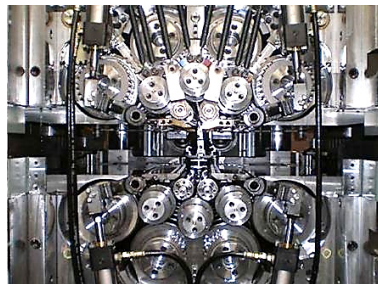
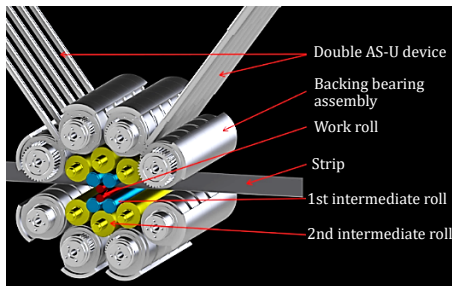


Figure 10.5 — Sendzimir 20-high mill [33] (to point 10.1)

10.2 Types of rolls for rolling

Different **types of rolls** and **roll passes in** rolling mills. There are two types of rolls. One is the “plain roll” and the second one is the “grooved roll” shown in the below Fig. 10.6. A plain roll used for rolling slabs, plate and sheet. A grooved rolls used for rolling billets, bars and sections.

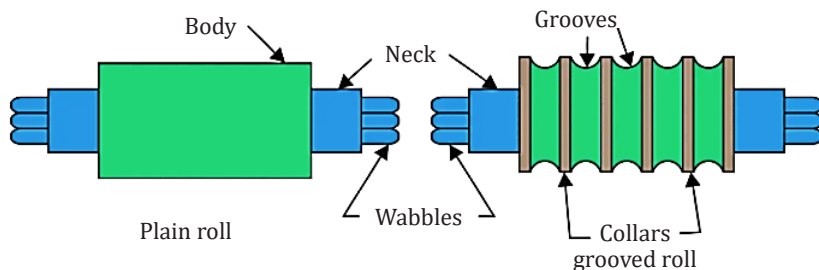


Figure 10.6 — Types of rolls [28] (to point 10.2)

The **roll stand** comprises two housings erected on the bed plates and joined together by separators or tie-rods, chocks bearings of the rolls and devices for adjusting the rolls.

Rolls do the most important work in a rolling mill. A roll failure is a big catastrophe in rolling mill which not only leads to partial or total loss of the rolls, also necessitates removal of resulting cobble in the mill, causes mill stoppage and damage to rolling mill equipment. All these affect the mill performance adversely [34].

Rolls have three main components (Fig. 10.7) namely (i) roll body, (ii) roll necks, and (iii) wobblers. The wobblers are for driving or rotating the rolls, the necks are to support the roll in the mill housings and the barrel portion is the working portion of the roll where actual rolling takes place. The body is the part which comes into direct contact and deforms the metal of the work piece.

Roll properties. A good quality roll is required to have several properties which include (i) high wear resistance for longer life and economy, (ii) resistance to fracture to withstand increasing rolling load, (iii) resistance to fire cracking to overcome the susceptibility of rolls to fire cracking due to the steep temperature gradient between

rolling temperature and the roll temperature, (iv) spalling resistance to resist the premature failure of rolls due to very high thermal and pressure gradients between the stock and rolls, (v) good surface finish to produce high quality surface in the products, and (vi) good biting properties [34].

The main parameters which control the properties of a roll are (i) mono or compound roll (roll design), (ii) chemical composition of the roll material, (iii) casting (mould design, temperatures, weights, inoculation, and down cooling), and (iv) heat treatment.

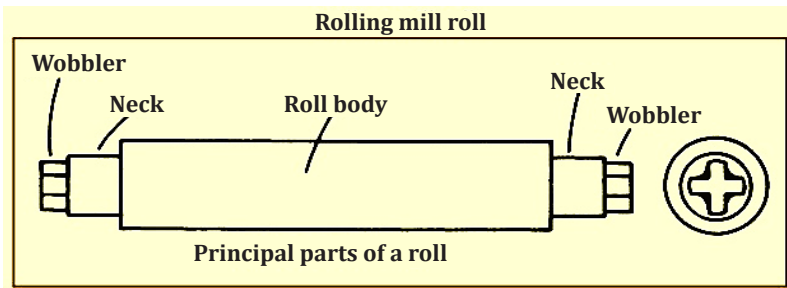


Figure 10.7 — Components of roll [34] (to point 10.2)

Classification of rolls. Based on applications, rolls can be for (i) longitudinal rolling for the rolling of flats or sections, (ii) transverse rolling, (iii) thread rolling, (iv) ring rolling, (v) tube piercing for seamless pipe rolling, and (vi) skew rolling.

Based on the production method for the rolls, rolls are produced by (i) casting, (ii) forging, (iii) sintering, and (iv) other methods. Cast rolls are classified as (i) single pour rolls, (ii) double pour rolls, and (iii) centrifugally cast rolls.

Based on the microstructure of the roll materials, the rolls are classified as (i) hypo eutectoid steel rolls, (ii) hyper eutectoid steel or Adamite rolls, (iii) graphitic hyper eutectoid steel rolls, (iv) high alloyed steel rolls, (v) spheroidal graphite iron rolls, (vi) indefinite chill cast iron rolls, and (vii) Special materials such as sintered carbide and ceramic rolls [34].

10.3 Arrangement of rollers for rolling mill

Continuous rolling mill (Fig. 10.8) uses a series of rolling mill and each set is called a stand. The strip will be moving at different velocities at each stage in the mills. The speed of each set of rolls is synchronized so that the input speed of each stand is equal to the output of preceding stand. The uncoiler and wind-up reel facilitates feeding the stock in to the rolls and coiling of the final product in addition of providing back tension and front tension to the strip [25].

Planetary rolling mill consists of a pair of heavy backing rolls surrounded by a large no of planetary rolls (see Fig. 10.9, p. 68).

Each planetary roll gives an almost constant reduction to the slab as it sweeps out a circular path between the backing rolls and the slab. As each pair of planetary roll ceases to have contact with the workpiece, another pair of rolls makes contact and repeat that reduction. The overall reduction is the summation of a series of small

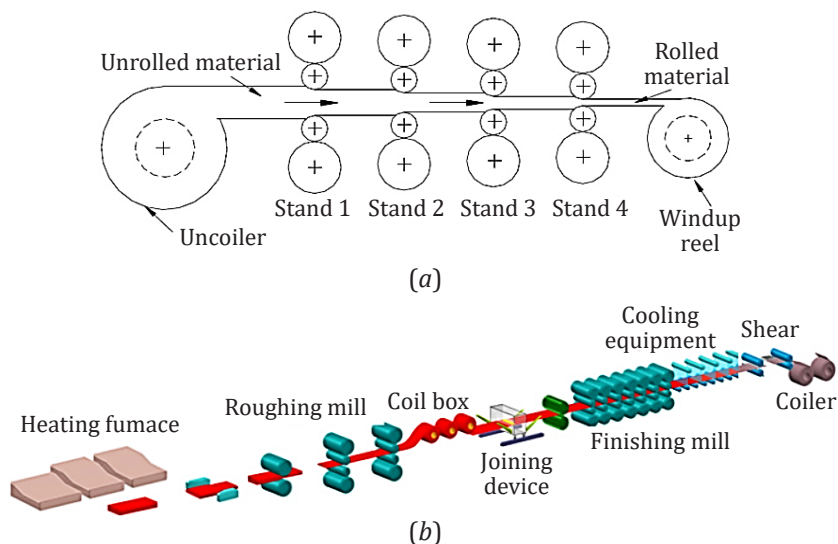


Figure 10.8 — The operating principle of a four-stand continuous tandem mill (a) [35] and the layout of the continuous mill (b) [36] (to point 10.3)

reductions by each pair of rolls. Therefore, the planetary rolling mill not only reduced a slab directly to strip in one pass through the mill. The operation requires feed rolls to introduce the slab into the rolling mill, and a pair of planishing rolls on the exit to improve the surface finish [25].

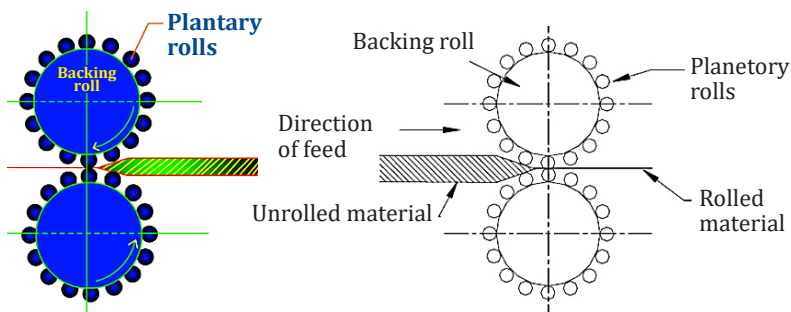


Figure 10.9 — The planetary rolling mill [26, 35] (to point 10.3)

TASKS

10.4 Short answer questions

1. What are the main components of a roll and their respective functions?
2. Explain the significance of wobblers in a roll's structure.
3. What are the properties a good quality roll should possess? Explain their importance.
4. Describe the different methods by which rolls are produced.
5. What is the purpose of planetary rolling mills, and how do they operate?

10.5 Fill in the blanks with the correct terms from the Chapter 10 to complete the sentences

1. A good quality roll should have high _____ resistance for longer life.
2. Rolls have three main components: roll body, roll necks, and _____.

3. The body is the part of the roll that comes into direct contact and deforms the metal of the _____ piece.
4. The main parameters that control the properties of a roll are roll design, chemical composition, casting, and _____ treatment.
5. Based on the production method, rolls can be produced by casting, forging, sintering, and _____ methods.

10.6 Match the type of rolling mill on the left column with its description on the right column (see Table 10.1)

Table 10.1 — Task to point 10.6

1) two high pull over rolling mill	a) consists of upper and lower driven rolls and a middle roll, reducing material handling
2) two high reversing rolling mill	b) stock is returned to the entrance for further reduction
3) three high rolling mill	c) work can be passed back and forth through the rolls by reversing their direction
4) four high rolling mill	d) small diameter rolls supported by larger diameter backup rolls
5) cluster rolling mill	e) each working roll is supported by two backing rolls
6) planetary rolling mill	f) consists of a pair of heavy backing rolls surrounded by a large number of planetary rolls

10.7 Scenarios

Provide specific scenarios or industries where each type of rolling mill (two high pull over rolling mill, two high reversing rolling mill, three high rolling mill, four high rolling mill, cluster rolling mill, planetary rolling mill) would be most commonly used. Explain why these particular rolling mills are suited for those applications.

For example:

Two high pull over rolling mill is suitable for... *(name an industry)*, because... *(name a reason)*.

Over to you

Imagine you are tasked with selecting rolls for a new rolling mill operation. What factors would you consider in choosing the type of rolls and their characteristics? Provide a brief justification for your choices.

CHAPTER 11

ROLLING PRACTICE. PART I

Basic text material in this chapter is taken from the sources [37].

11.1 History of rolling

The earliest rolling mills in crude form but the same basic principles were found in Middle East and South Asia as early as 600 BCE. The invention of the rolling mill in Europe may be attributed to Leonardo da Vinci in his drawings (see Fig. 11.1).

Earliest rolling mills were *slitting mills*, which were introduced from what is now Belgium to England in 1590. These passed flat bars between rolls to form a plate of iron, which was then passed between grooved rolls (slitters) to produce rods of iron (see Fig. 11.2, p. 71). The first experiments at rolling iron for tinplate took place about 1670. In 1697, Major John Hanbury erected a mill at Pontypool to roll “Pontypool plates” — *blackplate*. Later this began to be rerolled and tinned to make *tinplate*. The earlier production of plate iron in Europe had been in forges, not rolling mills.

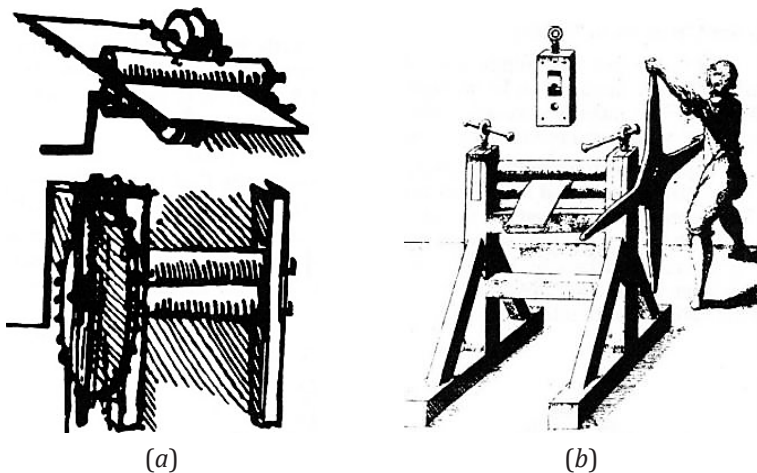


Figure 11.1 — Sketch of a Rolling Mill, Leonardo da Vinci, 1485 (a) [38]
and mill built by Solomon Caus to roll sheets of lead (b) [39]
(to point 11.1)

The slitting mill was adapted to producing hoops (for barrels) and iron with a half-round or other sections by means that were the subject of two patents in 1679.

Some of the earliest literature on rolling mills can be traced back to the Swedish engineer Christopher Polhem in his *Patriotista Testamente* of 1761, where he mentions rolling mills for both plate and bar iron. He also explains how rolling mills can save on time and labor because a rolling mill can produce 10 to 20 or more bars at the same time.

A patent was granted to Thomas Blockley of England in 1759 for the polishing and rolling of metals. Another patent was granted in 1766 to Richard Ford of England for the first **tandem mill**. A tandem mill is one in which the metal is rolled in successive stands; Ford's tandem mill was for hot rolling of wire rods.

Until well into the eighteenth century, rolling mills derived their power from water wheels. The first recorded use of a steam engine directly driving a mill is attributed to John Wilkinson's Bradley Works where, in 1786, a Boulton and Watt engine was coupled to a slitting and rolling mill. The use of steam engines considerably enhanced the production capabilities of the mills, until this form of power was displaced by electric motors soon after 1900.

