SHEET METAL ROLLING USING TWO ROLLER POWERED MACHINE

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ABSTRACT

In Sheet Metal working industry a wide range of power and hand operated machines are being used. As the sheet metal industry is a large and growing industry different types of machines are used for different operations. Rolling is a fabricating process in which the metal, plastic, paper, glass, etc. is passed through a pair (or pairs) of rolls. There are two types of rolling process, flat and profile rolling. In flat rolling the final shape of the product is either classed as sheet (typically thickness less than 3 mm, also called "strip") or plate (typically thickness more than 3 mm). In profile rolling the final product may be a round rod or other shaped bar, such as a structural section (beam, channel, joist etc). In this study, different metals are been rolled by using two roller electrically powered rolling machine and its properties are being analyzed. The influence of rolling process parameters such as sheet thickness, sheet width, , Elongation, Reduction in thickness on the Strip and shape and its profile have been investigated.

KEYWORDS

*Electrically powered machine, Roll Pass Design Calculations, Strain calculations***.**

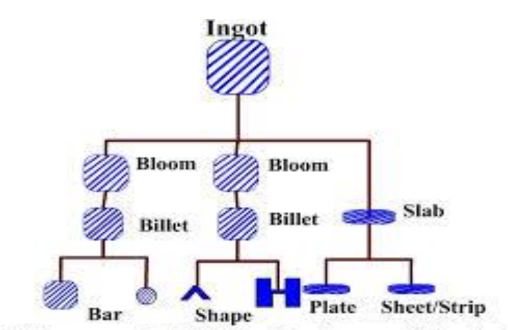
INTRODUCTION

Sheet Metal industry is a large and growing industry. There are many special purposes machines used in this industry to-day. The proper selection of the machines depends upon the type of the work under-taken by the particular industry. There are many examples of Sheet Metal work, which can be seen in our everyday lives. The metals generally used for Sheet Metal work include black iron sheet, copper sheet, tin plate, aluminum plate, stainless sheet and brass sheet.

My project the "SHEET METAL ROLLING USING TWO ROLLER POWERED MACHINE" finds huge application in Sheet Metal industry. Rolling is 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. Rolling operation can be done on hand or power operated rolling machines.

One of the most efficient ways of producing products that are long with respect to other dimensions and that have function that depends on cross-section shape, such a I-beam and rail road rails, is by rolling. An initial simple rectangular cross-section work piece can be passed between rolls that are shaped to produce the part cross-section shape. Since large amounts of material deformation are usually required the work will typically pass through a sequence of rolling operation each of which produces increasing deformation bringing the work piece closer to the required shape. The work piece may be heated to decease its strength and increase its ductility. This reduces deformation process-induced forces and so implies less roll deflection during the process and less still machines, rolling mills.

Many of the important aspects of mechanically modeling the general rolling process can be illustrated in describing the simpler plate or flat rolling process in which a rectangular cross-section work piece is reduced in height to form a rectangular section product - plate or sheet.



Rolling sequence for fabrication of bars,shapes and flat products from blooms,billets and slabs

GRAIN STRUCTURE IN ROLLING

When the wrought or cast product gets hot rolled, the grain structure, which is coarse grained, becomes finer in size, but elongated along the direction of rolling. This type of textured grain structure results in directional property [anisotropy] for the rolled product. In order to refine the grains, heat treatment is performed immediately after rolling, which results in recrystallization after rolling.

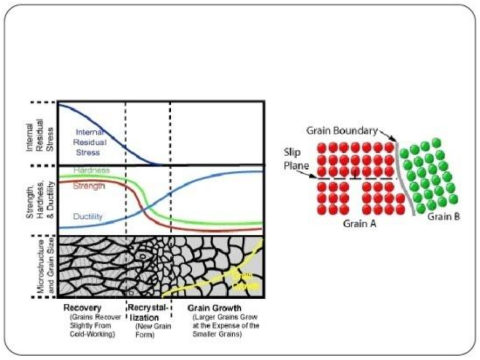


Fig 2 Grain structure

FORMING PROCESS

Forming processes are those in which the shape of a metal piece is changed by plastic deformation .Forming processes are commonly classified into hot-working and cold-working operations.

Typical forming processes are:

- Rolling
- Extrusion
- Forging
- Drawing

ROLLING

Rolling is a process of reduction of the cross-sectional area or shaping a metal piece through the deformation caused by a pair of rotating in opposite directions metal rolls.

Rolling is the plastic deformation of materials caused by compressive force applied through a set of rolls. The cross section of the work piece is reduced by the process. The material gets squeezed between a pair of rolls, as a result of which the thickness gets reduced and the length gets increased.

A machine used for rolling metal is called rolling mill. A typical rolling mill consists of a pair of rolls driven by an electric motor transmitting a torque through a gear and pair of cardans. The rolls are equipped with bearings and mounted in a stand with a screw-down mechanism.

