

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES FORMATION OF STEEL STRIP THROUGH COLD ROLLING

Bhaskar Das^{*1}, Rajesh Kumar² & Hari Parshad³

^{*1,2&3}M.Tech- M&A Scholar, Assistant Professor, Department of Mechanical Engineering, School of Engineering & Technology, Ganga Technical Campus, India

ABSTRACT

The research work deals with the formation of steel strip by cold rolling process. Generally cold rolling is a part of metal working under rolling process. Rolling is categorized into two process i.e. Hot rolling and Cold rolling processes according to the temperature of the metal rolled. When the temperature of the metal is below its recrystallization temperature, then it is known as hot rolling and when the temperature of the metal is below its recrystallization temperature, then the process is called cold rolling. The main focus of the research work is on the manufacturing of steel strips by cold rolling stages. Cold Formed steel is the common products made by rolling or pressing steel into semi - finished or finished goods are created by the working of steel billet, bar, steel plates or sheet using stamping, rolling (includes roll forming), or pressing to give it into desirable shape or into a usable product.

Cold rolled steel sheets offers a variety of outstanding properties, including easy formability and a smooth clean surface, and are used in automobiles, appliances, panels, doors, and many other items needed in everyday life. Due to several advantages over the hot-rolled steel sections, the usage of cold - formed high strength steel strips have rapidly increased lately. The present work also mentions about the characteristics, storage and safety of pickled products. How the waste water is being treated, is also described in this work in pickling section. The research work also deals with the effects of annealing on grain size which is helpful in determining the various parameters that result in the improvement of quality of metal sheets being cold rolled.

Keywords: *Strip formation through cold rolling process, H.R. Slitting (Hot Rolled Slitting), Pickling, . Rolling through cold roll mill , Annealing, Skin pass or Pinch pass rolling*

I. INTRODUCTION

Cold rolled steel sheets are broadly used as materials in electrical appliances, steel office equipments, automobiles, containers and other variety of products which are related to day today life. The new concept continue to remodel the steel strip producing process today which they did a century ago. Cold rolling produces the product with great mechanical properties, surface finish and dimensional tolerances. The use of computers in cold rolling process has fostered their foretelling efficiency to a level that was not possible several years ago.

1.1 Motivation

As we know that the rolling steel into flat sheets is a well authorized manufacturing process, the steel industry is continuously looking for the approach to improve the quality of its products. The best way to improve the quality is through better understanding and controlling of rolling process. This is the reason for the models of the rolling process have been developed in history to predict how appearance of the final product, such as thickness and flatness, quality, shape and sizes are to be affected. Basically flat rolled products (steel strip) face some flatness errors due to manufacturing processes. The error might range from small thickness variations to waves in the product. By controlling production process and lessening the variation in thickness, it would be possible to minimize the cost and increase the manufacturing efficiency.

1.2. Background

Here we deal with the flat rolling process which is the process by which a metal piece that is strip or slab is reduced in thickness to form flat sheets or plate. Flat rolled products are classified into two groups: sheets and plates.

To form flat rolled products, a steel strip with an initial thickness is continuously reduced in thickness which is being forced down by numbers of or series of rollers supported by stands. Each pass of a strip reduces some thickness in the sheet. And the quality of strip is observed by measuring the variations in its thickness.

1.3. Rolling

Rolling in metal working is a process in which a metal stock is passed through one or more pairs of rolls to reduce the thickness and making the thickness uniform. Also we can define it as the plastic deformation of material which is caused by the compressive force pressured by the set of rolls. The cross section and the thickness of the work piece is reduced by the rolling process. In this the metal sheet is squeezed between the rolls (pair of rolls) which results in the reduction of thickness and increase in length. It is the most widely used, high production and close tolerance. Friction between the rolls and the metal surface produces high compressive stress. In Rolling process, the metal will undergo bi-axial compression.

II. STRIP FORMATION THROUGH COLD ROLLING PROCESS

The cold rolled strips are formed using roller mills. Roller mills are the mills that use cylindrical rollers either in opposing pairs or against flat plates, to crush or grind various materials, such as grains, ore, gravel, plastic and others. Stages of the formation of steel strip through cold rolling:

2.1. Stages of the formation of steel strip through cold rolling:

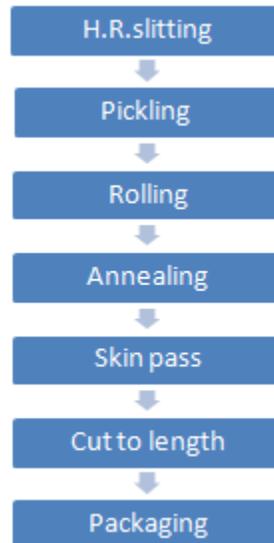


Figure 2.1.

