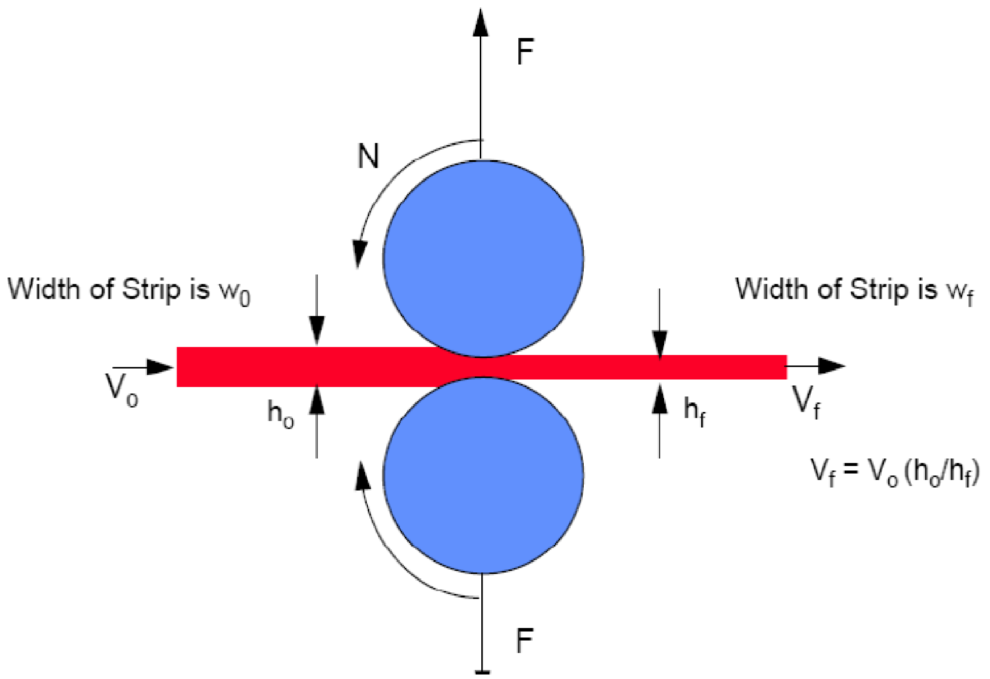
Rolling Process

Bulk deformation forming (rolling)

Rolling is the process of reducing the thickness (or changing the cross-section) of a long workpiece by compressive forces applied through a set of rolls. This is the most widely used metal working process because it lends itself high production and close control of the final product.

Bulk deformation forming (rolling)



Bulk deformation forming (rolling)

Rolling typically starts with a rectangular ingots and results in rectangular
Plates (t > 6 mm), sheet (t < 3 mm), rods, bars, I-beams, rails etc