Modern rolling practice can be attributed to the pioneering efforts of Henry Cort of Funtley Iron Mills, near Fareham in Hampshire,

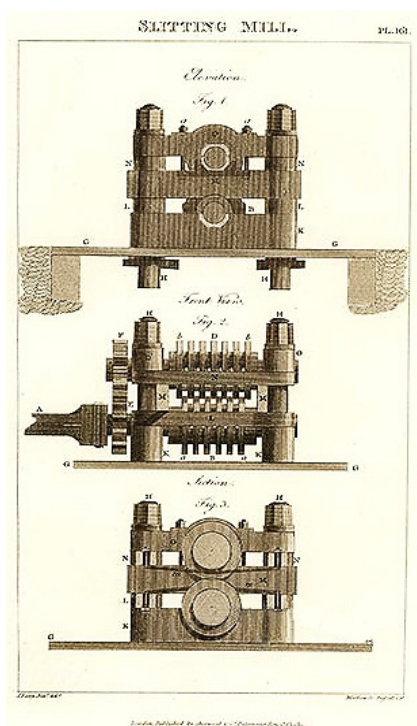


Figure 11.2 — Slitting mill, 1813 [37] (to point 11.1)

England. In 1783, a patent number was issued to Henry Cort for his use of grooved rolls for rolling iron bars. With this new design, mills were able to produce 15 times more output per day than with a hammer. Although Cort was not the first to use grooved rolls, he was the first to combine the use of many of the best features of various ironmaking and shaping processes known at the time. Thus, modern writers have called him “father of modern rolling”.

The first rail rolling mill was established by John Birkenshaw at Bedlington Ironworks in Northumberland, England, in 1820, where he produced fish-bellied wrought iron rails in lengths of 15 to 18 feet.

With the advancement of technology in rolling mills, the size of rolling mills grew rapidly along with the size of the products being rolled. One example of this was at The Great Exhibition in London in 1851, where a plate 20 feet long, 3 1/2 feet wide, and 7/16 of an inch thick, and weighing 1,125 pounds, was exhibited by the Consett Iron Company. Further evolution of the rolling mill came with the introduction of three-high mills in 1853 used for rolling heavy sections.

11.2 Hot rolling (in expansion to point 8.4)

Hot rolling is a metalworking process that occurs above the recrystallization temperature of the material. After the grains deform during processing, they recrystallize, which maintains an equiaxed microstructure and prevents the metal from work hardening. The starting material is usually large pieces of metal, like **semi-finished casting products**, such as ingots, slabs, blooms, and billets (see Fig. 11.3, p. 73).

If these products came from a continuous casting operation, the products are usually fed directly into the rolling mills at the proper temperature. In smaller operations, the material starts at room temperature and must be heated. This is done in a gas- or oil-fired soaking pit for larger workpieces; for smaller workpieces, induction heating is used. As the material is worked, the temperature must be monitored to make sure it remains above the recrystallization temperature.

To maintain a safety factor a finishing temperature is defined above the recrystallization temperature; this is usually 50 to 100 °C (90 to 180 °F) above the recrystallization temperature. If the temperature does drop below this temperature the material must be re-heated prior to additional hot rolling.

Hot-rolled metals generally have little directionality in their mechanical properties or deformation-induced residual stresses. However, in certain instances non-metallic inclusions will impart some directionality and workpieces less than 20 mm (0.79 in) thick often have some directional properties. Non-uniform cooling will induce a lot of residual stresses, which usually occurs in shapes that have a non-uniform cross-section, such as I-beams. While the finished product is of good quality, the surface is covered in mill scale, which is an oxide that forms at high temperatures. It is usually removed via pickling or the smooth clean surface (SCS) process, which reveals a smooth surface. Dimensional tolerances are usually 2 to 5% of the overall dimension.



Ingots lifted from soaking pit



Cold slabs



Steel blooms



Billets on rail wagon

Figure 11.3 — Semi-finished casting products [37] (to point 11.2)

Hot-rolled mild steel seems to have a wider tolerance for the level of included carbon than does cold-rolled steel, and is, therefore, more difficult for a blacksmith to use. Also, for similar metals, hot-rolled products seem to be less costly than cold-rolled ones. Hot rolling is used mainly to produce sheet metal or simple cross-sections, such as rail tracks. Other typical uses for hot-rolled metal are listed in Table 11.1.

Table 11.1 — Typical uses for hot-rolled metal (to point 11.2)

• truck frames • automotive clutch plates, wheels and wheel rims • pipes and tubes • water heaters	• agricultural equipment • strappings • stampings • compressor shells • metal buildings	• railroad hopper cars and railcar components • doors and shelving • discs • guard rails for streets and highways
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11.3 Cold rolling (in expansion to point 8.4)

Cold rolling occurs with the metal below its recrystallization temperature (usually at room temperature), which increases the strength via strain hardening up to 20%. It also improves the surface finish and holds tighter tolerances. Commonly cold-rolled products include sheets, strips, bars, and rods; these products are usually smaller than the same products that are hot rolled. Because of the smaller size of the workpieces and their greater strength, as compared to hot rolled stock, four-high or cluster mills are used. Cold rolling cannot reduce the thickness of a workpiece as much as hot rolling in a single pass.

Cold-rolled sheets and strips come in various conditions: *full-hard*, *half-hard*, *quarter-hard*, and *skin-rolled*. Full-hard rolling reduces the thickness by 50%, while the others involve less of a reduction. Cold rolled steel is then annealed to induce ductility in the cold rolled steel which is simply known as a Cold Rolled and Close Annealed.

Skin-rolling, also known as a skin-pass, involves the least amount of reduction: 0.5–1%. It is used to produce a smooth surface, a uniform thickness, and reduce the yield point phenomenon (by preventing Lüders bands from forming in later processing). It locks dislocations at the surface and thereby reduces the possibility

of formation of Lüders bands. To avoid the formation of Lüders bands it is necessary to create substantial density of unpinned dislocations in ferrite matrix. It is also used to break up the spangles in galvanized steel. Skin-rolled stock is usually used in subsequent cold-working processes where good ductility is required.

Other shapes can be cold-rolled if the cross-section is relatively uniform and the transverse dimension is relatively small. Cold rolling shapes requires a series of shaping operations, usually along the lines of sizing, breakdown, roughing, semi-roughing, semi-finishing, and finishing.

If processed by a blacksmith, the smoother, more consistent, and lower levels of carbon encapsulated in the steel makes it easier to process, but at the cost of being more expensive.

Typical applications of cold-rolled steel are given in Table 11.2.

Table 11.2 — Typical uses for cold-rolled metal (to point 11.3)

• metal furniture • desks • filing cabinets • tables • chairs • motorcycle exhaust pipes • computer cabinets and hardware	• home appliances and components • shelving • lighting fixtures • hinges • tubing • steel drums • lawn mowers	• electronic cabinetry • water heaters • metal containers • fan blades • frying pans • wall and ceiling mount kits • a variety of construction-related products
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11.4 Rolling processes (in expansion to point 9.1)

Roll bending. Roll bending produces a cylindrical shaped product from plate or steel metals. A *roll bender* is a mechanical jig having three rollers used to bend a metal bar into a circular arc (see Fig. 11.4, p. 76). The rollers freely rotate about three parallel axes, which are arranged with uniform horizontal spacing.

Two outer rollers, usually immobile, cradle the bottom of the material while the inner roller, whose position is adjustable, presses on the top side of the material.

Roll forming. Roll forming is a type of rolling involving the continuous bending of a long strip of sheet metal (typically coiled steel) into a desired cross-section. The strip passes through sets of rolls mounted on consecutive stands, each set performing

only an incremental part of the bend, until the desired cross-section (profile) is obtained (see Fig. 11.5).

Roll forming is ideal for producing constant-profile parts with long lengths and in large quantities. The geometric possibilities can be very broad and even include enclosed shapes as long as the cross-section is uniform.

Flat rolling. Flat rolling (see Fig. 11.6, p. 77) is the most basic form of rolling with the starting and ending material having a rectangular cross-section. The material is fed in between two rollers, called working rolls, that rotate in opposite directions. The gap between the two rolls is less than the thickness of the starting material, which causes it to deform. The decrease in material thickness causes the material to elongate.

Often the rolls are heated to assist in the workability of the metal. Lubrication is often used to keep the workpiece from sticking to the rolls (see Fig. 11.7, p. 78). To fine-tune the process, the speed of the rolls and the temperature of the rollers are adjusted.

For thin sheet metal with a thickness less than 200 μm (0.0079 in), the rolling is done in a cluster mill because the small thickness requires a small diameter rolls. To reduce the need for small rolls pack rolling is used, which rolls multiple sheets together to increase the effective starting thickness. As the foil sheets come through the rollers, they are trimmed and slitted with circular or razor-like



Figure 11.4 — Roll bending [37]
(to point 11.4)

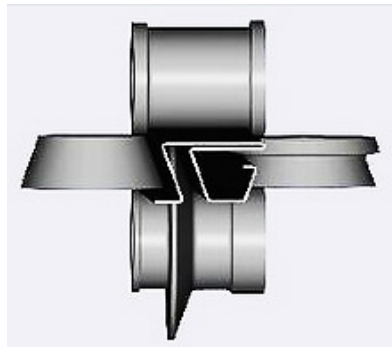


Figure 11.5 — Roll forming [37]
(to point 11.4)

knives. Trimming refers to the edges of the foil, while slitting involves cutting it into several sheets. Aluminum foil is the most commonly produced product via pack rolling. This is evident from the two different surface finishes; the shiny side is on the roll side and the dull side is against the other sheet of foil.

Ring rolling. Ring rolling is a specialized type of hot rolling that increases the diameter of a ring. The starting material is a thick-walled ring (see Fig. 11.8, p. 78). This workpiece is placed between two rolls, an inner idler roll and a driven roll, which presses the ring

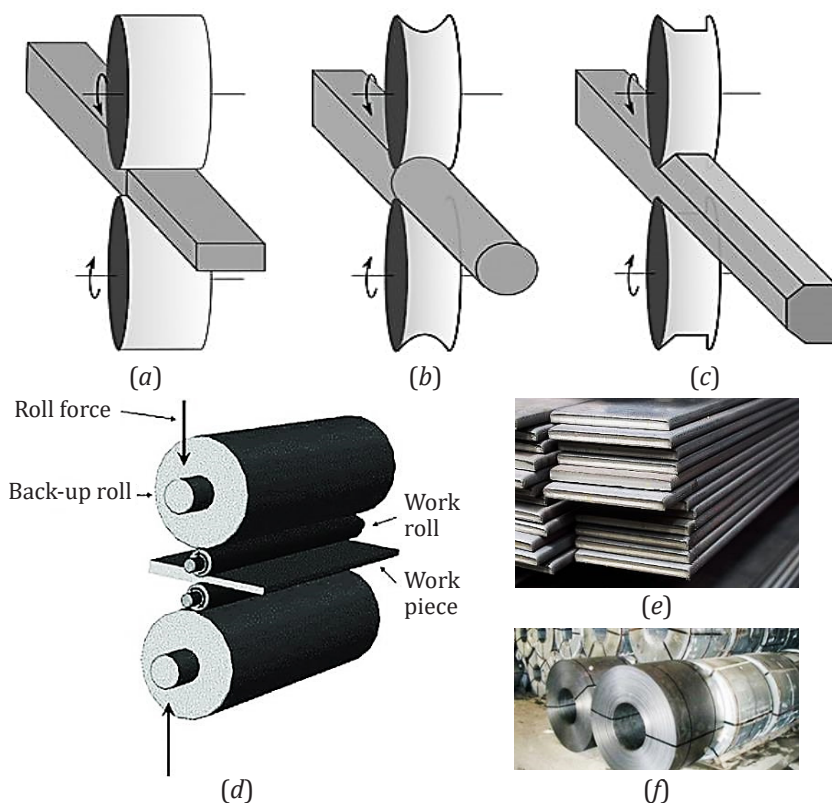


Figure 11.6 — Different types of rolls: flat (a), round (b), and non-symmetric (c) [40]; illustration of flat rolling operation (d) [41], steel plates and cold rolled coils [42] (to point 11.4)

from the outside. As the rolling occurs the wall thickness decreases as the diameter increases.

The rolls may be shaped to form various cross-sectional shapes. The resulting grain structure is circumferential, which gives better mechanical properties. Diameters can be as large as 8 m (26 ft) and face heights as tall as 2 m (79 in). Common applications include

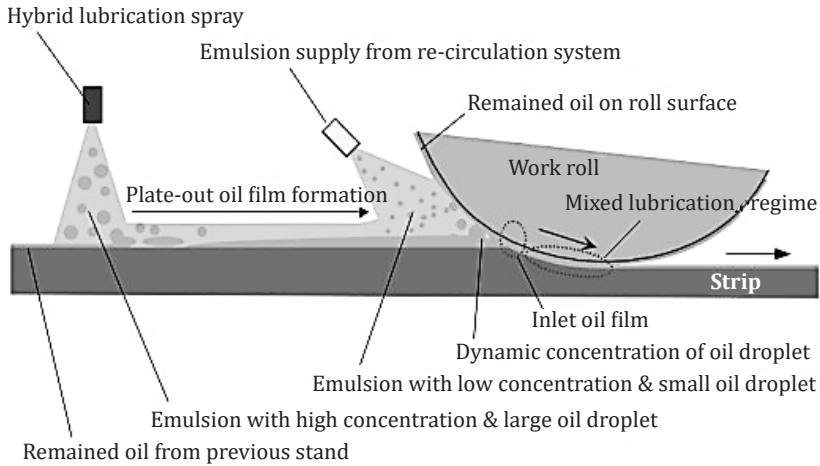


Figure 11.7 — Schematic illustration of hybrid lubrication system [43] (to point 11.4)

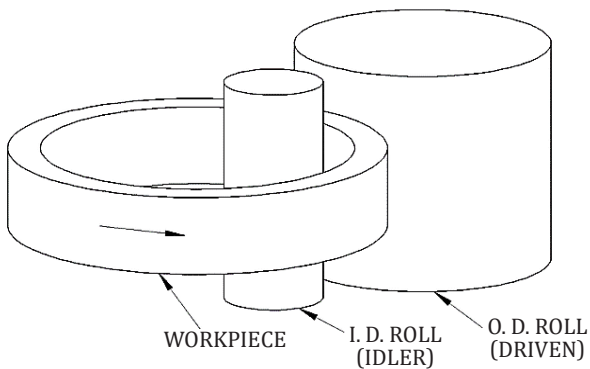


Figure 11.8 — Ring rolling [37] (to point 11.4)

railway tyres, bearings, gears, rockets, turbines, airplanes, pipes, and pressure vessels.