H.R. Slitting (Hot Rolled Slitting)

In this process the hot rolled coils are cut into various sizes and shapes or width.

In this unwanted material is removed through cutting and also provide flatness to the irregular surfaces of the hot rolled strips. The processes included in the hot rolled slitting are:

Loading coil in uncoiler: this is done by using cranes to load the steel coil in the uncoiler section and is firmly gripped by the mechanical components and support. The steel plate of a coil is made to flow through the bed where cutters of different size and shape are present.

Setting of cutter: the cutter is set or placed over the bed in an appropriate and accurately measured way according to the requirement of different sizes what a customer wants. The passing of strip over the cutters also experience force which provide little flatness to the rough steel strip which is unloaded uncoiler.

Trimmer: its purpose is to trim the edges of the strip in a continuous flow of the steel strip.

Recoiling: in this the slitted strip of different sizes that is passed through differently sized cutters are wound in the form of coil.

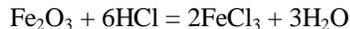
Unloading the coil from coiler: now the coil strips of different sizes are unloaded from the uncoiler.



Figure 2.2.

III. PICKLING

As the hot rolled coils are cut into various widths, these are brought into pickling line or arena. In Pickling the coils are used to get cleaned with the help of a solution of hydrochloric acid or sulfuric acid. Basically pickling is done in order to remove dirt and oxide layers from the coil. The reaction formed when hydrochloric acid reacts with the iron oxide is:



Pickling is one of the parts of the finishing process in the production of steel strips in which oxide and scaling is removed from the steel strip surface, steel wires other steel forms, by dissolution in acid. Mostly, the solution used is either Hydrogen Chloride (HCl) or Sulfuric acid in treating carbon steel products. Combination of hydrofluoric acid and nitric acids are also used sometimes for stainless steel. Pickling and its related process which is used for acid regeneration gives in the emission of Hazardous air pollutants (HAPs).

In this process, the HCl pickle liquor consists of iron chloride and HCl solution which is converted by a spray oxidation process into an iron oxide product and also HCl solution can be reused for the pickling operation. During hot rolling process the oxygen from the atmosphere comes in contact with iron in the steel surface. There are various methods that have been used to remove the iron oxides from metal surfaces. These methods are salt bath descaling, alkaline descaling, acid cleaning, abrasive blasting and acid pickling. The most used method in steel strip production is steel pickling.

When iron oxides get dissolved in HCl acid, the ferrous salt and water is formed.

Mechanism:



To minimize the acid attack on steel, an inhibitor is generally added to the acid solution. In this the rate of pickling is also affected such as base steel constituents, acid concentration and ferrous chloride concentration in the solution,

temperature, time of immersion and inhibitors presence. As temperature increases the pickling rate increases. As the process forwards further, in the pickling, the free HCl gets deplete and ferrous chloride starts generating in the pickle liquor to an extent that pickling cannot be done efficiently and the quality of the metal gets worse. And at that moment the pickle liquor is taken out of the pickling tank and thus pickling tank is filled with the fresh solution. The reutilization of acid solution will lead to manufacture the steel strips at low cost and thus there is cost reduction in material used for manufacturing strip. Acid transfer is executed either by continuous or in a batch mode pickling.

3.1. Safety and storage of pickling products

Pickling are harmful substances which must be supervised or tested or handled with care. Health problems can be avoided by means of air and skin protection. For high degree of personal safety following measures are recommended:

For personal safety, use facemask(fitted with breathing equipments) during pickling operations. The mask must contains dust filter, smoke filter, breathing filter.