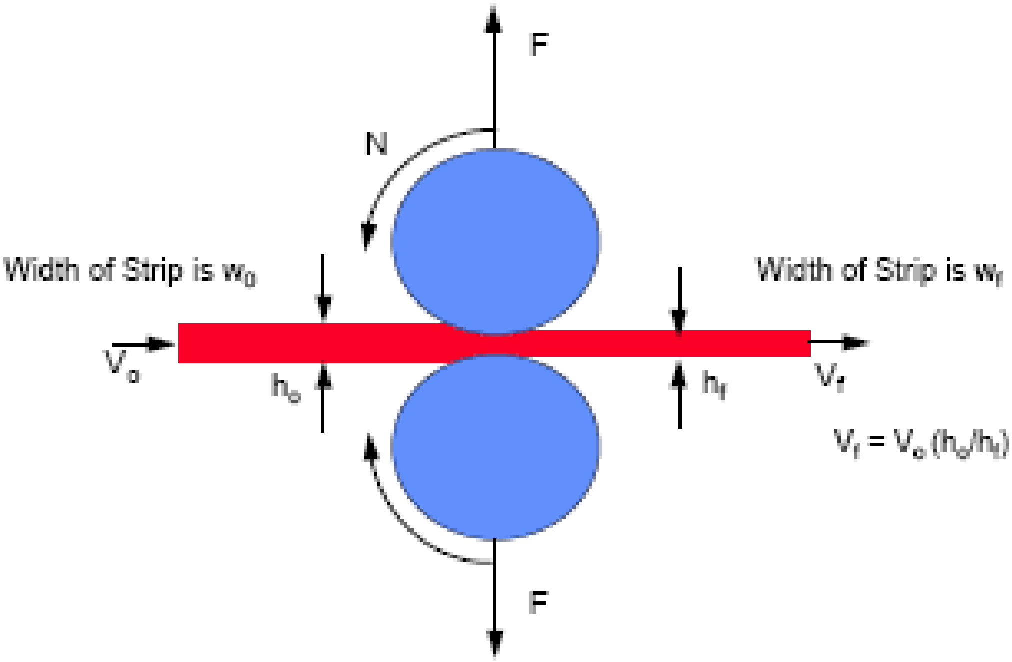


Figure: Rotating rolls reduce the thickness of the incoming ingot

Flat rolling practice

Hot rolled round rods (wire rod) are used as the starting material for rod and wire drawing operations

The product of the first hot-rolling operation is called a bloom

A bloom usually has a square cross-section, at least 150 mm on the side, a rolling into structural shapes

such as I-beams and railroad rails . Slabs are rolled into plates and sheets.

Billets usually are square and are rolled into various shapes

Hot rolling and cold rolling

Hot rolling is the most common method of refining the cast structure of ingots and billets to make primary shape.

Hot rolled round rods (wire rod) are used as the starting material for rod and wire drawing operations

Bars of circular or hexagonal cross-section like Ibeams, channels, and rails are produced in great quantity by hoe rolling with grooved rolls.

Cold rolling is most often a secondary forming process that is used to make bar, sheet, strip and foil with superior surface finish and dimensional tolerances.