Structural shape rolling. Structural shape rolling is the rolling and roll forming of structural shapes by passing them through a rolling mill to bend or deform the workpiece to a desired shape while maintaining a constant cross-section. Structural shapes that can be made with this metal forming process include I-beams, H-beams, T-beams, U-beams, angle iron, channels, bar stock, and railroad rails (see Fig. 11.9).

The most commonly rolled material is structural steel, including carbon steel and stainless steel. Other metals, plastic, paper, and glass can also be rolled. Common applications include railroads, bridges, roller coasters, art, and architectural applications.

It is a cost-effective way of bending these materials because the process requires less set-up time and uses pre-made dies that

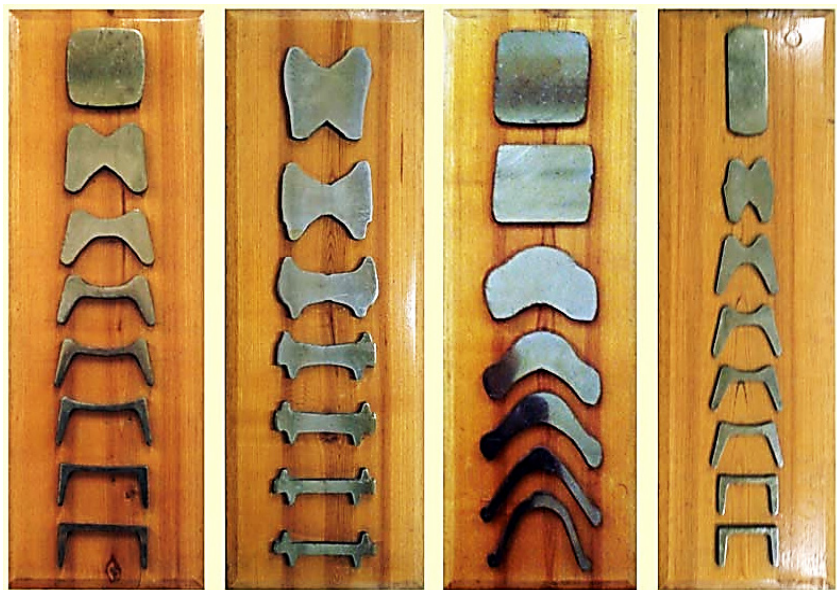


Figure 11.9 — Cross-sections of continuously rolled structural shapes [37] (to point 11.4)

are changed according to the shape and dimension of the workpiece. This process can roll workpieces into full circles.

Forge rolling. Forge rolling is a rolling (longitudinal, cross or screw) process to reduce the cross-sectional area of heated bars or billets by leading them between two contrary rotating roll segments (Fig. 11.10). The process is mainly used to provide optimized material distribution for subsequent die forging processes. Owing to this a better material utilization, lower process forces and better surface quality of parts can be achieved in die forging processes.

Basically, any forgeable metal can also be forge-rolled. Forge rolling is mainly used to preform long-scaled billets through targeted mass distribution for parts such as crankshafts, connection rods, steering knuckles and vehicle axles. Narrowest manufacturing tolerances can only partially be achieved by forge rolling. This is the main reason why forge rolling is rarely used for finishing, but mainly for preforming.

Characteristics of forge rolling:

- high productivity and high material utilization;
- good surface quality of forge-rolled workpieces;
- extended tool life-time;
- small tools and low tool costs;

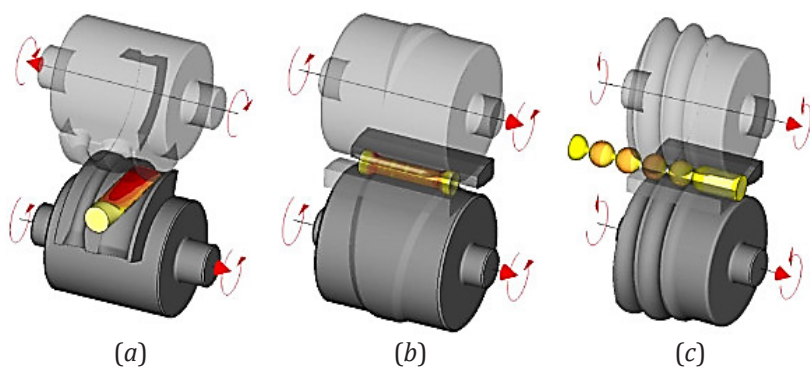


Figure 11.10 — Methods of forge rolling: longitudinal (a), cross (b), and skew (c) [44] (to point 11.4)

- improved mechanical properties due to optimized grain flow compared to exclusively die forged workpieces.

TASKS

11.5 Short answer questions

1. What is the difference between hot rolling and cold rolling? Which of these processes produces more tonnage?
2. Who is called the “father of modern rolling”? How much did the output of grooved rolls increase due to his inventions?
3. What semi-finished casting products do you know?
4. How many rollers does a typical roller bender have?
5. Is ring rolling a hot rolling process or a cold rolling one?

11.6 Match each type of rolling processes in the left column with its description in the right column (see Table 11.3).

Table 11.3 — Task to point 11.6

1) Forge rolling	a) produces a cylindrical shaped product from plate or steel metals.
2) Ring rolling	b) is the rolling and roll forming of structural shapes by passing them through a rolling mill to bend or deform the workpiece to a desired shape.
3) Structural shape rolling	c) is a longitudinal rolling process to reduce the cross-sectional area of heated bars or billets by leading them between two contrary rotating roll segments.
4) Roll bending	d) is a specialized type of hot rolling that increases the diameter of a ring.
5) Flat rolling	e) is a type of rolling with continuous bending of a long strip of sheet metal (typically coiled steel) into a desired cross-section.
6) Roll forming	f) is the most basic form of rolling with the starting and ending material having a rectangular cross-section.

11.7 Evaluate each of the statements below as

- **TRUE** if the statement agrees with the information given in the text;
- **FALSE** if the statement contradicts with the information;
- **NOT GIVEN** if there is no information on this.

1. If the temperature of the metal is below its recrystallization temperature, the process is known as hot rolling.
2. A patent was granted in 1766 to Richard Ford of England for the first tandem mill.
3. The yield strength or yield stress is a material property and is the stress corresponding to the yield point at which the material begins to deform plastically.
4. The strength of a material is its ability to withstand an applied load without failure or plastic deformation.
5. Ingots, slabs, blooms, and billets are semi-finished casting products.
6. I-beams, H-beams, T-beams, U-beams, angle iron, channels, bar stock, and railroad rails are semi-finished casting products.

11.8 Choose terms from the text to fill the gaps

1. If the temperature of the metal is above its recrystallization temperature, then the process is known as _____.
2. I-beams, angle stock, channel stock are types of _____.
3. It locks dislocations at the surface and thereby reduces the possibility of formation of ____.
4. _____ is a longitudinal rolling process to reduce the cross-sectional area of heated bars or billets by leading them between two contrary rotating roll segments.
5. A mechanical jig with three rollers used to bend a metal bar into a circular arc is called _____.
6. _____ reduces the thickness by 50%, while the others involve less of a reduction.
7. _____ is used mainly to produce sheet metal or simple cross-sections, such as rail tracks.

11.9 Put the following products into two columns: “Hot-rolled metal”, “Cold-rolled metal”:

truck frames, home appliances and components, lighting fixtures, automotive clutch plates, hinges, wheels and wheel rims, fan blades, pipes and tubes, water heaters, frying pans, railroad hopper cars and railcar components, doors and shelving, discs, wall and ceiling mount kits

11.10 Vocabulary Practice. Replace the highlighted phrases with suggested synonyms. Write the resulting sentences

Sample: Rolling is classified **according to** the temperature of the metal rolled.

based on, depending on, with regard to

Rolling is classified **based on** the temperature of the metal rolled.

Rolling is classified **depending on** the temperature of the metal rolled.

Rolling is classified **with regard to** the temperature of the metal rolled.

1. Pairs of rolls **are grouped together into** rolling mills.

assembled into, combined into, brought together to form

2. Modern rolling practice can be **attributed to** the pioneering efforts of Henry Cort.

credited to, ascribed to, associated with

3. Hot rolling is a metalworking process that **occurs** above the recrystallization temperature of the material.

takes place, happens, transpires

4. While the finished product is **of good quality**, the surface is covered in mill scale.

excellent, of superior quality, top-notch

5. The material is **fed** in between two rollers that rotate in opposite directions.

placed, inserted, introduced

6. Ring rolling is a specialized type of hot rolling that **increases** the diameter of a ring.

expands, enlarges, augments

7. It is a **cost-effective way** of bending these materials.

an economical method, a budget-friendly approach, a financially prudent way

11.11 Vocabulary Practice. Paraphrase, using the words and phrases given below instead of the highlighted words

Hot-rolled metals **generally** have **little** directionality in their mechanical **properties** or deformation-induced residual stresses. **However**, in certain instances non-metallic **inclusions** will **impair**

some directionality and workpieces less than 20 mm (0.79 in) thick often **have** some directional properties. **Non-uniform** cooling will **induce** a **lot of** residual stresses, which usually **occurs** in shapes that have a non-uniform cross-section, such as I-beams.

particles, typically, introduce, nevertheless, generate, a substantial amount of, uneven, characteristics, takes place, minimal, exhibit

KEY (in order): *typically, minimal, characteristics, nevertheless, particles, introduce, exhibit, uneven, generate, a substantial amount of, takes place*

11.12 Modality. English uses modals to convey different shades of meaning related to likelihood, possibility, necessity, and more. In particular, the “seem + to V” construction indicates an inference or likelihood based on appearance

For example: Hot-rolled mild steel **seems to have** a wider tolerance for the level of included carbon than does cold-rolled steel.

Translate into Ukrainian, paying special attention to the “seem + to V” construction

1. The efficiency of hot rolling in metalworking **seems to rely** heavily on maintaining precise temperature control.
2. In the world of metalworking, cold rolling **seems to be** a more cost-effective method for producing thinner sheets.
3. Rolling mills for different metals **seem to share** common structural features, regardless of the material being processed.
4. The technique of ring rolling in metalworking **seems to be** gaining popularity due to its ability to produce seamless and strong rings.
5. In the production of steel, the use of advanced rolling techniques **seems to contribute** significantly to product quality and consistency.

11.13 Phrasal verbs. Find the following phrasal verbs in the text

- *to attribute to, to trace back to, to derive from, to be fed into, to be covered in,*
- *to reduce by, to break up, to bend into, to rotate about, to be mounted on,*
- *to keep from, to be made with, to roll into*

Translate the sentences where these phrasal verbs are used.

Make sentences of your own.

11.14 Writing practice

Write a brief explanation what is forge-rolling and why it provides for better material utilization.

Over to you

Suppose you design a piece of metal furniture. Will you choose hot-rolled or cold-rolled metal for this product? Justify your choice.

CHAPTER 12

ROLLING PRACTICE. PART II

Basic text material in this chapter is taken from the sources [37].

12.1 Elements of rolling mills

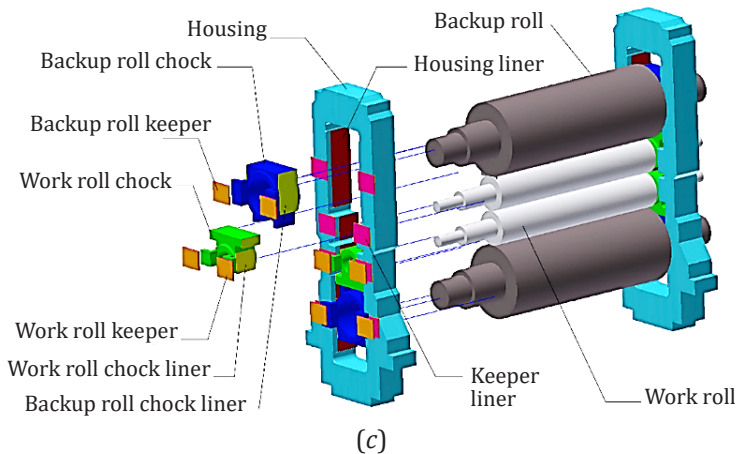
A *rolling mill*, also known as a reduction mill or mill, has a common construction independent of the specific type of rolling



(a)



(b)



(c)

Figure 12.1 — Mini rolling mill for cold rolling with rolled brass sheet (a) [37], plate hot rolling mill 3000 (b) [45] and perspective view of a mill stand (c) [46] (to point 12.1)

being performed, which includes the following main elements (see Fig. 12.1, p. 86):

- work rolls (see Fig. 12.1, Fig. 12.2);
- backup rolls — are intended to provide rigid support required by the working rolls to prevent bending under the rolling load (Fig. 12.1, Fig. 12.2);

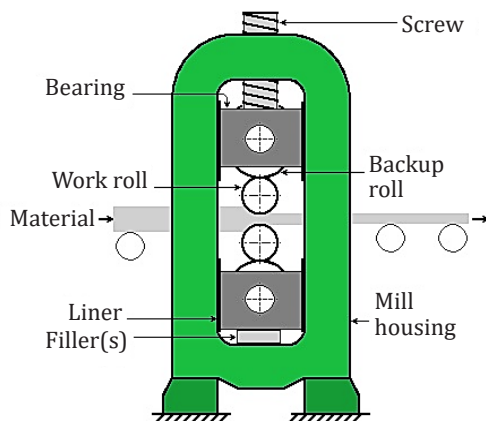


Figure 12.2 — Rolling mill stand [37] (to point 12.1)

- rolling balance system — to ensure that the upper work and back up rolls are maintained in proper position relative to lower rolls;
- roll changing devices — use of an overhead crane and a unit designed to attach to the neck of the roll to be removed from or inserted into the mill;
- mill protection devices — to ensure that forces applied to the backup roll chocks are not of such a magnitude to fracture the roll necks or damage the mill housing;
- roll cooling and lubrication systems (see Fig. 11.7);
- pinions — gears to divide power between the two spindles, rotating them at the same speed but in different directions;
- gearing — to establish desired rolling speed;
- drive motors — rolling narrow foil product to thousands of horsepower;

- electrical controls — constant and variable voltages applied to the motors;
- coilers and uncoilers (Fig. 12.3) — to unroll and roll up coils of metal.