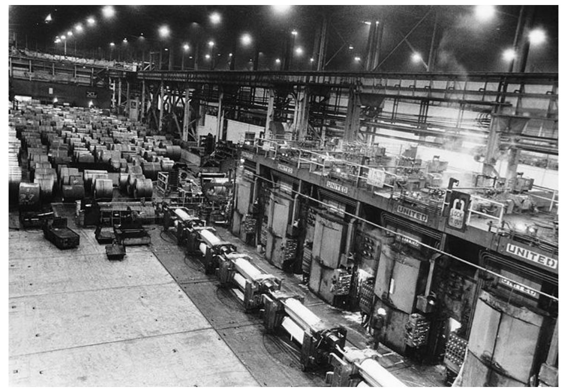


Fig 3 Rolling Mill

BASIC ROLLING PROCESS

- Heated metal is passed between two rolls that rotate in opposite directions
- Gap between rolls is less than thickness of entering metal Rolls rotate with surface velocity that exceeds speed of incoming metal, friction along the contact interface acts to propel the metal forward.
- Metal is squeezed and elongates result in decrease of the cross-sectional area.
- Amount of deformation in a single pass depends on the friction conditions along the interface.
- If too much material flow is demanded, rolls cannot advance the material and simply skid over its surface. Too little deformation per pass results in excessive production cost.

DESCRIPTION OF THE MACHINE

The Sheet Metal Rolling Machine works according to the principle of two point bending. The rotation of the driven rolls being utilized to feed the metal through the rolls by means of the frictional forces present between the surface of the rolls and sheet. No lubricant is used at its presence interference with the ability to grip. Sheet Metal Rolling Machine essentially consists of two rollers, used to manufacture circular components like cylinders. Sheet Metal Rolling Machine is classified into two types based on the arrangement of the rollers. They are as follows.

1. Pinch type machine
2. Pyramidal type machine

This machine is of pyramidal type here only the bottom roll is driven the top roll serves as an idler and rotates on friction with the work metal blank.

MANUAL ROLLING MACHINE

Fig 4 Manual Rolling Machine

ELECTRICALLY POWERED ROLLING MACHINE

Fig 5 Electrical Rolling Machine

PARTS

1. Electrical Box 2.Shaft 3.Pairs of rollers
4. Gears 5.Handle 6. Column

The rolling machine is electrically powered and consists of an electrical box provided with main power switch. The electrical box connects the main power to the rolling machine via a power connected box. To supply electric power to the apparatus, main power switch is turned ON and green button (Start button) of power connector box is pushed.

The rolling machine consists of an electric motor that rotates the output shaft at low RPM.The rotating motion of the output shaft is transmitted to two different pairs of rollers via a meshed gear assembly. The top set of rollers consists of plain cylindrical rollers. They are used for decreasing the thickness of a flat or plate shaped specimen. Whereas the plain rollers vertical gap can be verified by turning the plain rollers gap controller dial.

The rotation of a gap controller dial rotates a primary gear, as both are on the same shaft. The primary gear is meshed with a secondary gear twice its diameter. The secondary gear further transmits its rotating motion as a vertical displacement to a gap retainer.

WORKING PRINCIPLE

The Sheet Metal, which is to be formed in flat plate shape, is present at the edge by hammering. In rolling flat plate shape is to be put in the metal rather than sharp bends. Now the sheet metal is introduced between the top and the bottom roll, the gap between the top and bottom roll are adjusted as per the required diameter by regulating the screw rods.

When the hand wheel is rotated, the worm which is keyed to the shaft transmits power to the worm wheel, and the worm wheel rotates. The stud gear which is fixed to the worm wheel also rotates and so that the two spur gear which is keyed to the bottom roll. Both rollers rotate in the same direction. Now the sheet metal is bent, the top roller presses the sheet and gives it to the curvature; the cylindrical shape is formed by rotating the hand wheel. The formed material can be slipped off by removing the top roll.

Most metal rolling operations are similar in that the work material is plastically deformed by compressive forces between two constantly spinning rolls. These forces act to reduce the thickness of the metal and affect its grain structure. The reduction in thickness can be measured by the difference in thickness before and after the reduction, this value is called the draft. In addition to reducing the thickness of the work, the rolls also act to feed the material as they spin in opposite directions to each other. Friction is therefore a necessary part of the rolling operation, but too much friction can be detrimental for a variety of reasons. It is essential that in a metal rolling process the level of friction between the rolls and work material is controlled, lubricants can help with this. A basic flat rolling operation is shown in figure; this manufacturing process is being used to reduce the thickness of a work piece. During a metal rolling operation, the geometric shape of the work is changed but its volume remains essentially the same. The roll zone is the area over which the rolls act on the material; it is here that plastic deformation of the work occurs. An important factor in metal rolling is that due to the conservation of the volume of the material with the reduction in thickness, the metal exiting the roll zone will be moving faster than the metal entering the roll zone. The rolls themselves rotate at a constant speed, hence at some point in the roll zone the surface velocity of the rolls and that of the material are exactly the same. This is termed the no slip point. Before this point the rolls are moving faster than the material, after this point the material is moving faster than the rolls.