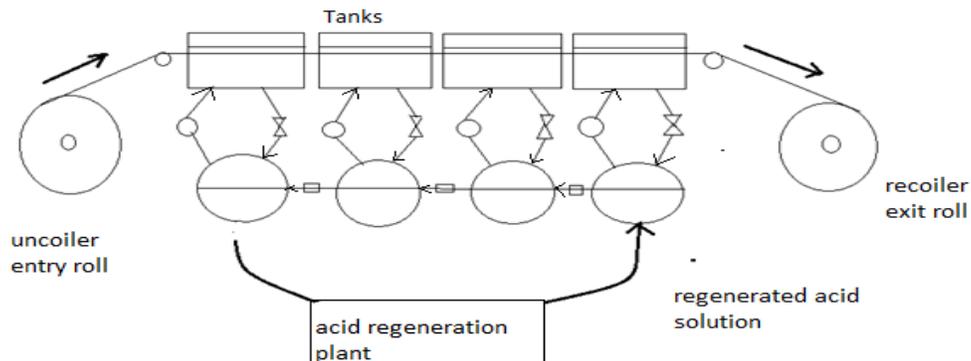
3.2. Storage

Pickling containers containing pickling chemicals are stored indoors at a temperature of 20⁰ to 22⁰C. The position of the containers should be upright as pickling chemicals are sensitive to high temperatures. Storage temperature should not exceed 45⁰C because they accelerate the ageing and may destroy the product.

Pickling process is categorized into three types –continuous, non-continuous and batch mode.

3.3. Continuous Pickling

This manufacture line is capable of handling continuous moving coil which is welded from head to tail of one coil to another. The starting point consists of a coil conveyor, one or two uncoilers, one or two processors, shears, and a welder. Processors consist of a mandrel, hold-down roll and a series of roll. Some cracking occurs in the scale layer, when the strip is passed through the processor. To avoid breaking of strip, good and proper welding of strip is necessary. Continuous pickling is basically done in the series of horizontal pickling tanks. The pickling portion is several hundred feet long and consists of three or four horizontal pickling tanks. Regenerated acid is added to the last pickling tank; then the pickle solution falls into the first over weirs between tanks and counter current to the moving direction of the steel strip. The pickling liquor is controlled at 180⁰ F by internal or external heat exchange process in order to allow a short pickling time at high line speed. A rinse section is present which expel the acid residue from the surface of the strip with fresh water. A drier section follows the rise section to dry the wet strip with hot air. The exit of the line consists of steering rolls, strip accumulator, a strip inspection station, dual side trimmers, an oiler to make the finishing surface shiny and recoilers. To prevent acid attacks on steel strips pickling solution can be drained into storage tanks.



Pickling line configuration

Figure 3.1

3.4. Batch Pickling

In this process the steel is dipped into acid solution tank containing acid solution for 20 to 40 minutes in order to remove the scales over the metal surface. It is then taken off from bath tank and allowed to drain and in the rinse tank the metal strip is rinsed or it can be done by spraying method. In order to pickle the steel rod and wire in coil form sheets must be held vertical and separated to enhance the acid contact. HCL concentration varies from 11 to 12 percent at beginning to 3 to 4 percent at the end of the process before acid replacement. The pickling is performed through fresh bath of acid solution unless the concentration of iron of acid solution reaches its maximum concentration limit i.e. 13 percent. A new batch of acid solution is prepared through non effective left over acid solution as these are pumped to the storage tanks. The temperature of the acid bath is upto 120⁰F.

3.5. Emissions through pickling

The emissions in the pickling process are generated in pickling tanks and rinse tanks and in a less amount from acid transfer operations. Basically in the emissions from the acid pickling depends on acid bath surface area, temperature, rate of ventilation, and agitation. Acid flow, heating and flow of steel through bath affects the agitation. Also the width of the steel that is being pickled affects the bath area.



Figure 3.2.

3.6.Strip parameters

Thickness = 1.2 to 6.0mm

Width = 750 – 1500 – 1900mm

Coil weight

For entering coil = upto 36 tonnes

For deliverd coils = upto 44 tonnes

3.7.Waste treatment

3.7.1.Neutralization

The waste water is polluted with heavy metals, i.e. iron, chromium and nickel and becomes acidic which is dissolved from the steel and thus undergoes neutralization. The waste water is neutralized by an alkaline agent that is graded slaked lime, or soda with a settling agent.

The neutralizing agent is added to the rinse water while it is being stirred. Now the reaction takes place with sudden instant. Then the pH of the mixture using litmus paper was checked and the pH was adjusted by adding more neutralizing agent. Precipitation of heavy metals is obtained. Precipitation is improved by adding a settling agent. Before the water is sent to sewer extra filter can be fitted before it so that the degree of treatment is increased. The sludge containing heavy metals can be treated in waste treatment plant.

Waste does come from the chemicals and from the packaging.

After the neutralization, the waste sludge is obtained which contains heavy metals i.e. chromium, iron and nickel. In accordance with the local waste regulations, the sludge should be moved off for waste disposal.