Slabs are the feed material for hot strip mills or plate mills and blooms are rolled to billets in a billet mill or large sections in a structural mill. The output from a strip mill is coiled and, subsequently, used as the feed for a cold rolling mill or used directly by fabricators. Billets, for re-rolling, are subsequently rolled in either a merchant, bar or rod mill. Merchant or bar mills produce a variety of shaped products such as angles, channels, beams, rounds (long or coiled) and hexagons.

12.2 Configurations of rolling mills (in addition to point 10.1)

Mills are designed in different types of configurations (see Fig. 12.4, p. 89), with the most basic being a **2-high non-reversing**, which means there are two rolls that only turn in one direction.

The **2-high reversing** mill has rolls that can rotate in both directions, but the disadvantage is that the rolls must be stopped, reversed, and then brought back up to rolling speed between each pass.

To resolve this, the **3-high mill** was invented, which uses three rolls that rotate in one direction; the metal is fed through two of the rolls and then returned through the other pair. The disadvantage to this system is the workpiece must be lifted and lowered using an elevator.

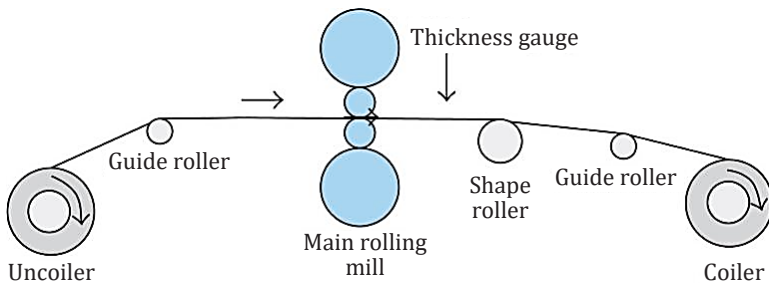


Figure 12.3 — Reverse rolling mill with coiler and uncoiler [47]
(to point 12.1)

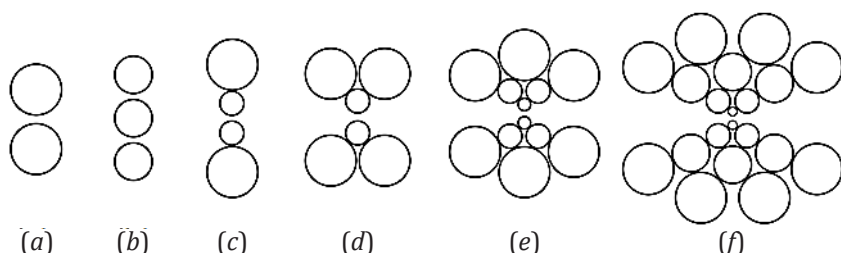


Figure 12.4 — Various rolling configurations: 2-high (a); 3-high (b); 4-high (c); 6-high (d); 12-high cluster (e); 20-high (f) (to point 12.2)

All of these mills are usually used for primary rolling and the roll diameters range from 60 to 140 cm (24 to 55 in).

To minimize the roll diameter a **four-high or cluster mill** is used. A small roll diameter is advantageous because less roll is in contact with the material, which results in a lower force and power requirement. The problem with a small roll is a reduction of stiffness, which is overcome using backup rolls. These backup rolls are larger and contact the back side of the smaller rolls. A four-high mill has four rolls, two small and two large. A cluster mill has more than four rolls, usually in three tiers. These types of mills are commonly used to hot roll wide plates, most cold rolling applications, and to roll foils.

12.3 Classification by products

By the products, rolling mills are historically classified as follows:

- *Blooming, cogging and slabbing mills*, being the preparatory mills to rolling finished rails, shapes or plates, respectively. If reversing, they are from 34 to 48 inches (864 to 1219 mm) in diameter, and if three-high, from 28 to 42 inches (711 to 1067 mm) in diameter.
- *Billet mills*, three-high, rolls from 24 to 32 inches (610 to 812 mm) in diameter, used for the further reduction of blooms down to 1.5×1.5-inch (38×38 mm) billets, being the preparatory mills for the bar and rod.
- *Beam mills*, three-high, rolls from 28 to 36 inches (711 to 914 mm) in diameter, for the production of heavy beams and channels 12 inches (304 mm) and over.

- *Rail mills* with rolls from 26 to 40 inches (660 to 1016 mm) in diameter.
- *Shape mills* with rolls from 20 to 26 inches (508 to 660 mm) in diameter, for smaller sizes of beams and channels and other structural shapes.
- *Merchant bar mills* with rolls from 16 to 20 inches (406 to 508 mm) in diameter.
- *Small merchant bar mills* with finishing rolls from 8 to 16 inches (203 to 406 mm) in diameter, generally arranged with a larger size roughing stand.
- *Rod and wire mills* with finishing rolls from 8 to 12 inches (203 to 304 mm) in diameter, always arranged with larger size roughing stands.
- *Hoop and cotton tie mills*, similar to small merchant bar mills.
- *Armour plate mills* with rolls from 44 to 50 inches (1117 to 1270 mm) in diameter and 140 to 180-inch (3556 to 4572 mm) body.
- *Plate mills* with rolls from 28 to 44 inches (711 to 1117 mm) in diameter.
- *Sheet mills* with rolls from 20 to 32 inches (508 to 812 mm) in diameter.
- *Universal mills* for the production of square-edged or so-called universal plates and various wide flanged shapes by a system of vertical and horizontal rolls.

12.4 Tandem rolling mill

A tandem rolling mill (Fig. 12.5) is a rolling mill with two or more close-coupled stands, where the reduction is achieved by the inter-stand tension(s) and the compressive force between the work rolls (see Fig. 10.8).

The first mention of a tandem rolling mill is Richard Ford's 1766 English patent for the hot rolling of wire.

The main advantages of a tandem mill are:

- only one single pass is required which saves time and increases production;

- greater tensions are possible between the stands, and this increases the reduction possible in the stands for the same roll force.

One disadvantage of a tandem mill is the high capital cost compared to that of a single stand reversing mill.

Tandem mills can be either of hot or cold rolling mill types.

Cold rolling mills may be further divided into continuous or batch processing.

A continuous mill has a looping tower which allows the mill to continue rolling slowly the strip in the tower, while a strip welder joins the tail of the current coil to the head of the next coil. At the exit end of the mill there is normally a flying shear (to cut the strip

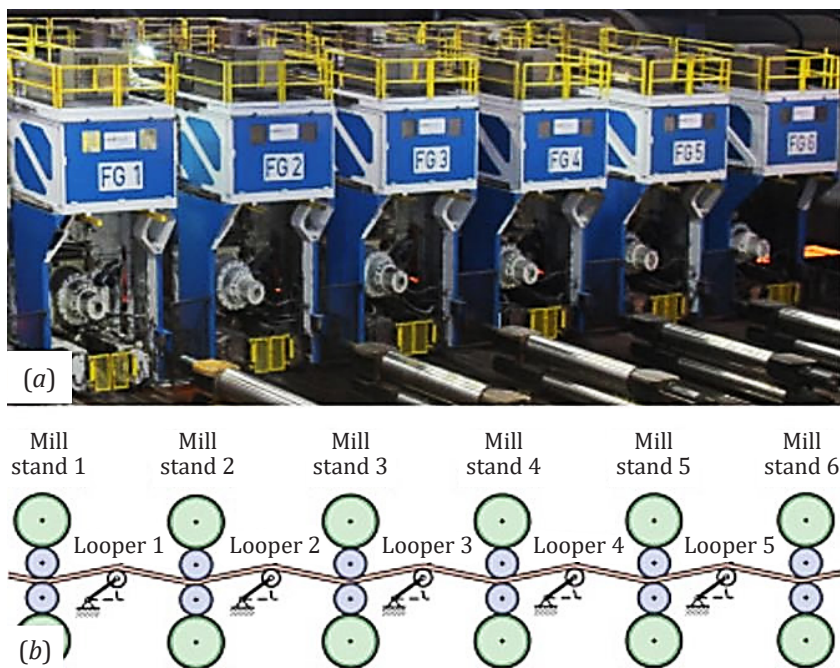


Figure 12.5 — Voestalpine Stahl GmbH Photo (a) and schematic overview (b) of the considered tandem hot strip finishing mill [48] (to point 12.4)

at or near the weld) followed by two coilers; one being unloaded while the other winds on the current coil.

Looping towers are also used in other places; such as continuous annealing lines and continuous electrolytic tinning and continuous galvanising lines.

TASKS

12.5 Complete short answer questions

1. What are the main elements of a rolling mill?
2. What rolling mill configurations do you know?
3. Mention 4–5 types of rolling mills depending on the products they produce.
4. What are advantages of a tandem rolling mill?

12.6 Evaluate each of the statements below as

- **TRUE** if the statement agrees with the information given in the text
 - **FALSE** if the statement contradicts with the information
 - **NOT GIVEN** if there is no information on this
1. A four-high or cluster mill is used to maximize the roll diameter.
 2. A four-high mill has four rolls, two small and two large.
 3. Mill scale can be used as a raw material in granular refractory.
 4. Slag is usually a mixture of metal oxides and silicon dioxide.
 5. One advantage of a tandem mill is the low capital cost compared to that of a single stand reversing mill.
 6. The deflection of the rolls causes the workpiece to be thinner on the edges and thicker in the middle.

12.7 Choose terms from the text to fill the gaps

1. _____ with rolls from 20 to 26 inches in diameter are used for smaller sizes of beams and channels and other structural shapes.
2. _____ is the per-unit change in thickness with respect to the entry thickness.
3. _____ is a measure of the thickness at one edge as opposed to the other edge.

4. The difference between the thickness of initial and rolled metal piece is called _____.
5. If one edge is “wavy” due to the material at one side being longer than the other side, this flatness defect is called _____.
6. _____ is the thickness in the center as compared to the average thickness at the edges of the workpiece.
7. _____ is the per-unit increase in length due to a decrease in area with respect to the entry, regardless of shape.

12.8 Vocabulary Practice. Replace the highlighted phrases with suggested synonyms. Write the resulting sentences

Sample: Rolling is classified **according to** the temperature of the metal rolled.

based on, depending on, with regard to

Rolling is classified **based on** the temperature of the metal rolled.

Rolling is classified **depending on** the temperature of the metal rolled.

Rolling is classified **with regard to** the temperature of the metal rolled.

1. A rolling mill has a common construction **independent of the** specific type of rolling being performed.

regardless of, irrespective of

2. A four-high or cluster mill is **used to minimize** the roll diameter. ***is employed to reduce, is utilized to decrease, is employed to diminish***

3. Cold rolling mills may be further **divided into** continuous or batch processing.

categorized as, classified into, separated as

4. Crown is the thickness in the center **as compared to** the average thickness at the edges of the workpiece.

in contrast to, relative to, in comparison with

5. If the temperature difference is **great enough** cracking and tearing can occur.

significant, substantial, considerable

12.9 Vocabulary Practice. Paraphrase, using the words and phrases given below instead of the highlighted words

A continuous mill **has** a looping tower **which allows** the mill **to continue** rolling **slowly** the strip in the tower, while a strip welder **joins** the tail of the current coil to the head of the next coil. At the exit end of the mill there is **normally** a flying shear (to cut the strip at or near the weld) **followed by** two coilers; one being **unloaded** while the other **winds on** the current coil.

incorporates, enabling, to keep on, gently, connects, typically, with, emptied, spools

KEY (in order): *incorporates, enabling, to keep on, gently, connects, typically, with, emptied, spools*

12.10 Modality. English uses modals to convey different shades of meaning related to likelihood, possibility, necessity, and more. In particular, the “*must + V*” construction indicates a strong degree of certainty

For example: The rolls **must be** stopped, reversed, and then brought back up to rolling speed between each pass.

Translate into Ukrainian, paying special attention to the “must + V” construction

To achieve precise thickness control in metal rolling, engineers **must** carefully **monitor** the rolling process.

In hot rolling, the material **must undergo** significant heat treatment to become malleable before rolling can occur.

For high-quality results in rolling aluminum sheets, the rollers **must be** impeccably maintained and aligned.

To avoid imperfections in the final product, the rolling speed **must be** controlled to prevent cracks and surface defects.

Engineers **must consider** the type of metal, temperature, and rolling speed when determining the appropriate rolling method for a specific application in metalworking.

Over to you

Suppose you should use lesser rolls to perform a task. What rolling configuration is the most preferable in this case? Justify your choice.

CHAPTER 13

ROLLING PRACTICE. PART III

13.1 Thermomechanical processing parameters of rolling

Major parameters at the 3 stages of processing on a rolling mill are as follows [1]:

Reheating — the input material usually billet is heated in the reheating furnace to the rolling temperature. The important parameters are heating rate, time of heating, and temperature of reheating.

Rolling — the important parameters for rolling in the roughing, intermediate, and finishing group of stands in the rolling mill are temperature, percentage of reduction in area, inter-pass time and strain rate.

Cooling — the major parameters after finish rolling during cooling of the rolled product are start temperature, cooling rate and the final temperature.

The Fig. 13.1 (see p. 96) shows the stages of thermomechanical controlled process (TMCP) for hot rolling as an example.

13.2 Rolling stages and operations

The traditional rolling process consists of the following stages (see Fig. 13.2, p. 97): rolling the ingot into the **semi-finished products** (blooms, billets and slabs); rolling the semi-finished product into the **finished products** as wire, rails, bars, sections (from the blooms and billets), plate, sheet, coil (from the slabs) [49].

The primary object of rolling is the breakdown of a coarse structure of the metal under operation, which makes it stronger.

The main requirements in rolling are: (1) to obtain a finished product at the highest possible rate of production and the lowest cost, (2) to obtain a finished product at the highest quality concerning not only its physical and mechanical properties, but also its surface condition. These requirements may be met only if the processing schedule for all operations in producing the given rolled product is strictly followed. These operations are (a) preparing the initial material for rolling, which consists in the removal of various surface defects, (b) heating the initial material before rolling either

in the soaking pits (for ingots) or in the heating furnaces (for blooms and slabs), (c) rolling, (d) finishing, including cutting, cooling, etc.

If it is not observed, the rolled product obtained may have defects such as flakes or cracks or may have unsatisfactory properties.

13.3 Defects and how to combat them

Below are some of the common rolling defects.