Schematic of various rolling processes

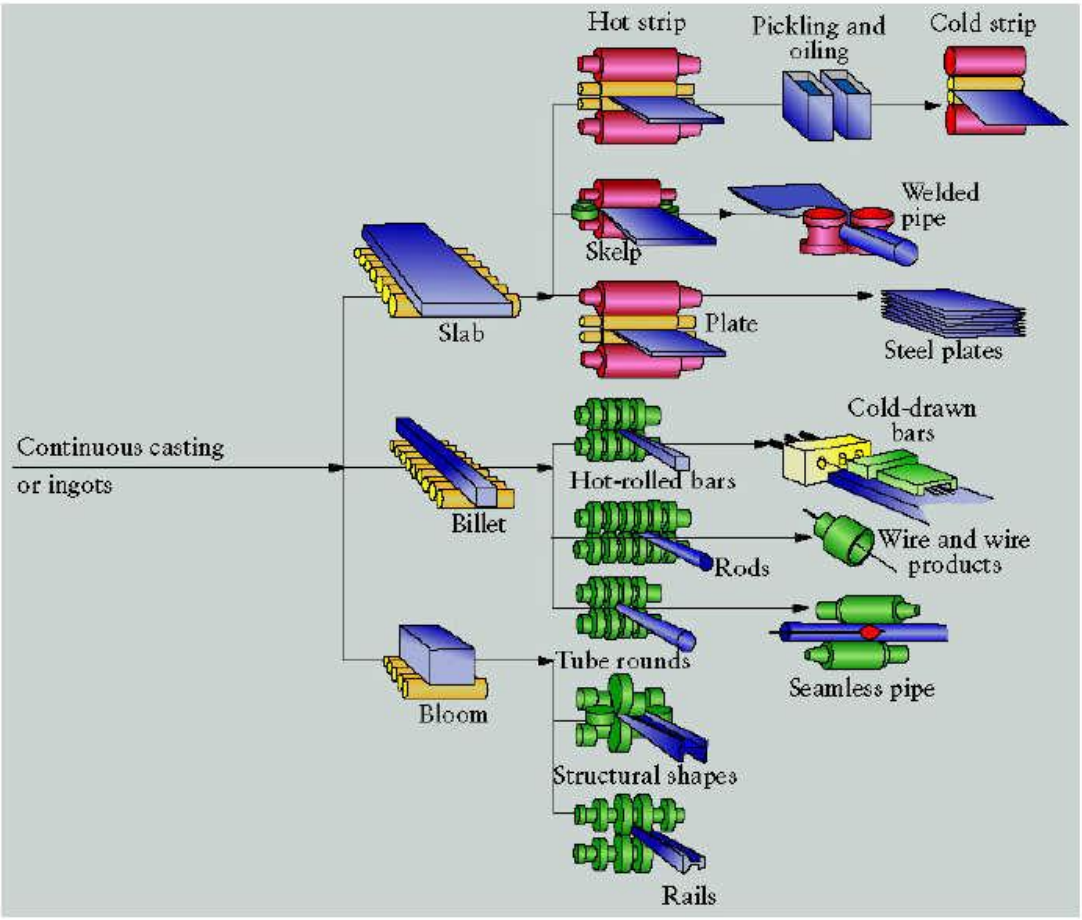
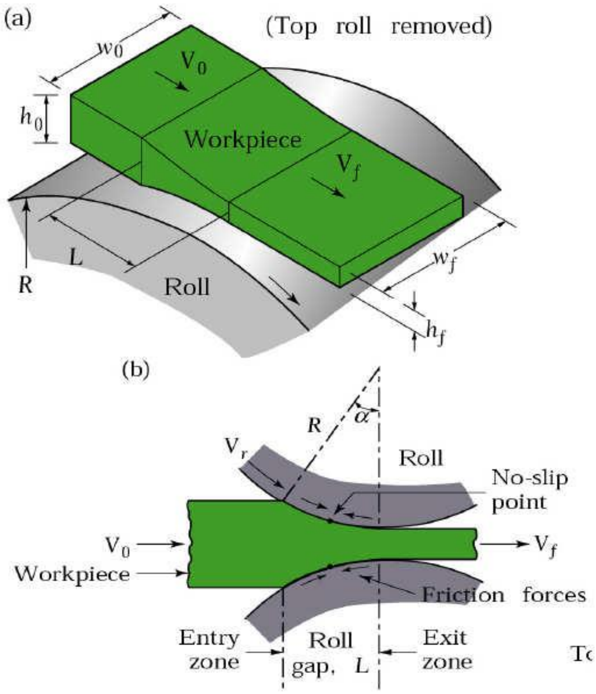


Figure: Schematic of various flat-rolling and shape-rolling processes.

Source: S. Kalpakjian, S.R. Schmid: Manufacturing Engineering & Technology, 5th edition, Prentice-Hall International, 2006; pp. 348

Rolling definitions and forces



To keep constant the volume rate of the material, the velocity of the strip must increase as it moves through the roll gap

$$V_f = V_0\left(\frac{h_0}{h_f}\right)$$

NEUTRAL POINT: point in the arc of contact where the roll velocity and the strip velocity are the same

$$\text{Forward slip} = \frac{V_f - V_r}{V_r}$$

(a)Schematic illustration of the flat rolling process
(b) Friction forces acting on the strip surfaces.

Source**:** S. Kalpakjian, S.R. Schmid: Manufacturing Engineering & Technology, 5th edition, Prentice-Hall International, 2006; pp. 349