IV. ROLLING THROUGH COLD ROLL MILL

Rolling is a metal forming process in which metal (coil) is passed between two rolls or more rolls in order to reduce its thickness. Basically the coils are in the rolling mills. The coil from the pickling plant is brought to the 4 - high roll mill where there is a continuous reduction in thickness of the coil. In this high compressive stress acts on the metal surface and rolls.

Cold rolling process reduces the thickness of pickled steel strip from 1.5mm to 4mm down which is carried out by tandem mills which might be six 4-high stands in a row or with cluster mills with 6 to 20 rolls. Sometimes in industries 2-high-mills are also used. Under rolling conditions the area which is in contact with the roll and stock surface undergoes wear and the parts of rolls are neck and body which is considered as the normal parts which are under high load. It actually means that neck doesn't experience plastic deformation.

4.1. History of rolling mill

The first rolling mill was invented by Leonardo da Vinci but rolling mill became popular in the steel industry in the 19th century. In the first half of the 20th century there was large number of production of flat rolled products.

Some developments were made to produce efficient flat steel and after the Second World War it became widespread.

In past it was not easy to achieve the better shapes of flat products as it is now with the technologies were being developed like 6-high stands, roll bending, etc.. these changes gave a great impact the load distribution.

Now a day's steel market are having tough competition and since the long period of time the prices of rolled products are falling inspite of inflation. Companies which donot innovate ideas and technical development will face problems in the long run.

4.2. Rolling mill rolls demand

In order to stay in the market roll makers try to enhance the performance of their products. The ratio of roll costs to the rolled materials has decreased due to better roll performance and mill technology. To develop the upgraded rolls with better performance and to advance new manufacturing technologies, low price rolls are counterproductive.

What should expertise of roll makers includes?

Optimum material selection

Understanding roll application

Ability to bring change in the requirements of rolls specifications and parts

Sufficient heat treatment of rolls.

Rolling mill includes rolls (work and power rolls), rolls supported by bearings, speed control devices, motor, gear box, hydraulic systems etc. The commonly used rolling is two high rolling mills. Two rolls working in opposite direction are used. In reverse mills, the direction of rotation of the rolls can be changed. The reversing is done, so that metal sheets can be fed into the rolls in either direction. The rolls in non reversing mills rotate in same direction.

4.3. Reversing cold rolling mill

A coil coming from pickling line after being pickled sits in waiting for the cold rolling process.

The coil is then loaded in payoff reel which is being processed to start at the entry tension reel or uncoiler, where it is uncoiled and passed forward through the reversing mill.

A four high sets of rolls applies pressure over the metal sheet (strip) which reduces the thickness of the sheets and thus maintains the shape and width of the strip. It includes the number of passes which depends upon the customer's specification for coated product thickness.

As it moves forward through the rolls, the strip is recoiled into the recoiler or delivery tension reel. Then the strip goes back to the rolls in reverse manner making it thinner or reduces its thickness according.

The thickness gauge is present in the midway between pairs of rolls and delivery tension reel which measures the thickness of the strip with each pass through the rolls.

On achieving the proper thickness, the strip is coiled into one of the tension reels and from there it is ready to move into annealing line.

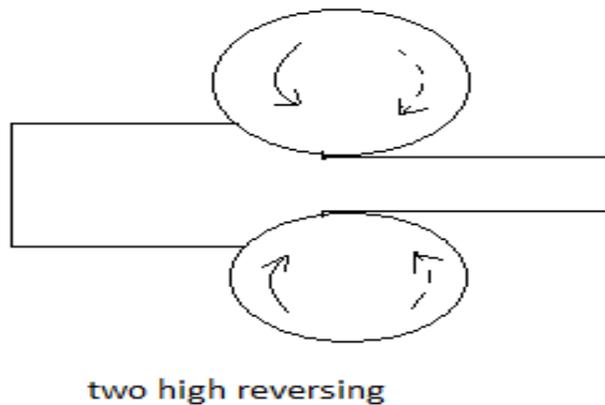


Figure 4.1.