ADVANTAGES

- Operation of this machine is very simple
- Unit is compact so less space is required
- No hand tools are required
- Cylindrical shaped objects of dia 50mm to 225mm can be produced
- The dia can be easily operate this machine
- The machine is hand operated. So the cost of the finished product will be less.
- The total cost of the machine is less.
- Maintenance of this machine is very easy.
- Easy to handle
- Less effort & productive

ROLL PASS DESIGN CALCULATIONS

DRAFT

Draft is the reduction in bar height in the pass. Absolute draft is expressed in linear units and is the difference between the entry height and exit height of the stock.

h_{in} = incoming bar thickness

h_{out} = delivered bar thickness

D_a = absolute draft

$h_{in} - h_{out} = D_a = \Delta_h$

Relative draft is the reduction in height expressed as a percentage of the entry height.

D_r = relative (%) draft

$[(h_{in} - h_{out}) / h_{in}] \times 100 = D_r$

ELONGATION

Elongation is the increase in length of the stock due to the reduction in area. Elongation usually defines the total elongation from billet to product, or in a specific section of the mill, for example the roughing mill or finishing block.

A_{in} = beginning cross sectional area

A_{out} = ending cross sectional area

E_t = total elongation

$A_{in} / A_{out} = E_t$

AVERAGE ELONGATION

Average elongation is the average elongation per stand through the whole mill. It can also be applied to certain sections of the mill, e.g., the average reduction through the roughing mill.

E_a = average elongation

n = number of passes

$n\sqrt{(A_{in} / A_{out})} = E_{ave}$

The billet elongates or gets longer after each pass. The total volume of the bar remains the same. If the cross section of the bar is reduced, then the length must increase. Therefore the final bar length (L_{final}) is the billet length (L_{billet}) multiplied by the average elongation multiplied by the number of stands:

$L_{final} = L_{billet}$ x E_a(Stand 1) x E_a (Stand 2) x E_a (Stand 3) x E_a (Stand 4) x ..... E_a (Stand n)

$L_{final} = L_{billet}$ x E_a(Number of Stands)

REDUCTION

Reduction is the decrease in area from stand to stand and is expressed as a percentage of the entry area.

[(Ain - Aout) / Ain] x 100 = R

Average reduction is the average reduction per stand through the whole mill, or through certain sections of the mill, e.g., the average reduction through the roughing mill.

[1 - (1 / (n√ (Ain / Aout))] x 100 = Rave

Given that the reduction is the percent change in cross sectional area:

R = [(Ain - Aout) / Ain] x 100

R = [(Ain / Ain - Aout / Ain)] x 100

R = [(1 - Aout / Ain)] x 100

SPREAD

Absolute Spread is the change in width between the stock entering and leaving a stand.

b_{in} = input width

b_{out} = delivered width

Δb = spread

$b_{out} - b_{in} = \Delta b$

Spread is dependent on several factors including

- draft,
- roll diameter,
- stock temperature,
- roll material,
- and material being rolled

For a given stock size and reduction, the bigger the roll diameter the greater the spread; the lower the temperature, the greater the spread.

Formulae for calculating spread

øn = new roll diameter

ød = discard roll diameter

R_n = new roll radius

R_d = discard roll radius

Tafel and Sedlaczak

$\Delta b = (\Delta h \times b_{in} \times \sqrt{(b_{in} \times R_n)}) / (3 \times (b_{in}^2 + (h_{in} \times h_{out}))$

Koncewicz

$\Delta b = 0.66 \times (\Delta h / (h_{in} \times h_{out})) \times \sqrt{(\Delta h \times R_n)}$

Wusatowski

$d = \varnothing n0.556$

$\partial = -10^{-1.269 \times (bin / hin) \times d}$

$b_{out} = b_{in} \times (h_{out} / h_{in})^{\partial}$

CONTACT OF ANGLE

The enclosed angle between a line from the point where the stock first contacts the roll to the center of the roll and the vertical centerline of the rolls is the angle of contact(sometimes referred to as the bite angle).

For a given roll diameter and gap setting, the contact angle will increase as the incoming stock height increases until a point is reached where the rolls will not grip, or 'bite' the stock.

The limiting bite angle will depend upon the friction between the stock and the rolls. The friction at the roll bar interface is dependent on:

- roll material,
- stock grade,
- bar temperature,
- roll speed,
- and the surface condition of the roll.

COEFFIECIENT OF FRICTION

The maximum bite angle is related to the coefficient of friction. The following formulae calculate the coefficient of friction based on the temperature of the bar.