Profile defects. Profile is made up of the measurements of crown and wedge (Fig. 13.3).

Crown is the thickness in the center as compared to the average thickness at the edges of the workpiece. **Wedge** is a measure of the thickness at one edge as opposed to the other edge.

Both may be expressed as absolute measurements or as relative measurements. For instance, one could have 2 mm of crown (the center of the workpiece is 2 mm thicker than the edges),

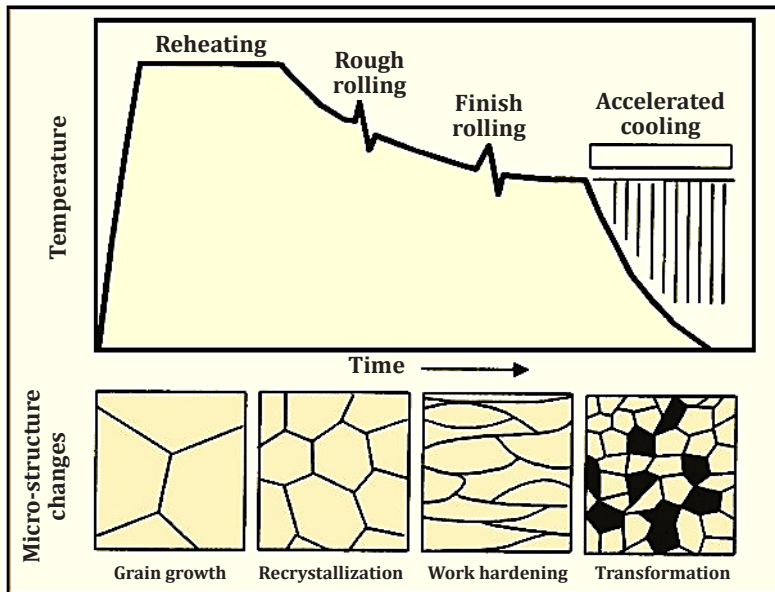
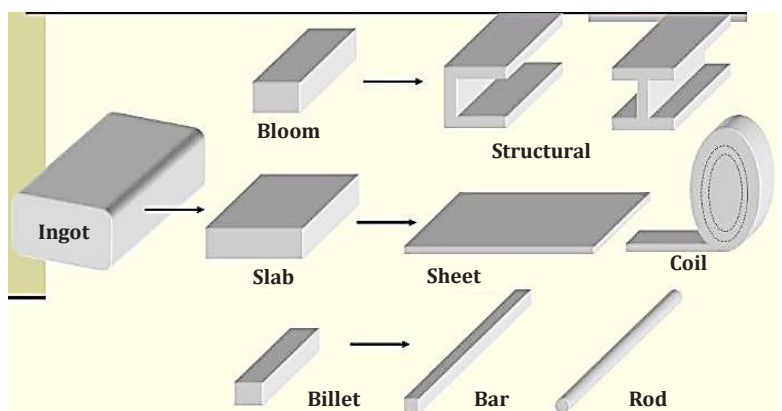
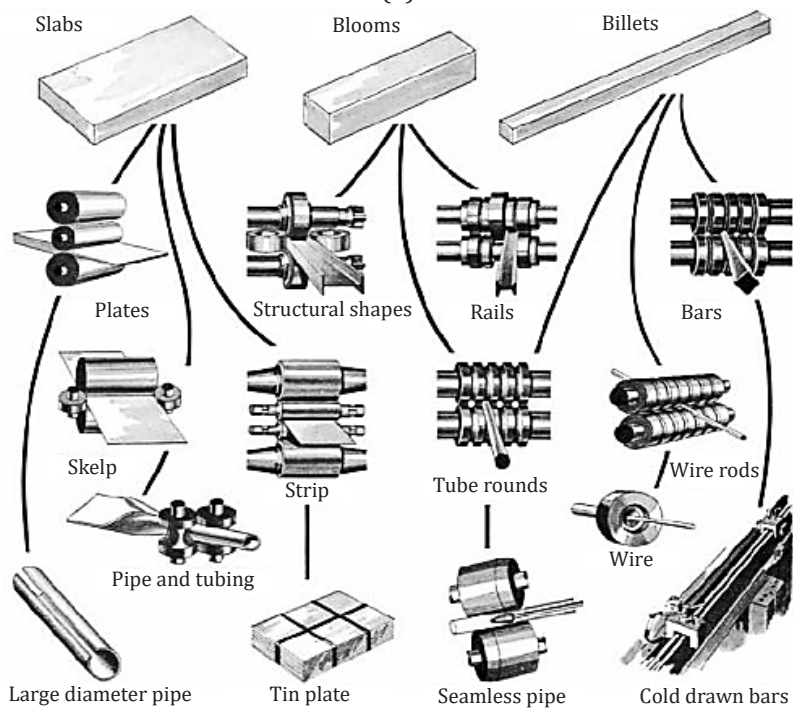


Figure 13.1 — Time-temperature profile and microstructural evolution in TMCP rolling [48] (to point 13.1)



(a)



(b)

Figure 13.2 — Rolling stages [35] (to point 13.2)

or one could have 2% crown (the center of the workpiece is 2% thicker than the edges). It is typically desirable to have some crown in the workpiece as this will cause the workpiece to tend to pull to the center of the mill, and thus will run with higher stability.

Thickness changes along length. In hot rolling, if the temperature of the workpiece is not uniform the flow of the material will occur more in the warmer parts and less in the cooler. If the temperature difference is great enough cracking and tearing can occur. The cooler sections are, among other things, a result of the supports in the re-heat furnace.

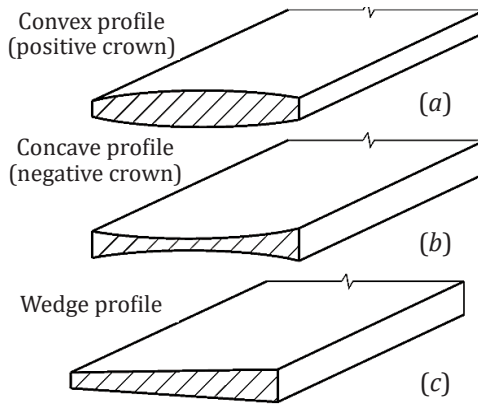


Figure 13.3 — Basic types of imperfect strip profile [50]
(to point 13.3)

When cold rolling, virtually all of the strip thickness variation is the result of the eccentricity and out-of-roundness of the back-up rolls, which can be up to 100 μm in magnitude per stack.

Flatness defects. Maintaining a uniform gap between the rolls is difficult because the rolls deflect under the load required to deform the workpiece. The deflection causes the workpiece to be thinner on the edges and thicker in the middle. This can be overcome by using a crowned roller (parabolic crown); however, the crowned roller will only compensate for one set of conditions, specifically the material, temperature, and amount of deformation.

Flatness defects can be classified as follows:

- *symmetrical edge — wave* the edges on both sides of the workpiece are “wavy” due to the material at the edges being longer than the material in the center;
- *asymmetrical edge wave* — one edge is “wavy” due to the material at one side being longer than the other side;
- *center buckle* — the center of the strip is “wavy” due to the strip in the center being longer than the strip at the edges;
- *quarter buckle* — this is a rare defect where the fibers are elongated in the quarter regions (the portion of the strip between the center and the edge); this is normally attributed to using excessive roll bending force since the bending force may not compensate for the roll deflection across the entire length of the roll.

Surface defects. There are six types of surface defects (see Table 13.1).

Table 13.1 — Six types of surface defects
(to point 13.3)

Lap	This type of defect occurs when a corner or fin is folded over and rolled but not welded into the metal. They appear as seams across the surface of the metal.
Mill-shearing	These defects occur as a feather-like lap.
Rolled-in scale	This occurs when mill scale is rolled into metal.
Scabs	These are long patches of loose metal that have been rolled into the surface of the metal.
Seams	They are open, broken lines that run along the length of the metal and caused by the presence of scale as well as due to pass roughness of Roughing mill.
Slivers	Prominent surface ruptures.

Many surface defects can be scarfed off the surface of semi-finished rolled products before further rolling. Methods of scarfing have included hand-chipping with chisels (18th and 19th centuries); powered chipping and grinding with air chisels and grinders; burning with an oxy-fuel torch, whose gas pressure blows away the metal or slag melted by the flame; and laser scarfing.

Classification of defects (Fig. 13.4) according to source [51] and their remedies.

Edge cracks. During both hot and cold rolling, the metal might show some cracks on the edges. This phenomenon occurs from secondary tensile stresses induced at the work piece surfaces. These cracks result from factors such as uneven heating, uneven rolling, or excess quenching.

What is the remedy for edge cracks? A trimming operation can remove edge cracks. Also, stretch and roller leveling under tension might work against edge cracks. Using edge rolls might help in achieving uniform rolls without any cracks.

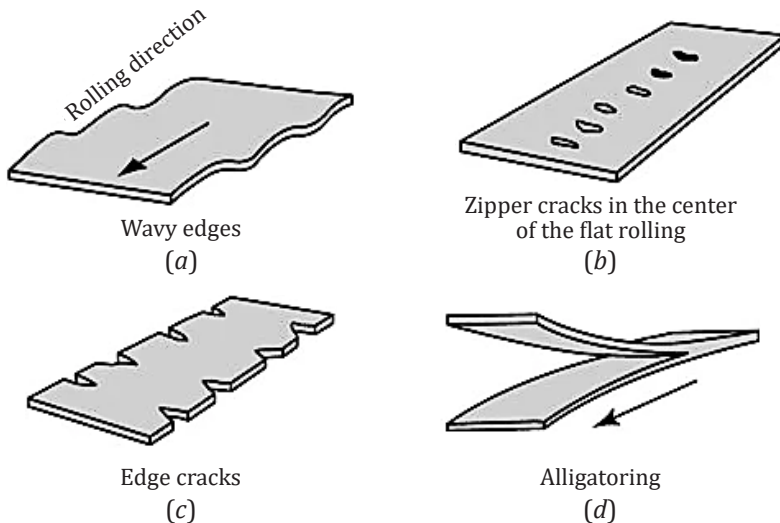


Figure 13.4 — Sketches of some rolling defects [51] (to point 13.3)

Alligator cracks. During rolling, layers of the metal stock might separate, leading to the opening of slabs resembling alligator cracks. The sheet metal adheres to the rolled surface and follows the path of respective rolls causing sheets to appear on the in the plane. Alligator cracking is majorly due to the non-homogeneous flow of materials across the sheet thickness. Greater spreading of materials occurs at the center of the material, thus metallurgical weakness.

How do you resolve alligator cracking? Cambering of rolls is one of the most common solutions to alligator cracking. By applying the camber on rolls in the opposite direction, the surface in contact with the sheet becomes flat after a deflection.

Wavy edges. One of the most common rolling defects is the occurrence of fibers at the edge, which are longer than those at the center. This occurs when concave rolls bend leading to elastic deformations. Thickness at the center implies that the edges are more elongated.

How can you prevent wavy edges? The use of hydraulic jacks works well in instances where wavy edges occur. These jacks control the elastic deformation of rolls as per the requirements. Also, the use of small diameter rolls works efficiently.

Zipper cracks. The occurrence of small cracks in the middle of the metal sheet explains this phenomenon. Mostly, zipper cracks occur due to the bending of rolls under the high rolling pressure. It causes compressive stress in the edges and tensile stress in the center. It's these tensile stresses induced at the work piece by homogeneous deformation that leads to the formation of zipper cracks.

How can you deal with zipper cracks? Cambering of rolls has proven effective when it comes to preventing zipper cracks. Camber provides a slightly large diameter at the center than on the edges.

Center buckling. This defect occurs due to the self-equilibrating residual stresses that result from the rolling process. During center buckling, fibers at the center of the metal piece are longer than those at the edges. In an event where hot or cold mills have too much crown, mills roll out at the center. Sideways deflection of a structural member perfectly explains center buckling.

Dealing with center buckling. Use crowned rolls is a solution to center buckling. The roll's parabolic curvature is sufficient to cover the problems of material, temperature, and deformation.

TASKS

13.4 Decide whether the sentences below are true or false, and correct the false sentences. Look at point 13.2 to help you

1. The rolling process comprises rolling the ingot into the finished products.
2. The blooming mill has two vertical rolls in addition to its horizontal rolls.
3. During hot rolling, the coarse-grained, brittle, and porous structure of the continuously cast steel is broken down into a wrought structure having finer grain size and improved properties.
4. The stands are grouped into roughing, intermediate and finishing stages.
5. Steel rolling consists of passing the material, usually termed as rolling stock, between two rolls driven at the same peripheral speed in opposite directions.

13.5 Complete a structural engineer's description using the words in the Table 13.2

Table 13.2 — Task to point 13.5

final product	internal defects	edge cracks	rust	surface
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Defects in metal rolling

A wide variety of defects are possible in metal rolling manufacture.

(1) defects commonly occur due to impurities in the material, scale, (2) , or dirt.

Adequate surface preparation prior to the metal rolling operation can help avoid these.

Most serious (3) are caused by improper material distribution in the (4)

Defects such as (5) , center cracks (cracks through inner region), and wavy edges, are all common with this method of metal manufacturing.

13.6 Give the grounds for these statements

1. The rolls are arranged so that the distance between them is less than the thickness of the metal fed.
2. The primary object of rolling is the breakdown of a coarse structure of a metal.
3. Strict observance of the prescribed conditions for heating the metal before rolling and cooling it after rolling is very significant.

13.7 Phrasal verbs. Find the following phrasal verbs in the text

*to attach to, to apply to, to divide between, to roll up, to bring back to,
to be used for, to be shaped by, to compare to, to divide into,
to be followed by, to be up to, to attribute to, to compensate for,
to fold over, to roll into, to run along, to scarf off*

Translate the sentences where these phrasal verbs are used.
Make sentences of your own.

13.8 Speaking practice

Using Fig. 13.2, a, describe rolling configurations and their usage for different kind of products.

Over to you

Think about the specific types of rolling processes that are used in your industry, or industry you're familiar with. How are they used? Give examples of types of loads which act on specific components or members. How would the different components or members deform or fail if they were not adequately designed, or if they were overstressed?

CHAPTER 14

UKRAINIAN-ENGLISH DICTIONARY

При укладанні словника використані матеріали посібників [55, 56]. Російську мову з матеріалів вилучено.