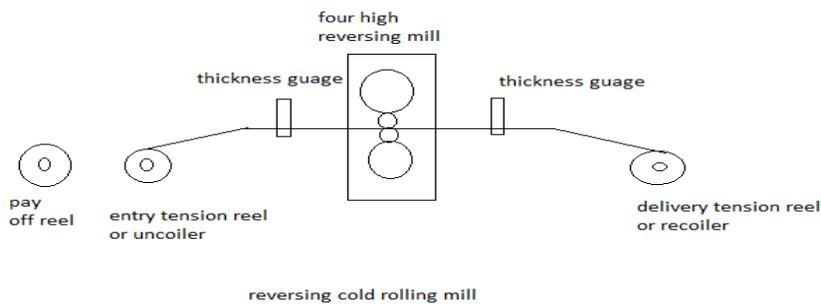


Figure 4.2.

4.4.A strip roll mill

A convention single mill stand strip rolling consists of the components:

Rolls

Frame

Gap control mechanism.

Instrumentation and operation control

Power transmission and power system

In this single mill stand the bearings on each end of the each rolls positions the crowned cylindrical rolls and the controls the measure of the roll gap. These are bound by the hydraulic cylinders or by the mill frame. The strip or sheet then invades into the gap between the rolls with thickness gauge greater than the gap. When it passes through the rolls from entry to exit, the thickness of the strip decreases. The pressure on the strip to cause the thickness reduction through plastic deformation is developed by roll separating force. The bearings on the end of the rolls by the frame of the mill get supported by the force developed between the rolls. The rolls get bend and flatten and the frame gets expanded under these loads. Large mill possesses 1 meter diameter rolls with force equivalent to 4500 tons on the bearings.

The rolls are pressed in contrast to each other that creates a negative gap when the strip is to be rolled and the gap between the rolls is to be set on the mill running empty without strip. As the strip enters the mill, the mill's elasticity gives a positive gap between the rolls equivalent to the desired strip thickness at the exit.

An electric driven screw down mechanism controls the gap between the rolls, which now a days has been replaced by a piston and hydraulic cylinder. These roll are driven by the DC motors.

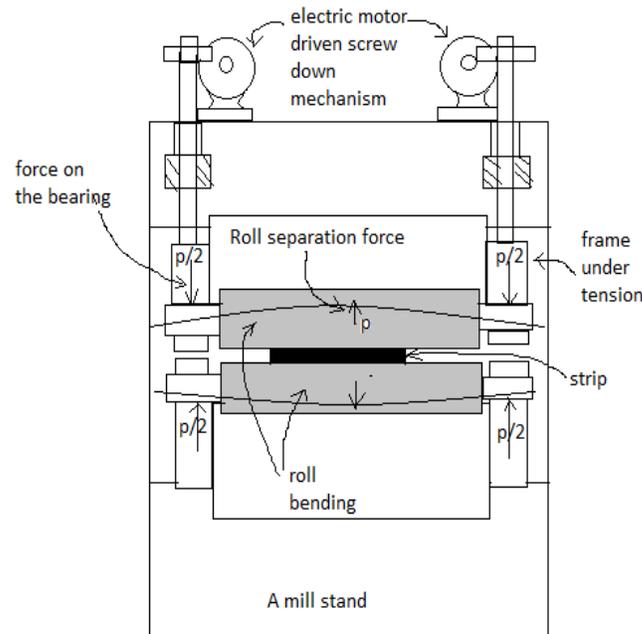


Figure 4.3.

4.5. Tandem rolling mills

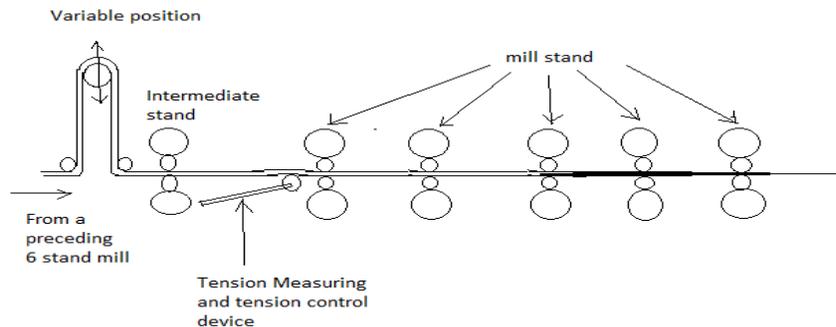
Reversible blooming mills breaks the ingot into a plate for further rolling into strip. After this reversible blooming mill many rolling passes are required before it reaches to particular or required thinness. For effective and efficient production of steel strip, the strip is rolled on a non-stop continuous production line, moving at a high speed from one mill to another.