Independent variables in rolling

Roll force

Power

Speed of exiting strip

Final strip temperature

Maximum draft

Roll strip contact length

Sheet or plate shape

Dependent variables for rolling

Roll speed

Amount of thickness reduction

Billet thickness and with

Billet materials

Billet temperature

Lubricant

Advantages of hot rolling

Forces smaller

Stresses lower

Less power requirement

No work hardening

Large deformation possible

Breaks up the cast structure into preferable form

Closes porosity

Disadvantage of hot rolling

Rolls need to be cooled

Materials handling difficult

Personnel must be protected

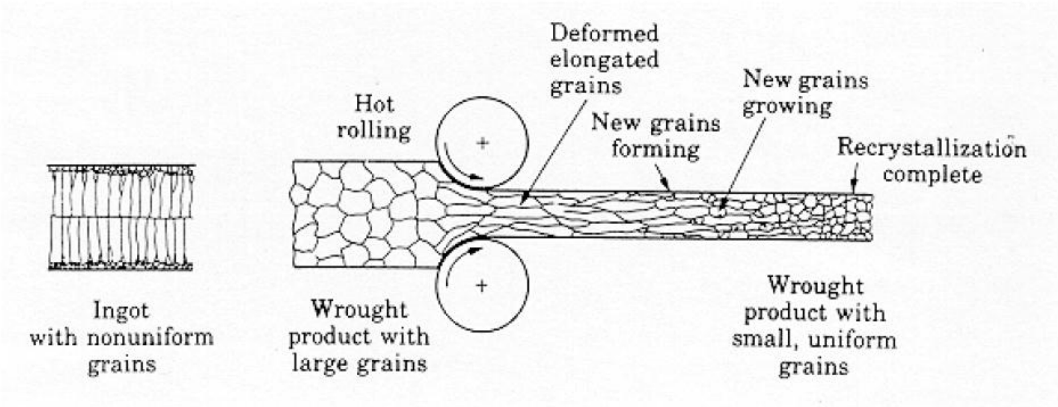
Hot rolling microstructure

The initial rolling steps of the material typically done by hot rolling (above the recrystalisation temperature of the metal)

A cast structure includes coarse and non uniform grains, this structure usually if brittle and may be porous

Hot rolling converts the cast structure to a wrought structure with finer grains and enhanced ductility

Hot rolling and microstructure



Cold rolling

Cold rolling is most often a secondary forming process that is used to make bar, sheet, strip and foil with superior surface finish and dimensional tolerances.

Cold rolling is carried out at room temperature and, compared with hot rolling, produces sheet and strips
with a much better surface finish (because of lack of scale), dimensional tolerances, and mechanical properties (because of strain hardening).

Advantage/disadvantage of cold rolling

Disadvantage

High forces

Small reductions give rise to surface stresses and non-uniform stress distribution

Advantage

Work hardening increases strength

Excellent surface finish

Excellent tolerance on thickness and shape

Thread rolling

Thread rolling is a cold-forming process by which straight or tapered threads are formed on round rods or wire by passing them between dies.

Threads are formed on the rod or wire with each stroke of a pair of flat reciprocating dies.

In another method, threads are formed with rotary dies, at production rates as high as 80 pcs per second.

Steps of thread rolling

1.A blank is placed between the two threading dies, and one of the dies moves in translation while the other die remains stationary.

2. The friction between the blank and the dies causes the blank to spin and rolled down the length of the stationary die.

3. The dies are tapered so that as the blank is getting

rolled, the threads are being formed in the blank.

Thread rolling

Advantages:
No loss of material
Good surface finish
Increased strength through cold working favorable grain flow

Thread rolling advantages

The deformation involved in the rolling process work hardens the threads, resulting in increased strength

Rolled threads have improved fatigue resistance.

The grain structure in a rolled thread is continuous, as opposed to the cut grains found in a machined product.

Rolled thread typically have superior surface finish and a lower cost relative to machined threads

Rolling mills

Different types of rolling mills and equipment are available with diverse roll arrangements

Although the requirement for hot and cold rolling is essentially same, there are important differences in the roll materials, process parameters, lubricants and cooling systems.

Highly automated mills produce close tolerance, high quality plates, and sheets at high production rates and low cost per unit weight.

Rolling speeds may range up to 40 m/s. The width of rolled products may range up to 5 m.

Rolling mills

Two-high rolling mills are used for hot rolling in initial break down passes (primary roughing or cogging mills) on cast ingots with roll diameters ranging 0.6 -1.4 m.