А		
Українською	Англійською	Визначення, пояснення, приклади
абразив	abrasive	тверді частки
абразивний	abrasive, abrasion wear	абразивне зношення
аварія, пошкодження	breakdown	пошкодження механізму
	failure	вихід з ладу
	emergency	аварійна ситуація
агломерат	agglomerate	окускований рудний концентрат, який отримують шляхом спікання дрібнодисперсних часток залізної руди (збагаченого рудного концентрату) та подрібнення до кусків потрібних розмірів
агрегат	assembly	
адгезія	adhesion	явище з'єднання (прилипання) поверхонь різнорідних твердих або рідинних тіл
адсорбція	adsorption	явище вибіркового поглинання газу або рідини поверхнею твердого тіла
аналіз	analysis	metallographic analysis — металографічний аналіз
аналізувати	analyse review	
анізотропія	anisotropy	неоднаковість властивостей середовища в різних напрямках
апріорний	a priori	такий, що не ґрунтується на досвіді
апроксимація	approximation	наближення
арматура	rolling guides	привалкова арматура
	roller guides	роликові проводки; entry guides — ввідні лінійки; delivery guides — вивідні проводки
арматурний профіль	rebar	періодичний профіль для армування бетону
	reinforcing rod	стрижні для підсилення залізобетону

Українською	Англійською	Визначення, пояснення, приклади
аустеніт	austenite	твердий розчин вуглецю в γ -залізі; retained austenite — залишковий аустеніт

Б		
Українською	Англійською	Визначення, пояснення, приклади
бабіт	babbitt	антифрикційний сплав на основі олова, що містить сурму, свинець, мідь, кадмій, нікель, миш'як
балка	beam girder	wide flanged beams — широкополічні двотаврові балки; parallel-flanges beam — балочний профіль з паралельними полицями
бандаж	sleeve, tyre, bandage	sleeve rolls — бандажовані (збірні) валки
барабан, моталка, котушка, намотувати	reel, drum	reel block — барабан моталки; reeler — моталка, розмотувач
безпека	safety	
безстанинна кліть	housingless stand	
безшовна труба	seamless tube	
бейніт	bainite	структурна фаза сталі, що утворюється при загартуванні (перетворення аустеніту за температури нижче від 450 °C), являє собою дрібнодисперсну суміш фериту та цементиту, причому ферит має збільшений до 0,2 % вміст вуглецю
білий чавун	white cast iron	
бічний	lateral	bow lateral — deviation from straight of a longitudinal edge — бічна кривизна — відхилення від прямої повздовжніх кромок (розкату)
бочка	barrel	length barrel roll — довжина бочки валка
бронза	bronze	сплав міді з іншими металами, за винятком цинку; wrought bronze — деформівна бронза; stannous bronze — олов'яниста бронза
брухт (металевий)	scrap, junk, waste	

Українською	Англійською	Визначення, пояснення, приклади
буріння	cobbles	аварійна ситуація на прокатному стані через застрягання розкату в арматурі або валках
бурт	collar	ділянки бочки валка, які розташовані по краях бочки й розділяють калібри

В

Українською	Англійською	Визначення, пояснення, приклади
важіль	lever	
вал	shaft	driving shaft — ведучий вал; driven shaft — ведений вал; transmission shaft — передаточний вал
валок	roll	length of roll barrel — довжина бочки валків; length of neck — довжина шийки; tungsten carbide rolls — валки з твердого сплаву (напр., карбідо-вольфрамові); breakdown roll — валки обтискної кліті; forming roll — формувальні валки; double poured roll — двошаровий валок
вальцівник	mill roller	
ввідна (арматура)	entry (guide), inlet	
вивідна (арматура)	exit (guide), outlet	exit guide — арматура на виході з кліті; outlet roller table — відвідний рольганг
вигин	bend	
вигинання, згинання (як операція обробки); вигин, згин (як величина, завершена дія)	bending	як вид деформації
	buckling	повздожнє викривлення
видовження	elongation	явище процесу прокатування, коли в процесі деформування валками довжина розкату збільшується
визначати	assign	встановлювати, призначати
	define	давати визначення
	designate	призначати, вказувати
	determine	визначати
	evaluate	оцінювати, визначати кількість (значення)
	quantify	визначати кількість

Українською	Англійською	Визначення, пояснення, приклади
виконання	performance	
вимога	requirement	
випередження	forward slip	
виправлення	straightening	технологічна операція, яку виконують, піддаючи прокат знакозмінній пружно-пластичній деформації, наприклад пропускаючи прокат між роликками, розташованими в шаховому порядку, для забезпечення прямолінійності прокату та зняття залишкових напружень; straightening machine — правильна машина
випробування	test	tension testing — випробування на розтягування
випуск (калібру)	flare	flare — a shape that spreads outward — випуск — форма, що розширюється назовні; to expand or open outward in shape: a skirt that flares from the waist
випуск (продукції)	output	relace — випуск (оформлення) документації
виріз у вигляді ластівчиного хвоста	dovetail slot	
висадка	upset	операція обробки металів тиском, що передбачає осаджування на частині довжини заготовки для формування потовщень на кінці
витрата	consumption	
відпалювання, відпал	annealing	операція термічної обробки, що включає нагрівання виробу до певної температури, витримку за цієї температури та наступне повільне охолодження, метою якої є зменшення внутрішніх напружень, зменшення міцності та збільшення пластичних властивостей; напр.: рекристалізаційний, дифузійний (гомогенізація), ізотермічний; нормалізація
відповідність	conformity	nonconformity — невідповідність
візок	trolleys	translating trolleys — передаточний візок
вкладиш	bearing shell, inserts	вкладиші відкритих підшипників застосовують з металевих або неметалевих матеріалів

Українською	Англійською	Визначення, пояснення, приклади
волока	die	die bell — вхідний конус волоки; die approach angle — кут робочого конуса волоки; die bearing — калібрувальний поясок волоки; die back — вихідна зона волоки
волочіння	drawing	вид обробки металів тиском, що зводиться до протягування заготовки через отвір волоки, розмір якого менше за розмір заготовки; wire drawing process consists of pointing the rod, threading the pointed end through a die, and attaching the end to a drawing block; the block, made to revolve by an electric motor, pulls the lubricated rod through the die, reducing it in diameter and increasing its length; fine wire is made by a multiple-block machine, because the reduction cannot be performed in a single draft [52]
вріз (на поверхні бочки валка прокатного стану)	groove, roll pass groove	кільцевий вріз на поверхні бочки прокатного валка, який разом зі врізом іншого валка утворює калібр для формування потрібного профілю прокату
втулка, вставка	bush, bushing, collar, hub	
вус	ridge	дефект прокату, який являє собою подовжній виступ з однієї або двох діаметрально протилежних сторін прутка, що утворився внаслідок неправильної подачі металу в калібр, переповнення калібрів або неправильного налаштування валків і привалкової арматури
в'юстит	wustite	оксид заліза FeO , що являє собою фазу змінного складу, яка може існувати у врівноваженому стані лише в діапазоні температур $833 \text{ K} \leq T \leq 1644 \text{ K}$
в'язкість	viscosity	фізична властивість рідини або газу, що характеризує здатність опиратися течії
	impact viscosity, toughness	фізична властивість металу сприймати динамічні навантаження (ударна в'язкість)

Г, Г		
Українською	Англійською	Визначення, пояснення, приклади
гайка	nut	
гальмівний клапан	apron	inlet roller table with lifting aprons — підвідний рольганг (холодильника) з гальмівними клапанами, що піднімаються
гвинтовий домкрат	screw jack	screw jacks adjust the height of the entire stand to the roller table height — гвинтові домкрати регулюють висоту всієї кліті відносно висоти рольганга
гематит	hematite	мінерал, різновид залізної руди; фаза оксиду заліза Fe_2O_3 , складова вторинної окалини, що утворюється при нагріванні магнетиту в окислювальному середовищі, має ромбоєдричну решітку
гнучкість	flexible	
головний механік	mechanical supervisor	
границя міцності	ultimate strength	показник механічних властивостей металу, який визначають як частку від ділення максимальної сили на діаграмі розтягування (за якої починається утворення шийки на зразку) на площу поперечного перерізу зразка
границя плинності	yield strength	(ДСТУ 2825-94. Розрахунки та випробування на міцність)
грубий, неопрацьований	coarse, rough	hard powder consists coarse spherical granules carbide tungsten with dimensions 3.5–5.0 μm used for manufacturing rolls — твердий порошок, що складається з грубих сферичних гранул карбіду вольфраму з розмірами 3,5–5,0 мкм, використовують для виготовлення валків
група клітей	train	ряд, послідовність; roughing mill (roughing train) — чорнова група клітей; intermediate (prefinishing) train — проміжна (передчистова) група; finishing train — чистова група
густина	density	щільність; щільність пакування атомів

Д		
Українською	Англійською	Визначення, пояснення, приклади
двадцятивалковий стан	cluster mill	
двигун	motor, engine	direct current motor — двигун постійного струму; reversible motor — реверсивний двигун
двовимірний	two-dimensional	
дефект	defect	
	pit	виїмка, вдавлення
	flaws	тріщина, вдавлення
	fault	вада, пошкодження
	dent	вибоїна, вминати
	valleys	заглиблення
	scratch	подряпина
деформація (величина, dokonana дія)	strain	nominal stress — nominal strain curves — крива «номінальні напруження — номінальна деформація»
деформування (процес, nedokonana дія)	deformation	пластична — plastic deformation; пружна — elastic deformation; поперечна — lateral deformation
диспетчер	dispatcher	
довжина осередку деформування	contact length of deformation zone	
допоміжний	auxiliary	
допуск	tolerance	the difference between the upper and lower limits between which a size must be held — різниця між верхнім і нижнім значеннями, між якими повинен знаходитись розмір
допустиме відхилення	deviation permit	
доробка	finishing, adjustage	finishing area — ділянка доробки; adjustage of finished products — відділка готового прокату
досліджувати	explore	розглядати, аналізувати
	investigate	отримувати відомості
	research	дослідження, вивчення

Українською	Англійською	Визначення, пояснення, приклади
дресування	skinpass (temper)	технологічна операція у виробничих процесах виготовлення тонких штаб зі сталі та кольорових металів, яка передбачає холодну деформацію після термічної обробки з обтисненнями до 5 % для збільшення міцності, площинності, попередження утворення ліній зсуву при штампуванні, створення потрібного мікрорельєфу поверхні
	skinpass mill	дресувальний стан
дрібносортні профілі	small section	довгомірний прокат простої або складної форми з характерним розміром менше ніж 80 мм
дріт	wire	
дугоподібність	bow	вид дефектів прокату, які проявляються як дугоподібне викривлення розкату в напрямку довжини (bow longitudinal, coil set), у напрямку ширини (cross bow) або скручування навколо поведовжньої осі (twist)

Е

Українською	Англійською	Визначення, пояснення, приклади
евтектоїдний	eutectoid	дрібнодисперсна суміш твердих речовин, що одночасно викристалізувалися з розплаву за температури більш низької, ніж температура плавлення окремих компонентів
еджер	edger	прокатна кліть або пристрій з вертикальними валками
експлуатація, робота	operating	operating duty — робочий режим; operation — робота, дія, виробництво, процес експлуатації
ексцентричність	eccentricity	eccentric shaft — ексцентриковий вал
емульсія	emulsion	змащувально-охолоджувальна або технологічна рідина, що являє собою достатньо стабільну систему з двох рідин, одна з яких (дисперсна фаза) розпорошена у вигляді дрібних краплинок в іншій (дисперсійна фаза)

Є		
Українською	Англійською	Визначення, пояснення, приклади
ємність, місткість	capacitance, capacity	

Ж		
Українською	Англійською	Визначення, пояснення, приклади
жовтіння	sulling	штучне іржавіння металу перед волочінням, для створення підзмашувального прошарку
жорсткість	rigidity, stiffness	

З		
Українською	Англійською	Визначення, пояснення, приклади
завантаження	charging	
загартування	quenching, hardening	операція термічної обробки, що передбачає нагрівання до температури 940...960 °C (доевтектоїдні сталі) або 760...780 °C (заевтектоїдні сталі) та швидке охолодження у воді або мастилі
загострений	pointed	pointed end — загострений кінець (прута або стрижня перед волочінням)
загострення	pointing	технологічна операція, яку виконують перед волочінням для забезпечення проходження переднього кінця заготовки через волоку
заготовка	billet, blank	blank for section — заготовка для профілів прокату
задир	scoring	дефект поверхні
	scuffing	задирання
	galling	налипання металу
	scratching	шкрябання, подряпина
задирка	fin	
зазор (між валками), проміжок	gap (roll gap), clearance	
закат, складка	fold, rolling lap, slab	дефект поверхні прокатного походження

Українською	Англійською	Визначення, пояснення, приклади
закритий калібр	closed pass	closed groove — закритий вріз; dead flange — закритий фланець (калібру)
залишкові напруження	residual stress	напруження, які виникають у прокатаному матеріалі через нерівномірність деформації та залишаються після деформації
залізо	iron ferrum	
залізобетон	reinforced concrete	
замовлення	order	
замовник	customer	
запас міцності	factor of safety, margin	
затвердження (документа)	validation	заява, твердження, висловлювання — statement, assertion
захват	grabbing bite, bite	bite is necessary for grabbing the metal and starting it through the mill — захват (металу валками), необхідний для втягування металу й переміщення його через стан
зварний профіль	welded section	довгомірний виріб, який виготовляють переважно формуванням з наступним повздовжнім з'єднанням елементів зварюванням
зварюваність	weldability	показник якості прокату, що характеризує його здатність до утворення нероз'ємних з'єднань шляхом зварювання
згинання	bending	
здатність	capability	
здатність до згинання	bendability	властивість металевих виробів, що характеризує їхню здатність згинатися без руйнування
зенкерування	reaming, core drilling	