A Tandem mill contains about six individual stands from which the strip continuously pass through them on a path a mile long. There is a mechanism called bend and variable position roll which provides the tandem mill a reservoir of strip. For non-stop continuous working or running of the plant equipment, large reservoirs of strip are needed at some points along the production line. Reservoir of strip contains coils of 100 to 200 tons with 60-inch wide strip. The incoming strip gets collected on the outside whereas payoff is removed from inside. The layers on the outside

gets collected by the top coil and pay off on the inside into inside bottom of the coils, which then pays off through its outside. The accumulation and release speed is controlled by the operator independently depending upon the conditions.

To control the roll gap and speed between the individual stations in tandem mill is critical. The volume rates of the strip must be same. Let the volume production rate is V , the width w of the strip is constant, then

$$V_1 t_1 = v_2 t_2 = \dots = v_n t_n = V/w$$



A Tandem mill
Figure 4.4.

The exit velocity v_f from each station is particularly decided by the emerging steel strip thickness from that station. The velocity and mill gap is set at their initial conditions before rolling starts and therefore both have to be frequently restrained to accommodate fluctuations in the thickness of the incoming strip, temperature etc. The monitoring and control station of the mill is handled by the team of operators with each operator appointed the limited task of controlling the gap and speed of each station. The operator predicts or judges whenever the changes are required to increase or decrease the tension between stands through observation of the behavior of the steel strip between a pair of rolls. The action of each operator influences the appearance on both sides of his station and with declining strength the appearances farther along the line. Like, an enhancement in the speed at an intermediate station will enhance the back tension and decrease the front tension of that station. The entire cooperates by reacting fast and quickly and in complete reconciliation. This reconciliation is achieved by the experience in addition to the training of new members. There must be accurate and immediate response when the slack enters the mill with speed of 2000 meters per minute. Here the tension is removed so that the extra length of strip between the two stations gets folded and doubles up. This creates separation force and stations cannot hold this force which may result in breaking of rolls at its transition from bearing to full diameter.

To provide continuous reading of the roll separation force by the load cells and interstation tension was introduced. Now days, standard load cell units can be adhered to the column of any mill so that it can facilitate the roll separation force. The roller in the tension device is preloaded and its position recorded to point out the interstation tension. If the speed and the gap control are manually affected, these readings of roll separation force are helpful to the team who are controlling the continuously running mill. The readings of the roll separation force and the interstation tension are automatically connected to the mill controlled by closed-loops. They are basically controlled and undertaken by computers. All the stations should deliver maximum power at their full capacity in order to use the mill efficiently and effectively.

4.6. Cluster rolling mill

For the thinner strip to be rolled, a small diameter roll is needed before the limiting thickness is reached. Working rolls starts to deflect horizontally if a four-high rolling mill is used with working rolls of small diameter too large backup rolls i.e. more than twice the diameter of working roll. In order to prevent from deflection, the cluster rolling mill was introduced which has very small diameter working roll the train of supporting rolls (backup rolls) with increasing diameter.

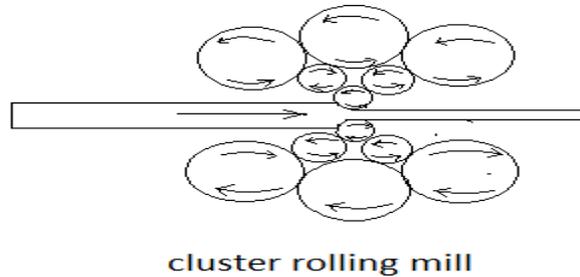


Figure 4.5.

V. ANNEALING

In annealing process the steel strip is heated to a temperature, generally with a longer holding period to achieve soaking and then slow cooling. The objective of the process is to shape and control the microstructure and internal stress of steel strip towards a uniform and stable state. Annealing process can be done in two either ways i.e. batch annealing or continuous annealing. The annealing process restores ductility and formability required by the customers for processing. In continuous annealing, the annealing of cold rolled strips is done in a continuous furnace in which the sheets or strips enters in an integral type tunnel furnace for annealing.