In the three-high mill (reversing mill) the direction of material movement is reversed after each pass, using elevator mechanisms and various manipulators.

The plate being rolled, which may weigh as much as 145 tonnes, is raised repeatedly to the upper roll gap, rolled, and then lowered to the lower roll gap and rolled; and so on..

Four-high mills and cluster mills are based on the principle that small-diameter rolls lower roll forces and power requirements.

Shape rolling

Straight and long structural shapes (such as channels, I-beams, railroad rails, and solid bars) are formed at elevated temperatures by shape rolling (profile rolling) in which the stock goes through a set of specially designed rolls

Non-flat shapes can be produced by having rolls with shape:
I -beams
H- sections
Rails
Angle irons

Stages in shape rolling of H-section

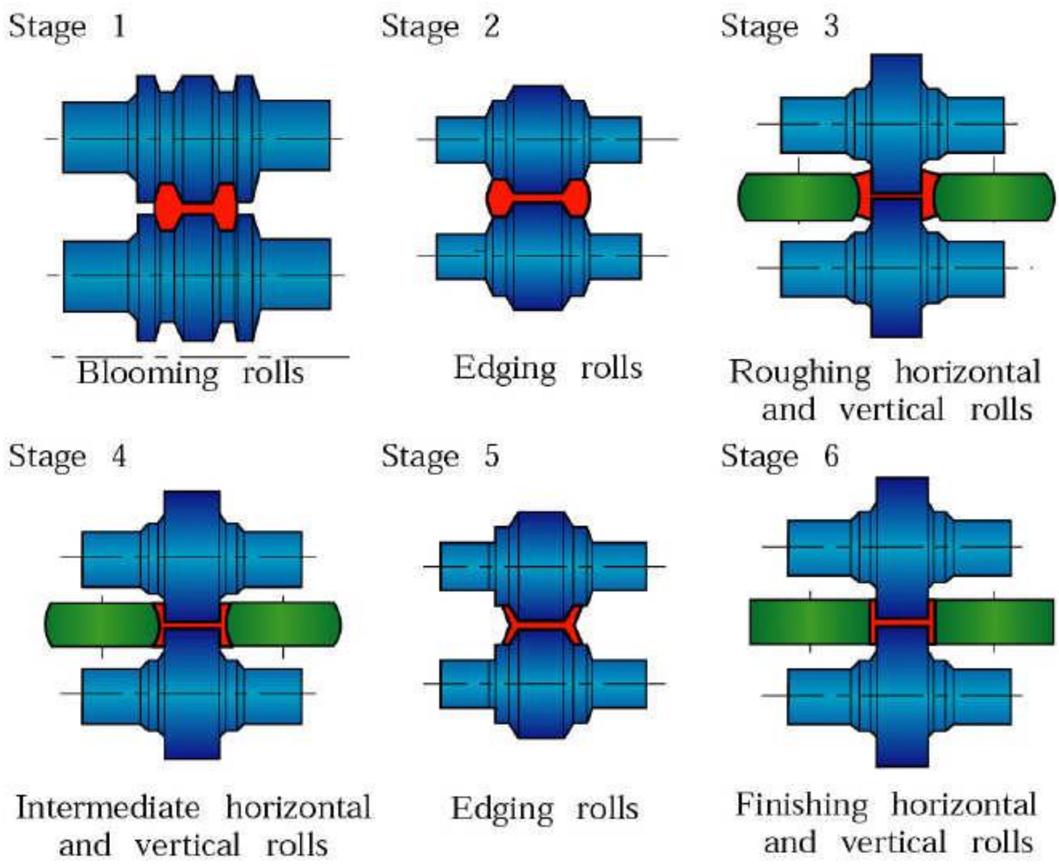


Figure: Stages in shape rolling of an I-beam part
Source: S. Kalpakjian, S.R. Schmid: Manufacturing Engineering & Technology, 5th edition, Prentice-Hall International, 2006; pp. 361

Ring rolling

Thick ring small diameter transformed into thin ring, large diameter

Used in jet engines, large ring gears

Advantage:

Circular shapes with no joins can be made with varieties of cross-sections

Roll materials

The requirements for roll materials are:
Strength and resistance to wear. Common roll materials are:
Cast iron
Cast steel
Forged steel
Tungsten carbides are also used for small diameter rolls
Forged steel rolls, although more costly than cast rolls, have higher strength, stiffness and toughness than cast- iron rolls.