Українською	Англійською	Визначення, пояснення, приклади
з'єднання (завершена дія); з'єднування (процес)	compound, joint, connecting	threaded joint — різьбове з'єднання; detachable joint — роз'ємне з'єднання; hinge joint — шарнірне з'єднання; splined joint — шліцьове з'єднання; chemical compound — хімічне з'єднання (сполука)
зливоч	ingot	
змащувати	lubrication	boundary lubrication — граничне змащування; mixed lubrication — змішане змащування; hydrodynamic lubrication — гідродинамічне змащування
зміна (як період роботи)	shift	shift foreman — начальник зміни; eight hours shift — восьмигодинна зміна
зміцнення (операція, доконана дія); зміцнювання (процес, недоконана дія)	strengthening	
знання	knowledge	
зневуглецьовування	decarburization	наприклад, вигорання вуглецю з поверхневих прошарків заготовок високовуглецевих сталей при нагріванні
зношування (як процес); знос (величина)	wear	трибологічний процес зміни мікро- та макроеконометрії поверхонь — як наслідок процесу тертя, який призводить до відділення часток металу з поверхні
зсув	shear	shear stress — напруження зсуву
зумовити, зумовлювати	cause	бути причиною чогось, створювати умови для виникнення чогось; викликати щось, спричиняти; бути умовою існування або формування чогось, визначати його якість, відмінності
зумовлений	caused, due to	є причиною

К		
Українською	Англійською	Визначення, пояснення, приклади
калібр (як інструмент)	gauge	gauge — калібр, утворений двома врізами у валки; groove — вріз у валки, проточка; pass shape — форма калібру; caliber — окрема деталь, наприклад, у метрології; шаблон
калібр «гладка бочка»	gauge bullhead, bullhead groove	
калібрування (як наслідок, результат)	grooving, roll pass design	наслідок, результат процесу визначення форми та розмірів врізів у валки, що утворюють калібр; roll pass designer — калібрувальник — розробник калібрування валків
калібрування (як процес ОМТ)	sizing	sizing block — блок (клітей) для калібрування
кантувач	edger, canting machine	
кипляча сталь	rimming steel rimmed steel	
клапан	valve	valve bench — клапанний стенд
клин	wedge	
кліть	stand	shiftable stand — кліть з осьовим переміщенням
коефіцієнт використання стану	mill utilization factor (MUF)	визначається як відношення фактичного часу роботи стану до номінального фонду робочого часу за рік (різниця між цими величинами включає простої, пов'язані з переналагодженням стану при зміні профілю, час, необхідний для усунення браку, можливі простої через вихід з ладу електричного або механічного обладнання)
колесо	wheel	spur wheel — циліндричне колесо; worm wheel — черв'ячне колесо
комірка, чарунка, вічко, осередок (організаційна група)	cell	pickling cell — ванна травлення; screw down cell — месдоза, що встановлюється під натискний гвинт

Українською	Англійською	Визначення, пояснення, приклади
консоль	console, cantilever	
консольний	cantilever	cantilever stand — прокатна кліть з консольним розташуванням валків
креслення	drawing	
крива	curve	
кривизна, вигин	curvature, camber, bow	camber or bow lateral — deviation from straight of a longitudinal edge — серповидність або бічна кривизна — відхилення від прямої бічних кромок (розкату); cambered work roll — профільований робочий валок
крихкий	brittle fragile	крихкість — brittleness; fragility, friability
кронштейн, підвіска	hanger	
крупносортні профілі	heavy section	вид прокату простої або складної (фасонної) форми з характерним розміром понад 80 мм
крутний, обертальний	torque	про обертальний момент
кування	forging	deformation process in which woks is compressed between two dies — процес деформації, який здійснюється обтисненням між двома штампами (бойками), (що здійснюється послідовними ударами або тиском з використанням молотів, кувальних пресів, висадочних пресів, вальців)
кут захвату	bite angle	the maximum angle, measured from the center of a roll in a rolling mill, between a perpendicular and a line to the point of contact where a given object to be rolled will enter between the rolls [53]; максимальний кут, що вимірюють від центра валка прокатного стану між перпендикуляром (проведеним через осі валків) та лінією до точки контактування, у якій об'єкт, що прокатується, буде входити між валками

Українською	Англійською	Визначення, пояснення, приклади
кут нейтральний	neutral angle	кут між радіусами, проведеними з центра валка через площину осей валків та до площини, у якій швидкості поверхні валків та розкату однакові
кутик	angle	довгомірний прокат з плоскими елементами однакової або різної довжини, які розташовані під прямим кутом; unequal-leg angle — нерівнополичний кутик

Л

Українською	Англійською	Визначення, пояснення, приклади
ланцюг	chain	ланцюг
латунь	brass	подвійні або багатокомпонентні сплави міді, в яких основним легуючим елементом є цинк (від 5 до 40 %)
легуювання	alloying	alloyed — легований
ледебурит	ledeburite	проміжна фаза, що являє собою евтектичну суміш аустеніту та цементиту
лом (інструмент)	crow-bar	

М

Українською	Англійською	Визначення, пояснення, приклади
магнетит	magnetite	мінерал, різновид залізної руди; фаза оксиду заліза Fe_3O_4 , складова вторинної окалини, що має кубічну решітку і значну абразивність
маркування	labeling	операція обробки прокату, що зводиться до нанесення інформації про прокат на бирку, яка навішується на пакет
мартенсит	martensite	метастабільна структурна фаза сталі, що утворюється в переохолодженому аустеніті за температури 230 °C, являє собою перенасичений розчин вуглецю у фериті та має тетрагональну будову
мастило	lubricant	oil — олива (рідинне мастило); grease — масло (пластичне мастило); emulsion — емульсія

Українською	Англійською	Визначення, пояснення, приклади
маточина зубчатого колеса	hub gear	
маятник	pendulum	pendulum shear — маятникові ножиці
мета	aim, goal	
механізм	mechanism, device	screw-type mechanism — гвинтовий механізм; crank mechanism — кривошипний механізм
міцність	strength, toughness	
моток	coil	
муфта	coupling	motor coupling — моторна муфта; gear coupling — зубчата муфта

Н

Українською	Англійською	Визначення, пояснення, приклади
надійність	reliability safety	for a reliability factor higher than 90% — для показника надійності понад 90 %
накатування різби	tread rolling	
налагодження, налаштування	adjustment, regulation	roll adjustment — регулювання валків; roll alignment — вирівнювання валків до горизонтального розташування; roll arrangement — приведення до ладу — налагодження певного взаємного розташування валків
налипання	sticking	явище перенесення матеріалу з розкату на поверхню валка, що в подальшому призводить до утворення поверхневих дефектів прокату
наплавлення	build-up welding	
напруження, напруга	stress	нормальні н. — normal stress; напруження зсуву — tangential stress; залишкові н. — residual stress; допустимі н. — permissible stress
насічка (валків)	ragging	як процес формування грубої поверхні для збільшення захвату, включає також наварку
наступний	subsequent	

Українською	Англійською	Визначення, пояснення, приклади
натискний гвинт	screwdown	деталь натискного механізму прокатного стану, що забезпечує зміну положення валків у вертикальній площині й передає силу прокатування від подушки до гайки, розташованій у поперечині станини
нахил	slope, tilt	
нахиляє, який нахиляє	tilting	похилий — tilting, oblique
начальник цеху	plant manager	
неперервний стан, стан неперервного прокатування	tandem mill	стан з послідовним розташуванням клітей, в яких здійснюється неперервний (тобто одночасно в кількох клітях) процес прокатування
неспіввісність валів	misalignments	
ножиці	shear scissors	dividing shear — ділильні ножиці; flying shear — летучі ножиці; crank-type shears — кривошипні ножиці; crop shears (for nose and tail cropping) — ножиці для видалення обрізі (видалення передніх і задніх кінців розкату); pendulum shears — маятникові ножиці
нормалізація	normalizing	операція термічної обробки, різновид відпалу, що передбачає нагрівання до температури 960 °С, нетривале витримання та охолодження на повітрі, забезпечує усунення крупнозернистої структури та підвищення механічних властивостей виробів

О

Українською	Англійською	Визначення, пояснення, приклади
обв'язка	bundle	технологічна операція для забезпечення формування пакетів прутів або мотків прокату та їхнє транспортування

Українською	Англійською	Визначення, пояснення, приклади
обв'язувати (обв'язування)	tie, tying	технологічна операція обробки прокату, що зводиться до обв'язування сформованих пакетів проволокою або стрічкою для їхнього транспортування
обґрунтування (підтвердження правильності)	validation	
обід (колеса)	tire	tire gear wheel — обід зубчастого колеса
обладнання	equipment, device	highlights of equipment — характеристики (основні показники) обладнання
обладнування, упорядковування (дія)	arranging, equip, fit, adjust	
обробка, обробляння	working	як технологічний процес
	treatment	термічне обробляння
	forming	обробка тиском
оброблюваність	workability	
обслуговування	maintenance	підтримання обладнання в робочому стані
обтискний стан (обтискна кліть)	roughing stand, roughers, breakdown	
обтиснення	draught, draft reduction	the difference between the initial and final thickness of the strip being rolled is called absolute draught — різниця між початковою та кінцевою товщиною штаби, що прокатується, називається абсолютним обтисненням; draught per pass — обтиснення за прохід; relative draught — відносне обтиснення
обумовити, обумовлювати	condition determine give rise to	обмежити якоюсь умовою, застереженням, ставити в залежність від певних умов
обумовлений	agreed upon	прийнятий за домовленістю
одиниця	unit	

Українською	Англійською	Визначення, пояснення, приклади
одиничний	singular	
однаковий	uniform	
окалина, жаровина	scale	
окапиноламах	descaler	water descaler — гідрозбив окалини
оковування, обковування	collaring	
оператор поста керування	pulpit operator	
опорний валок	supporting roll, back-up roll	
оправка	mandrel	
опуклий	convex camber	cambered work roll — опуклий робочий валок (опуклий профіль валка)
опуклість (по дну калібру)	convexity	
освіта	education	
осередок	bite, cell deformation	roll bite inlet; entrance of the roll bite — вхід в осередок деформації при прокатуванні

П

Українською	Англійською	Визначення, пояснення, приклади
пакет прутів	stack bar	
пакування	stacking	технологічна операція з формування окремих прутів у пакет
	packaging	пакування сформованих пакетів
парний	even	
перевалка	roll change	заміна валків у робочій кліті, яку здійснюють безпосередньо на стані або на спеціальних стендах поза станом
перевірка	verification	
переточування (валків)	dressing roll	

Українською	Англійською	Визначення, пояснення, приклади
перліт	pearlite	евтектоїдна суміш фериту (α -розчин) та цементиту; fine pearlite — дрібнопластинчастий перліт; lamellar pearlite — пластинчастий перліт; sorbite pearlite — сорбітоподібний перліт
петлеутворювач	looper	
пилка	saw	hot saw — пилка гарячого різання; sled-type cold saws — пилки холодного різання полозкового типу
підшипник, вальцівниця	bearing	plain bearing — плоский підшипник ковзання; journal bearing — підшипник ковзання з вкладишами; thrust bearing — упорний підшипник; ball bearing — кульковий підшипник кочення; roller bearing — роликовий підшипник кочення
підшипник ковзання закритий	enclosed oil film bearing	
підшипниковий вузол	bearing unit	сукупність деталей, які забезпечують закріплення підшипника на шийці валка та його роботу
плановий ремонт	scheduled maintenance	
пластичність	plasticity, ductility	властивість металів, що характеризує їхню здатність до пластичної деформації
плитовина	baseplate	деталь прокатного стану, яка закріплюється на фундаменті та призначена для розміщення робочих клітей
площина	plane	
площинність	flatness	показник якості плоского прокату, що відображає відхилення (у мм) від ідеально рівної площини

Українською	Англійською	Визначення, пояснення, приклади
плющення	flattening, spreading	вид обробки металів тиском, характерними відмінностями якого є деформація круглого дроту в циліндричних валках
повздожнє вигинання	buckling	
повздожній вигин	buckle	buckle — a distortion of the surface of the metal — викривлення (спотворення) поверхні металу — вид дефектів плоского прокату
подавальні ролики, ролики подачі	feeding pinch rolls	
подушка	chock	конструктивний елемент робочої кліті, де розміщують підшипникові вузли
полірування	buffing	вид механічної обробки повстяним інструментом
	burnish	полірування, обкочування — roller burnishing
	polishing	вид механічної обробки абразивними пастами
поперечина	cross-arm	
порожнисті профілі	hollow section	вид прокату, який виготовляють формуванням із труб або згинанням та зварюванням
послідовність	sequence	
постачальник	supplier	
постачання (готової продукції)	delivery	technical delivery requirements — технічні умови постачання
початковий	initial	
пошкодження	disturbance, spalling	spalling — пошкодження поверхні (валків) через сколювання поверхні, що виникає від втомлюваності металу
привалковий брус (опорний брус)	rest bar	the guides are locked on the rest bar by means of two bolts — проводки закріплені на опорному брусі двома болтами
привідна ділянка (прокатного валка)	wabblers	ділянка валка, що забезпечує передачу крутного моменту на валок від механізмів приводу прокатного стану

Українською	Англійською	Визначення, пояснення, приклади
призначення	duty, employ	
прикріплювати	attach	attached — прикріплений, приєднаний; attaching — закріплення, захват; attachment — прикріплення;
прилад	device, instrument	measuring instrument — вимірювальний прилад; precision instrument — контрольний (зразковий) прилад
пристрій (механізм, пристосування)	device, arrangement, equipment, facility	
притирання	lapping	вид механічної обробки, що зводиться до абразивної обробки поверхні спеціальним інструментом — притиром; забезпечує шорсткість поверхні $Ra=0,8-0,012$ мкм
прогин	deflection	the elastic roll deformation is determined by superimposition of deflection due to bending and deflection due to shear on the roll — пружна деформація валків визначається накладенням на валки прогинання, зумовленим згинанням та прогинанням, зумовленим зсувом
прогинання	deflect, flex, sag	
продуктивність	productivity, capacity	annual capacity — річна продуктивність
проектування	design	
прокатування	rolling	process consists of passing the metal between pairs of rollers revolving at the same speed but in opposite directions and spaced so that the distance between them is slightly less than the thickness of the metal [54]; вид обробки металів тиском, який зводиться до проходження металу між парами валків, що обертаються з однаковою швидкістю, але в протилежних напрямках, та розташованих так, що відстань між ними менша ніж товщина металу (початкова)