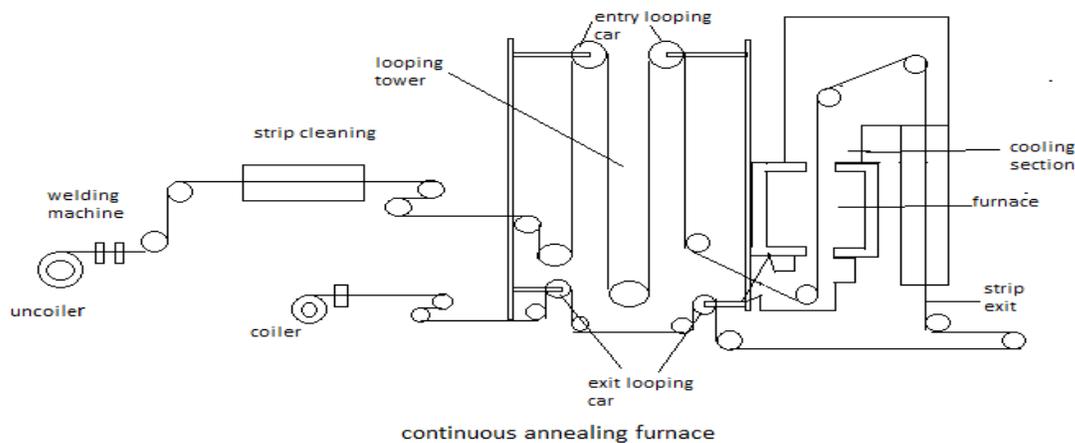


Figure 5.1

In batch annealing method, 4-5 cylindrical steel coils (15-20 tons each) are in a stacked form on a furnace base and annealed under a hydrogen atmosphere. A very low radial thermal conductivity is resulted through the air gaps between the coils sheets. Therefore there is a structural variation in temperature in the annealing process. Hotspots, which are outer surfaces of the coil gets heated faster and achieve the annealing temperature in relatively shorter time in comparison to the temperature of the inner coil, which is known as cold spot. Thermal lag such as recrystallization and grain growth is resulting into the spatial variation in microstructure in the coil. Also there are coil to coil variations in the microstructure and mechanical properties along the furnace due to variation in axial temperature. As there is reduction in mechanical and micro structural properties due to increase in soaking time, therefore, for the development of productivity and quality, selection of soaking time in an industrial batch annealing is important.

Plant productivity, emissions, energy consumption, quality characteristics like strength, drawability, formability and ductility are improved by the batch annealing method.

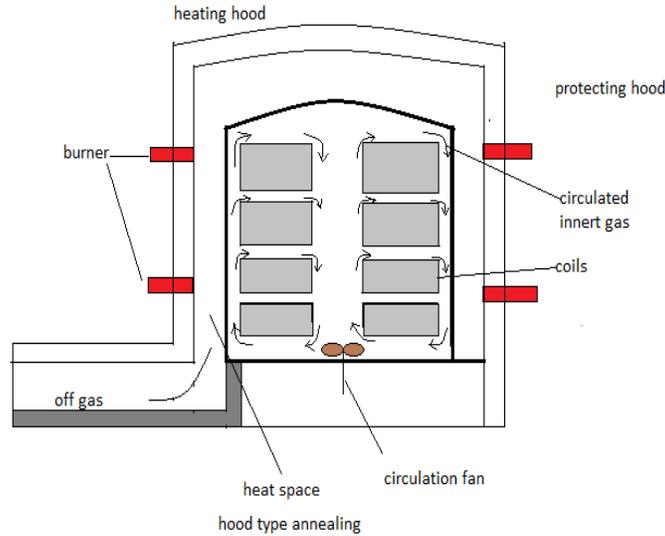


Figure 5.2.

VI. SKIN PASS OR PINCH PASS ROLLING

After annealing process, the annealed strip is re-rolled with reduction in its thickness of around 0.6 to 2.5 percent so that it can be level and compress the surface of strip to improve the stacking factor of the electro plate and also to decrease the propensity of strips (sheets) in formation of crease lines. To prevent it from a defect known as stretcher strain the annealed coil is rolled through skinpass mill. Thus it improve the strip shape and adjust the mechanical properties.

VII. FINISHING

After skinpass rolling, coils are processed at the recoiling line, where they are cut to produce the product coils of the particular weight, or at the shearing line, where they are cut to sheets of required dimensions. Product thickness, width, shape and surface quality and mechanical properties are inspected. In finishing process the strips are cut according to the length required for the customer or according to the order placed in the form of rectangular, square plates as per requirement and is packed and dispatched to the customers.

VIII. CONCLUSION AND FUTURE WORK

8.1. Inputs and outputs through cold rolling

In this study there are sub-processes in cold forming, they are pickling, trimming oiling, cold rolling and annealing process, moreover skin pass or pinch pass rolling and finishing process is also included.