FOR STEEL ROLLS

T = bar temperature (°F)

$\mu = 1.06 - (0.000278 \times T)$

FOR IRON ROLLS

$\mu = 0.8 \times (1.06 - (0.000278 \times T))$

MAXIMUM BITE ANGLE

$C_{max} = \tan^{-1} (u)$

MAXIMUM BITE ANGLE

The maximum possible bite angle is illustrated in figure 6, showing a free-body diagram of the forces acting upon a bar entering a pass. As can be seen by the large roll bite on the right, the resultant force pulling the bar into the roll bite is reversed into a force pushing the bar out. This force is equal to zero at the inverse tangent of the coefficient of friction.

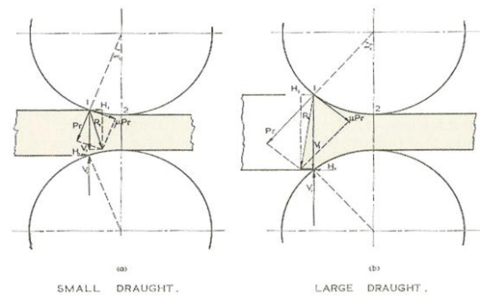


Fig 6 Maximum Bite Angle

CONTACT AREA

Projected Area of Contact

r = radius of roll at bottom of pass

b_m = mean width of stock

$A_{Cp} = (\sqrt{r} (h_{in} - h_{out})) * b_m$

A line along the centerline of the groove from the point where the stock first makes contact with the roll, to the point where the stock exits the groove is the arc of contact. The projected area of contact is the area of contact described, projected onto the horizontal rolling plane at the centerline of the bar.

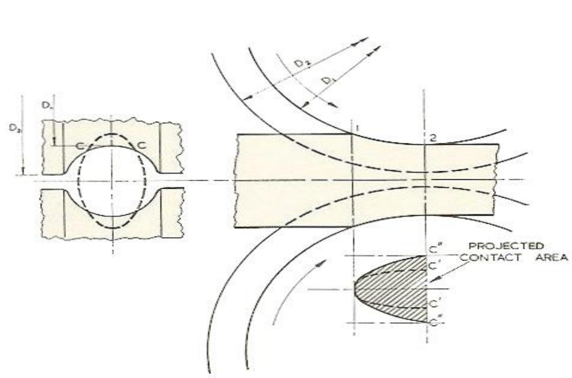


Fig 7 Contact Area

EFFECTIVE DIAMETER

- The roll rotates at constant speed, therefore the rotational speed (revolutions per minute or RPM) at any given point in the roll groove remains constant.
- In grooved rolls the surface speed (feet per minute or meters per second) at the bottom of the groove is less than the surface speed at the top of the groove where the diameter of the roll is larger. Since all points on the surface of the stock leave the rolls at the same speed the speed of the stock will be faster than the roll speed at the bottom of the groove, but slower than the speed of the roll at the top of the pass. At some point in between the speed of the roll and the speed of the stock at the exit plane will be equal.
- The roll radius at this point is known as the effective radius. The corresponding diameter is known as the effective diameter or working diameter.
- We need the area and delivered width to find the height of an equivalent flat bar. Using this thickness the work diameter is:
  - $t = A_{out} / b_{out}$
  - $ø_w = ø_c + g - t$

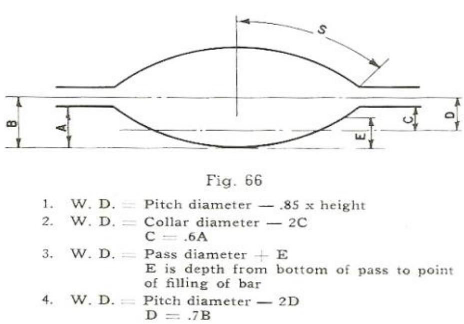


Fig 8 Effective Diameter

FORWARD SLIP

If a piece of hot steel is placed in a press and reduced in height, it spreads in the other two dimensions. Similarly when a hot bar is worked between two rolls, it spreads in the pass filling the pass and it pushes out in the direction of rolling (forward slip)and backwards in the direction of the incoming stock (backward slip). This phenomenon is also called 'the extrusion effect'. Forward slip must be added to the bar speed to calculate roll speed for tension free rolling at high speeds in rods.

h1 = entering height

h2 = delivered height

da = average roll diameter

$\mu = 1.05 - 0.0005 * t\ (°C)$

$$Sf = \text{Forward Slip Factor} = \frac{3}{4}\left[\frac{\psi \hat{} 2}{2} \times \left(\frac{da}{h1} - 1\right) \times 100\%\right]$$

$$\text{Where, } \psi : \text{Strain}\left[\sqrt{\frac{(h1-h2)}{2xda}} - \frac{1}{\mu} - \frac{(h1-h2)}{2xda}\right]$$

NEUTRAL POINT

- When the stock is in the pass, the cross-sectional area is reduced as it moves through the roll gap.
- The velocity of the bar must therefore increase as it passes between the rolls.
- When the stock exits the roll gap, the speed of the bar exceeds the peripheral speed of the roll.
- As the bar speed increases between the point of entry and point of exit there will be a point where the speeds coincide. This is the neutral point.