Українською	Англійською	Визначення, пояснення, приклади
прокатування-розділення	slit rolling	
проміжна група	intermediate train	
пропускна здатність	capability, capacity, traffic capacity	
простої (стану), затримка	downtime, delay	
протягування	pulling	вид обробки металів тиском, що зводиться до деформування заготовки під дією тягнучої сили, що прикладається до готового виробу, через калібр, утворений непривідними валками (роликами)
	broaching	вид механічної обробки, що зводиться до протягування спеціального ріжучого інструменту (broach — протяжки) через отвір для обробки поверхні цього отвору
профіль	section	heavy section — крупносортний профіль; small section — дрібносортний профіль; special sections — спеціальні профілі; equal angle section — рівнополічний кутовий профіль; mining frame sections — шахтні профілі
профілювання валків	shape roll, ground camber roll	the initially ground camber roll can compensate for the combined effects of bending and thermal expansion — профілювання валків може компенсувати комбінований ефект від прогинання та теплового розширення; cambered roll — профільований (листовий) валок
прохід	pass	як технологічна операція обробки (прокатування), яка здійснюється за незмінних параметрів на одному технічному засобі (калібрі, стані)
пружний	elastic	elasticity — пружність
пруток	bar	довгомірний виріб, який постачається в прямих відрізках, але не в мотках, на відміну від стрижнів

Р		
Українською	Англійською	Визначення, пояснення, приклади
редуктор	gear box	
режим	schedule	schedule rolling — режим прокатування (обтисень); pass schedules — режим (технологічні параметри) прокатування по проходах
рейка	rail	довгомірний прокат спеціальної форми для залізниці та іншого транспорту
ремонт	repair	як відновлення працездатності
	maintenance	поточний ремонт (обслуговування)
	overhaul	капітальний ремонт
рідинний	liquid	
різновтовщинність (прокату)	crown	різновтовщинність визначається як різниця між товщиною штаби по середині та середньою товщиною кромки штаби
робоча кліть	stand	pre-stressed stand — попередньо напружена кліть; shiftable stand — кліть з можливістю осьового зміщення; housingless stand — безстанинна кліть
розріз	section, sectional view	cross section — поперечний розріз
розробляння, розроблення, опрацювання	development	
розташування обладнання	highlights, layout	
розточування	boring	вид механічної обробки, що зводиться до збільшення діаметру отвору шляхом зняття стружки з внутрішньої поверхні
розузгодження, непогодження	mismatch, misalignment	
розчин	solution	rolling solution — розчин технологічного мастила та охолодної рідини
розширення	spread	явище процесу прокатування, коли в процесі деформування валками ширина розкату збільшується

Українською	Англійською	Визначення, пояснення, приклади
роликова волока	die-roller	інструмент для волочіння, який утворюють непривідні ролики
рольганг, роликовий транспортер	roller table	by pass roller table — обвідний рольганг

С

Українською	Англійською	Визначення, пояснення, приклади
свердлення	drilling	
серповидність	camber, bow lateral	відхилення форми, при якому краї (кромки) листа або штаби в горизонт. площині мають форму дуги; camber or bow lateral — deviation from straight of a longitudinal edge — серповидність або бічна кривизна — відхилення від прямої бічних крамок (розкату)
сляб	slab	напівпродукт із прямокутною формою поперечного перерізу; slab ingot — литий сляб
сорбіт	sorbite	структура сталі, що утворюється при її загартуванні (розпад аустеніту за температури 500...600 °С), що являє собою більш дрібнодисперсну суміш фериту та цементиту, ніж у перліті
споживана потужність, витрата енергії	consumed power	
спокійна сталь	killed steel	
сталь	steel	матеріал, масова частка заліза в якому перевищує масову частку будь-якого іншого окремого елемента, котрий містить вуглецю загалом менше ніж 2 %, а також деякі інші елементи
сталь вуглецева	carbon steel	
	medium-carbon steel	середньовуглецева сталь
	high-carbon steel	високовуглецева сталь

Українською	Англійською	Визначення, пояснення, приклади
сталь дрібнозерниста	fine grain steel	
сталь легована	alloy steel	леговані сталі розділяють на: якісні, спеціальні
сталь неіржавна	stainless steel	
сталь нелегована	non-alloy steel unalloyed steel	нелеговані сталі розділяють на: базові, якісні, спеціальні
станина	housing	housingless stand — безстанинна кліть
стикове зварювальне з'єднання	butt weld	flash butt weld — з'єднання, отримане при стиковому зварюванні оплавленням; flash upset welding — стикове зварювання оплавленням з осаджуванням
стійкий, сталий	stable	constant — постійний; stability — стійкість, сталість
стрижень	rod	гарячекатаний довгомірний виріб, який має номінальний розмір 5 мм або більше та змотаний у неправильні вільні мотки (на відміну від прута)
стяжка, зв'язка	tie rod	housingless stand have four tie rods — безстанинна кліть має чотири стяжки (стяжні гвинти)
сфероїдизувальний відпал	spheroidize annealing	вид термічної обробки, що зводиться до нагріву, витримки за температури трохи вище за критичну та повільного охолодження
схема	scheme	arrangment — схема механізму, пристрою; layout — схема розташування обладнання; rolling scheme — схема прокатування
схований, прихований	hidden	hidden layer — прихований шар (прошарок); hidden unit — прихований елемент

Т		
Українською	Англійською	Визначення, пояснення, приклади
текучість, плинність	fluidity, yield, flow	yield — плинність металу; yield stress — границя плинності металу
тепле прокатування	warm-rolling process	
теплоємність	thermal capacity	фізична властивість речовини, що відображає кількість тепла, яке потрібно витратити на нагрівання одиниці маси речовини для збільшення її температури на один градус, Дж/(кг · К)
термічна обробка	thermal treatment, heat treatment	технологічний процес, що складається із сукупності операцій нагрівання, витримування за певної температури та охолодження виробів з металу або сплавів з метою зміни їхньої структури та властивостей у заданому напрямку
техніка	equipment, facilities, machinery	як сукупність технічних засобів; як галузь діяльності — engineering; як методика, спосіб — technique, method, procedure
технічні умови	specification	
тиск (як величина); тиснення (незавершена дія, процес)	pressure	uniformly distributed pressure — усебічний рівномірний тиск
тлумачення	interpretation	
товстий	thick	thickness — товщина
товстий лист	heavy plate	
торець	end, face, butt end	
точіння	turning	
точкове зварювання	spot welding, button welding	
точність	accuracy, precision	
траверса	crossmember, traverse	

Українською	Англійською	Визначення, пояснення, приклади
травлення	pickling	pickling bath — травильна ванна
тривалість пауз	idle time	
тримач, стійка	holder, support	spindle holder — тримач шпindelних головок
труба	tube, pipe	
трубопровід	pipe, pipe-line	

У

Українською	Англійською	Визначення, пояснення, приклади
увігнутий, угнутий	concave	concave barrel roll — увігнута бочка валка
упор, що піднімається	lifting stop	упор, що піднімається
установка (закінчена дія; про пристрій, комплекс механізмів)	plant, unit	power plant — силова установка; installation of equipment — установлювання обладнання
	installation, mounting, assembly	установлювання (незакінчена дія; про процес монтажу обладнання)
	set-up, setting	установлювання (незакінчена дія; про регулювання приладу, встановлення програмного забезпечення)
	directive	настанова, вказівка
устрій (будова, конструкція)	construction, design	
утворення	formation	утворення
утомлюваність, втомленість	fatigue	fatigue strength — міцність утомленості

Ф

Українською	Англійською	Визначення, пояснення, приклади
фабрикатор	scheduler	
ферит	ferrite	твердий розчин вуглецю в α -залізі та β -залізі
фольга	foil	used for wrapping candy, thickness of 0.008 mm — використовується для обгортання цукерок, товщиною від 0,008 мм
фрезерування	milling	вид механічної обробки багатолезовим інструментом

Х		
Українською	Англійською	Визначення, пояснення, приклади
характеристика	characteristic	властивість, ознака; volt-ampere characteristic — вольт-амперна характеристика
	feature	риса, відмінність
	performance	сукупність показників роботи або функціонування; only perfect rolling conditions allow excellent roll performance — тільки бездоганні умови прокатування дозволяють (отримати) відмінні характеристики валків
хвилястість	wavy	вид дефектів, що проявляється як відхилення від площинності, при якому металопродукція або її окремі частини мають вигляд випуклостей та увігнутостей, що чергуються, не передбачених формою прокату
	buckle	криволінійно обмежені хвилі або місцева кривизна, що утворюється в осередку деформації через розузгодження між поперечним профілем вхідного металу та зазором, який утворюють робочі валки
	waviness	показник якості поверхні мікромасштабу, що застосовується так само, як і показники шорсткості
холодильник	cooling bed	комплекс механізмів для охолодження прокату у вигляді прутів після гарячого прокатування

Ц		
Українською	Англійською	Визначення, пояснення, приклади
цапфа	pin, pivot, trunnion	
цементит	cementite	з'єднання заліза з вуглецем — Fe_3C ; annealing to granular cementite — відпал на зернистий цементит — сфероїдизувальний відпал
цех	shop	

Ч		
Українською	Англійською	Визначення, пояснення, приклади
чавун	cast iron	grey cast iron — сірий чавун; cast-iron — чавунний
частка (уламок)	particle debris	debris — уламок
чистовий	finishing	finishing train — чистова група
чорновий	roughing	roughing train — чорнова група
чотиривалкова кліть (кварто)	four-high stand	

Ш		
Українською	Англійською	Визначення, пояснення, приклади
шайба	washer	елемент різьбового з'єднання, наприклад, підкладка під гайку
шарнір	hinge	
швелер	channel	
швидкість	velocity	вектор
	speed	скаляр
	rate	характеристика
шевронне зачеплення	herringbone gearing, shevron	
шестеренна кліть	pinion stand, gearwheel cage	складова головної лінії прокатного стану, призначена для розподілення крутного моменту між валками
шестивалкова кліть	six-high stand	
шестикутник	hexagon	вид прокату з шестикутною формою поперечного перерізу
шестірня	pinion	
шийка (валка прокатного стану)	neck	конструктивний елемент валка прокатного стану, призначений для розміщення підшипників
шліфування	grinding	вид механічної обробки абразивним інструментом
шліцьовий	slitted, splined	
шорсткість поверхні	surface roughness	

Українською	Англійською	Визначення, пояснення, приклади
шпала	sleeper	спеціальний профіль прокату для залізниці
шпindelь	spindle	складова головної лінії прокатного стану, призначена для передачі крутного моменту від шестеренної кліті до валків, відстань між якими змінюється
шпунтові палі	sheet piling	
штаба	strip	плоский виріб, який безпосередньо після остаточного прокатування, або після травлення чи тривалого відпалювання змотаний у рулон
	narrow strip	вузька штаба
штабель	stack	
штовхач	pusher	

Я

Українською	Англійською	Визначення, пояснення, приклади
язик	uneven end horns	дефект прокату у вигляді нерівних торців, що утворюється через неоднакове видовження металу по ширині розкату
якість	quality	quality capability — здатність забезпечити якість продукції; quality performance — показник якості; quality rating — оцінка якості
ящичний	box	box grooves — ящичний калібр

APPENDIX A

Table A.1 — Mathematical symbols [1]

Symbol	Example	Meaning in full
.	3.14	three point one four
+	$a + b$	a plus b
–	$c - d$	c minus d
=	$T = 24$	T equals twenty four
×	3×10	three multiplied by ten / three times ten
:	$16 : 8$	sixteen divided by eight
%	10%	ten per cent
°	20°	twenty degrees
>	>10	greater than ten
<	<20	less than twenty
≤	≤ 12	less than or equals to twelve
≥	≥ 30	greater than or equals to thirty
√	√16	the square root of sixteen
n^3	10^3	ten to the power of three
{ }		curly brackets
[]		square brackets
()		round brackets
∞	$A \propto B$	A is proportional to B

Table A.2 — Conventional metric units

Name	Multiplication	Symbol
nano	10^{-9}	n
micro	10^{-6}	μ
milli	10^{-3}	m
kilo	10^3	k
mega	10^6	M
giga	10^9	G
tera	10^{12}	T

APPENDIX B

METAL FORMING GENERAL TERMINOLOGY

Table B.1 — Common terms and their definitions [1]

Component	Function
forging	manufacturing process in which a piece of (usually hot) metal is formed into the desired shape by hammering, pressing in one or more forging equipment
rolling	metal shaping process in which a billet is repeatedly passed between hard rolls to get a desired shape, thickness, and surface finish
extrusion	manufacturing process in which a billet is forced through a shaped metal piece or die to produce a continuous ribbon of the formed product
drawing	process of pulling a metal bar, rod, or wire through the hole of a die to alter its finish, shape, size, and/or mechanical properties
stress	load (force) per unit area that tends to deform the body on which it acts; compressive stress tends to squeeze a body, tensile stress to stretch (extend) it, and shear stress to cut it
strain	measure of the extent to which a body deforms under stress
mechanical properties	characteristics that indicate the elastic or plastic behavior of a material under pressure (force), such as bending, brittleness, elongation, hardness, and tensile strength
tensile strength	resistance to elongation, the maximum longitudinal stress a material can bear with fracture or permanent deformation
yield strength	load at which a material deforms permanently without increase in the load
equipment	tangible property (other than land or buildings) that is used in the operations of a business; examples of equipment include rolling mills, machines
tool	an item or implement used for a specific purpose; a tool can be a physical object such as mechanical tools including mill rolls and hammers

APPENDIX C

Table C.1 — *SI** units for metal forming [1]

Name	Unit	Symbol
time	second	s
length	metre	m
mass	kilogram	kg
force	newton	N
pressure, stress	pascal	Pa
energy, work	joule	J
power	watt	W
temperature	degree Celsius	°C
speed, velocity	metre per second	m/s
angular velocity	radian per second	rad/s
area	square metre	m ²
volume	cubic metre	m ³
moment of force	newton metre	N·m
density	kilogram per cubic metre	kg/m ³
moment of inertia	kilogram square metre	kg·m ²

* *SI* — International System of Units [57, 58]

Table C.2 — Structural sections [1]

Symbol	Meaning
I	<i>Universal beam (UB)</i> an I-section with a depth greater than its width
L	<i>Rolled steel angle (RSA)</i> an L-section
T	<i>Structural tee</i> a T-section
O	<i>Circular hollow section (CHS)</i> a circular tube
[	<i>Rolled steel channel (RSC)</i> a C-section
Π, Π, ς	Roll-formed U-channel
□, 	<i>Rectangular hollow section (RHS)</i>

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ТИСКОМ І ДОСЛІДЖЕНЬ У МЕТАЛУРГІЇ
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