Factors affecting rolling

The material being rolled
The material of the rollers
The shape being rolled
The size of the stock being rolled
The size of the rollers
Power requirements

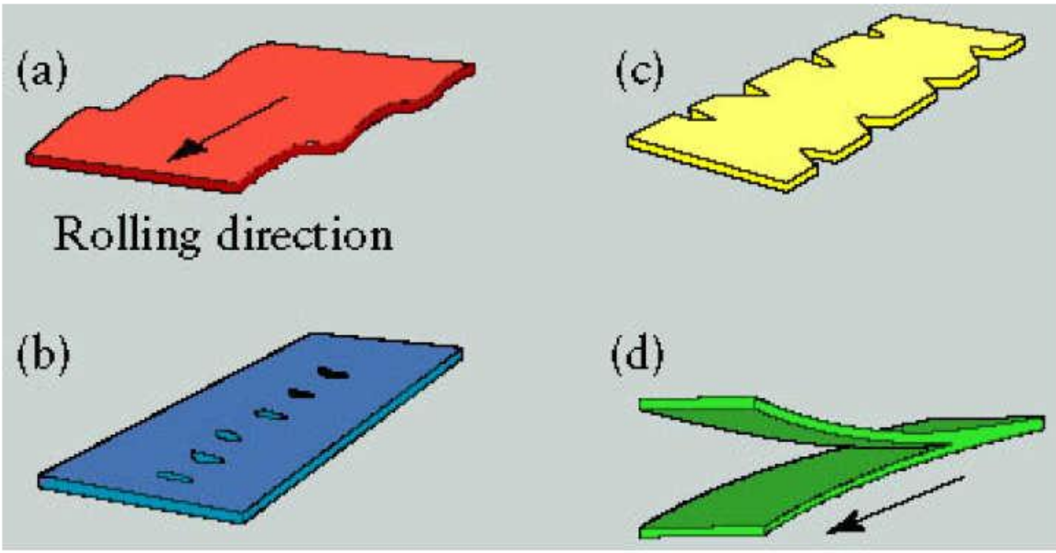
Defects in rolled sheet and plate

Defects may be present on the surfaces of rolled plates and sheets, or there may be internal structural defects.

Several surface defects (such as scale, rust, scratches, gouges, pits, and cracks) have been identified for sheet metals.

These defects may be caused by inclusions and

impurities in the original cast material or variation other conditions related to material preparation and to the rolling operation



Schematic illustration of typical defects in flat rolling: (a) wavy edges; (b) zipper cracks in the center of strip; (c) edge cracks; (d) alligatoring.

Source**:** S. Kalpakjian, S.R. Schmid: Manufacturing Engineering & Technology, 5th
edition, Prentice-Hall International, 2006; pp. 356

Defects in rolled sheet and plate

Wavy edges **on sheets are the results of roll bending. The strip is thinner along its edges than at its centre, thus the edges elongate more than the centre.**

The cracks **are formed as a result of poor material ductility at the rolling temperature.**

Alligatoring **is a complex phenomenon and typically is caused by non-uniform bulk deformation of the billet during rolling or by the presence of defects in the original cast material.**

References

1. S. Kalpakjian, S.R. Schmid: Manufacturing Engineering & Technology, 5th edition, Prentice-Hall International, 2006.
2. E. Paul Degarmo, J. R. Black, R. A. Kohser; Materials and Processes in Manufacturing, 9th edition, John Wiley & Sons, Inc, 2003.
3. R. L. Timings, S. P. Wilkinson: Manufacturing Technology, 2nd edition, Pearson Education Limited, London, 2000.