SEPERATING FORCE

- The deformation process in the roll gap creates a force that pushes the rolls apart. This is called the separating force or rolling load.
- Factors influencing the magnitude of this force include:
  - the material being rolled,
  - its temperature,
  - the rate at which the material is being compressed,
  - the diameter of the rolls,

    and the reduction taken in the pass.
- There are two methods of calculating the separating force.
- Starting with the resistance to deformation_we calculate the separating force based on the area of contact. The units of resistance to deformation are force per unit area

Figure below illustrates this force applied to the rolls when rolling flats.

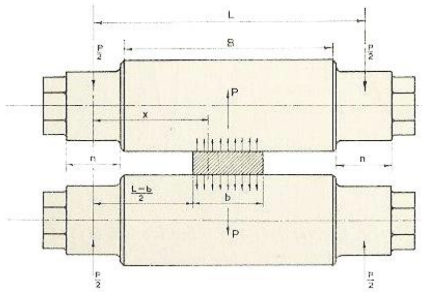


Fig 9 Separating Force

- Starting with the motor power required, we calculate the torque from the roll RPM, the separating force using the moment arm from the centre of the contact area to find the separating force.

TORQUE

- The torque is calculated by using the centroid of the contact area as the point where the separating force is applied.
- The distance from the roll centre to the centre of the contact area is the moment arm.
  - F = separating force
  - d = moment arm
  - T = F x d
  - Power is work per unit time. Torque is rotational work, rotation rate (RPM) is the rate the work is applied. Starting at the motor, the torque is found using the roll RPM.

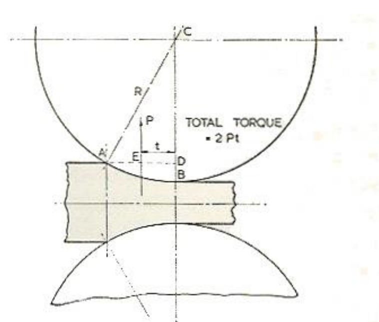


Fig 10 Torque

RRPM = roll RPM

P = motor power

For metric units:

P = (Tt * RRPM) / 9.55

Tt = (P * 9.55) / RRPM

RESULTS AND OBSERVATION

TABLE 1

Material: Alluminium

Length of the material: 100mm

Width of the material: 50 mm

Thickness of the material: 1mm

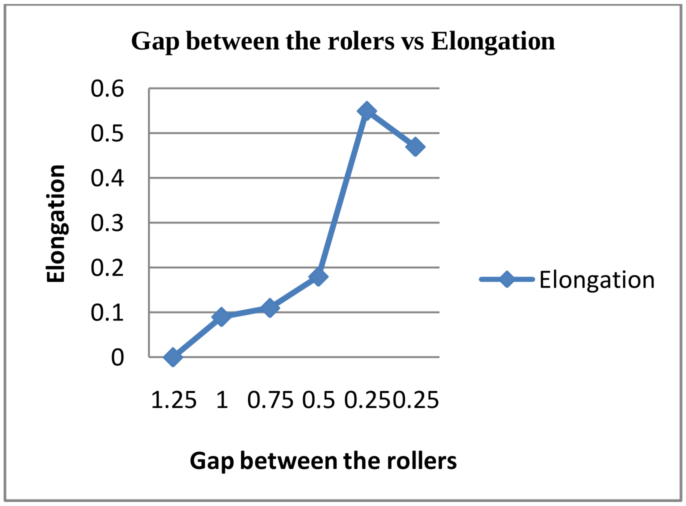
TABLE OF PERFORMANCE TESTS

No of passes	Gap Between the rollers(mm)	Change in Length of the material(mm)	Change in Width of the work/mm	Change in Thickness of the material /mm
Pass 1	1.25	100	50	1
Pass 2	1	109	50	1
Pass 3	0.75	122	50	1
Pass 4	0.5	145	51	0.8
Pass 5	0.25	226	52	0.6
Pass 6	0.25	332	52	0.4

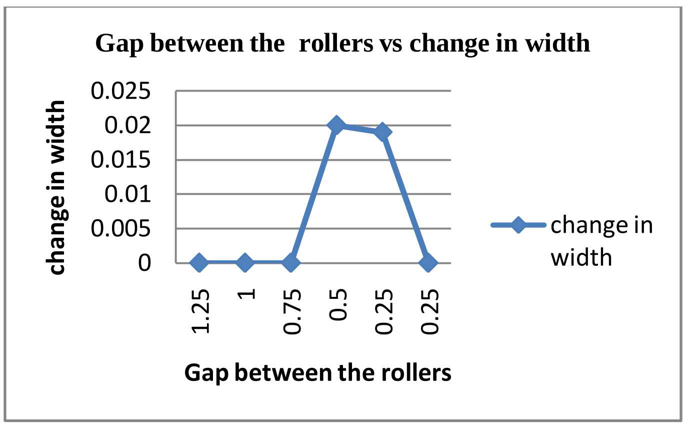
STRAIN CALCULATION

S.NO	ELONGATION	STRAIN IN WIDTH OF THE MATERIAL	STRAIN IN THICKNESS OF THE MATERIAL
1	0	0	0
2	0.09	0	0
3	0.11	0	0
4	0.18	0.02	0.2
5	0.55	0.019	0.25
6	0.47	0	0.33

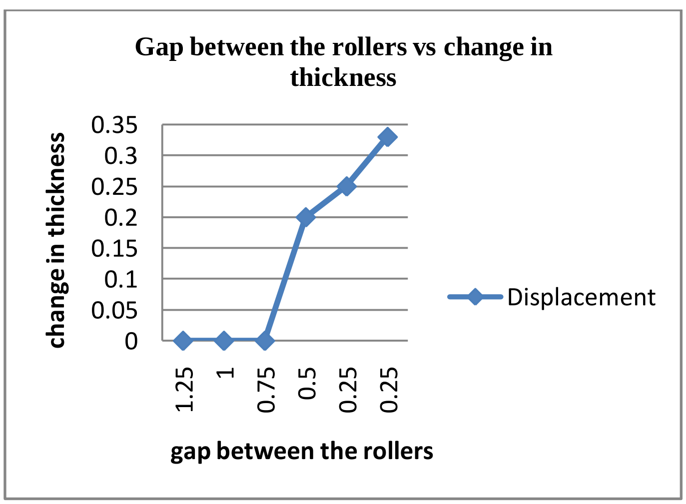
GRAPH 1



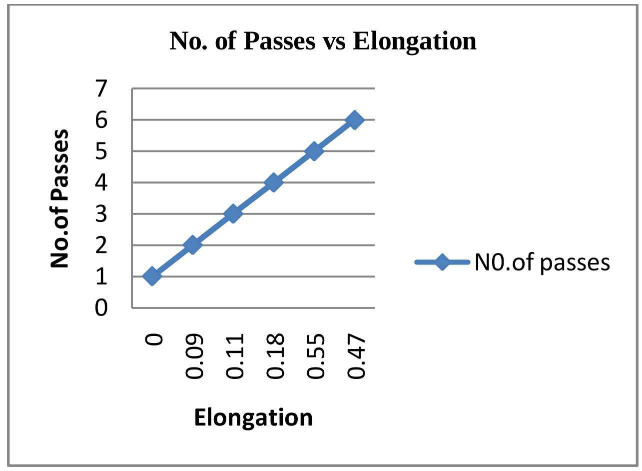
GRAPH 2



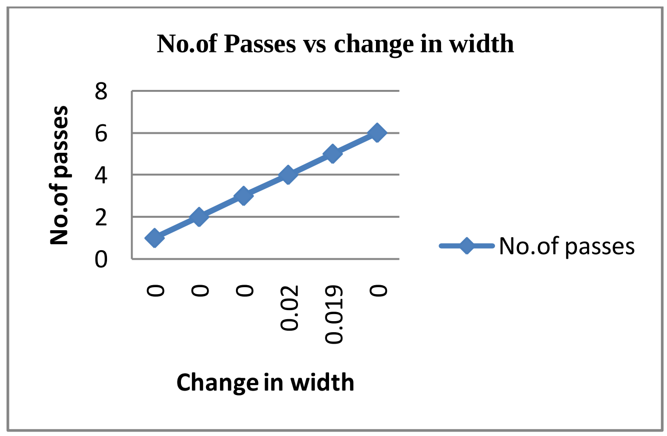
GRAPH 3



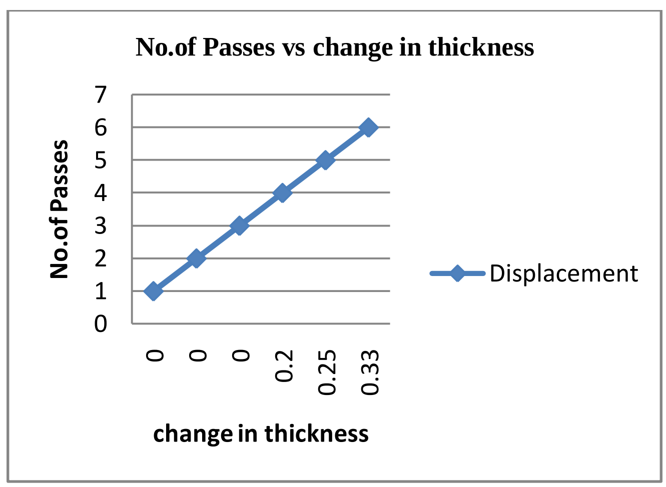
GRAPH 4



GRAPH 5



GRAPH 6



OBSERVATION

It is been observed from the above graphs that, length of the material is increasing gradually with a slight difference in width and thickness.

From pass 4 we can observe wavy edges. At pass 5 and pass 6 we can observe that the edges are broken.

APPLICATIONS OF ALUMINUM SHEETS

Aluminium is also a popular metal used in sheet metal due to its flexibility, wide range of options, cost effectiveness, and other properties. The four most common aluminium grades available as sheet metal are 1100-H14, 3003-H14, 5052-H32, and 6061-T6.

Grade 1100-H14 is commercially pure aluminium, highly chemical and weather resistant. It is ductile enough for deep drawing and weldable, but has low strength. It is commonly used in chemical processing equipment, light reflectors, and jewellery.

Grade 3003-H14 is stronger than 1100, while maintaining the same formability and low cost. It is corrosion resistant and weldable. It is often used in stamping, spun and drawn parts, mail boxes, cabinets, tanks, and fan blades.

Grade 5052-H32 is much stronger than 3003 while still maintaining good formability. It maintains high corrosion resistance and weldability. Common applications include electronic chassis, tanks, and pressure vessels. Grade 6061-T6 is a common heat-treated structural aluminium alloy. It is weldable, corrosion resistant, and stronger than 5052, but not as formable. It loses some of its strength when welded. It is used in modern aircraft structures.

TABLE 2

Material: Copper Length of the material: 205 mm

Width of the material: 52 mm Thickness of the material: 1.25mm

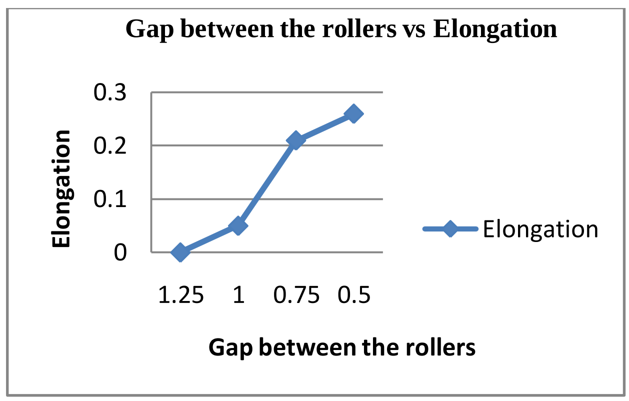
TABLE OF PERFORMANCE TESTS

No of passes	Gap Between the rollers(mm)	Change in Length of the material(mm)	Change in Width of the work/mm	Change in Thickness of the material /mm
Pass 1	1.25	205	52	1.25
Pass 2	1	217	52.5	1
Pass 3	0.75	264	54	0.75
Pass 4	0.5	335	56	0.6

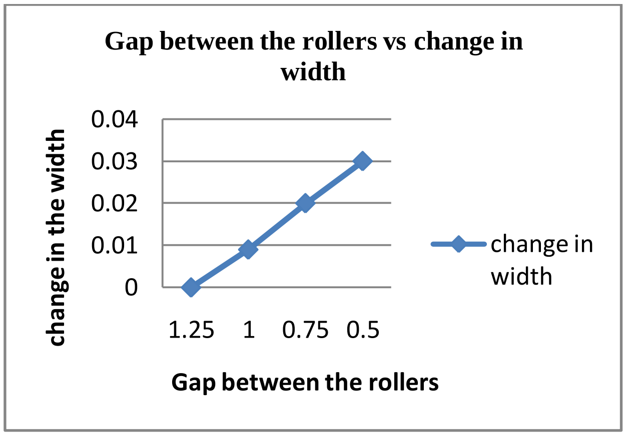
STRAIN CALCULATION

S.NO	ELONGATION	STRAIN IN WIDTH OF THE MATERIAL	STRAIN IN THICKNESS OF THE MATERIAL
1	0	0	0
2	0.05	0.009	0.2
3	0.21	0.02	0.25
4	0.26	0.03	0.2

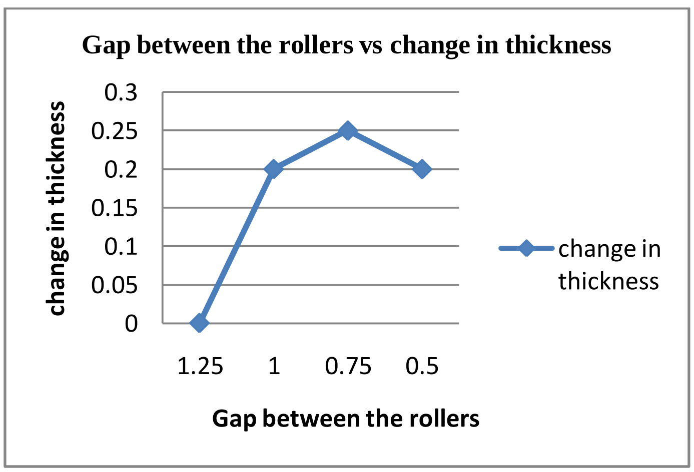
GRAPH 7



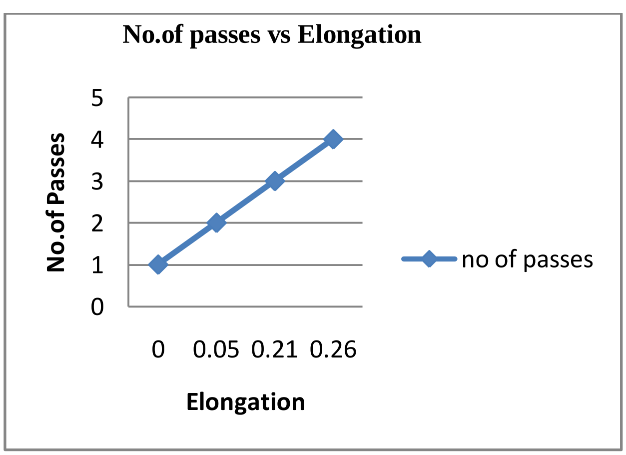
GRAPH 8



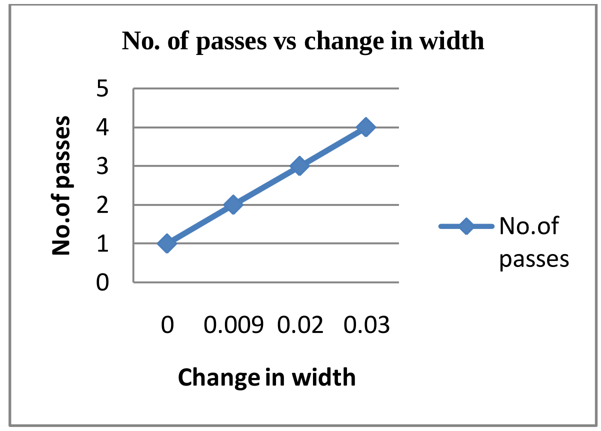
GRAPH 9



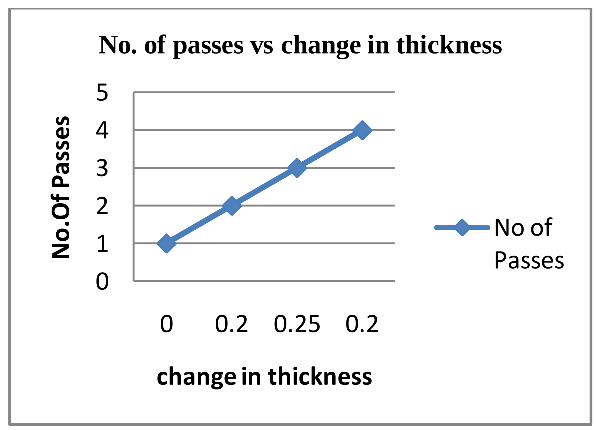
GRAPH 10



GRAPH 11



GRAPH 12



OBSERVATION

It is been observed from the above graphs that, length of the material is increasing gradually with a slight difference in width and thickness.From pass 6 we can observe wavy edges.

APPLICATIONS OF COPPER

The major applications of copper are in electrical wires (60%), roofing and plumbing (20%) and industrial machinery (15%). Copper is mostly used as a pure metal, but when a higher hardness is required it is combined with other elements to make an alloy (5% of total use) such as brass and bronze .A small part of copper supply is used in production of compounds for nutritional supplements and fungicides in agriculture. Machining of copper is possible, although it is usually necessary to use an alloy for intricate parts to get good machinability characteristics.

RECENT TECHNOLOGIES

- Heated Roll Rolling, and the suitability of this technique for magnesium sheet production.
- Asymmetric Cryorolling, which has potential for large-scale industrial production of nanostructural materials
- Variable-Gauge Rolling, used for production of flat products with variable thicknesses
- Through-width Vibration Rolling, used for fabrication of ultrafine material sheets.

CONCLUSION

Flat rolling is a forming method which reduces the cross-sectional area of the work piece, i.e. a semi-finished product and enlarges its length. Furthermore, material properties such as strength, toughness and surface structure are enhanced.

It is been observed from the graphs that, as the gap between the rollers decreases we can observe that length of the material is increasing gradually with a slight difference in width and thickness.

As the No. of passes increases we can observe that length of the material is increasing gradually with a slight difference in width and thicknes

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