8.1.1. Pickling

Table 8.1.

Input	Output
Pickled hot strip	Cold strip
Energy	Oil mist
Lubricant	Waste water
water	Scrape

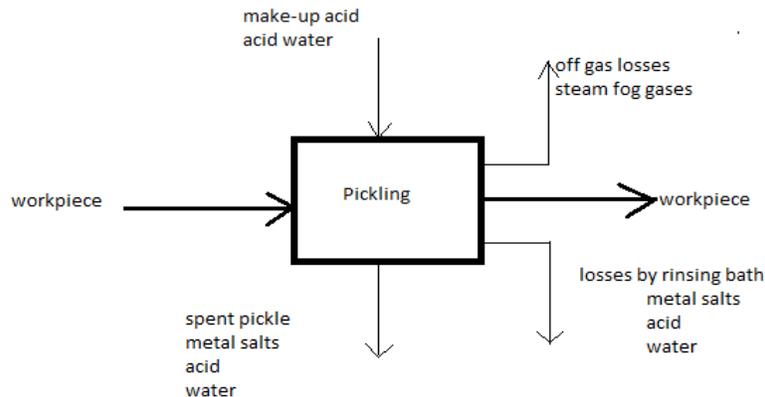


Figure 8.1

Inputs of the pickling process mainly depend upon the steel grade that is being pickled. The pickling agents are hydrochloric acid or sulphuric acid. Acid mixtures are used pickling stainless steel. Different amounts of energy inputs are required at different temperature that depends upon acid. The pickling process operated at temperatures generally give rise to acid aerosols and fumes at the bath surface. Waste water from rinsing that comes out contains acid wastes. Solid outputs like pickle tank sludge, effluent treatment hydroxide sludge and acid regeneration sludge that are arisen through pickling and acid regeneration. The regeneration of used pickle cause effluents and these are treated as for waste acids.

8.1.2. Cold rolling section

With the help of rollers, cold rolling reduces the strip thickness by compressive force. During the input, the drive of the rolls requires a continuous energy supply. Because of high rolling driving force, the strip is heated by the forming heat to up to 60-2500 C Therefore, for cooling the rolls and work piece; they are cooled and lubricated by the oil, water emulsion. The reason for lubricating is to reduce the roll forces and moments, and also reduces tool wear and thus improves the strip surface. As there is temperature increase in strip, the oil gets evaporated partly and does forms oil mist, that is being exhausted by suction plants.

8.1.3. Annealing section

Due to high strain, the strip that is cold rolled gives higher values. Therefore, to insure plentiful material properties of final products, after the heat treatment i.e. annealing which is done at about 650 to 7000 C and thus allows the desired strength to be set up. The input and output rely upon the type of fuel used and furnace. If natural gas provides the energy for heating particulate emission can be expected there. Annealing is done through inert gas that is hydrogen or nitrogen, which support a good convection from the protecting hood to the coils in batch type furnace. Scrap can also get generates if different layers of the coils get bake together as the heating temperatures are too high.

8.1.3.1. Effects of annealing on the grains

The betterment in mechanical properties,, notably it is the yield strength that develops attraction in grain refinement. According to Petch relationship

$$\sigma_y = \sigma_0 + k_y d^{1/2}$$

where σ_0 is yield strength with no grain boundaries, d is the diameter of grain and k_y is the coefficient.

Transformation of austenite to ferrite is used to develop refined ferrite structure in steel in transformation grain refinement which was first brought up by Hodgson et al and got refined microstructure of $1\mu\text{m}$ in a consequential fraction of its volume. In this similar process in order to achieve the results in grain size less than $1.5\mu\text{m}$ through

thickness of a micro alloyed steel which was rolled to nearly 2.5mm thickness by the Priestner and Ibraheem. The cold rolling process was applied after transformation grain refinement process. In cold rolling the dispersed cementite and vanadium carbides does handle the grain coarsening of the re-crystallized grains. There was a final thickness of 1mm steel plate after being cold rolled.

Five sets of annealing at temperatures of 580⁰, 600⁰, 620⁰, 650⁰ and 675⁰ C was taken that had different soaking time which varies from five minutes to two hours to support re-crystallization. Five readings were taken for hardness measurement after annealing at different positions of the strip (specimen). The microstructure were observed on microscope. The grain size was measured by concentric circle getting superimposed on the image of the microstructure to achieve the intercepts on the grain boundaries and also the tensile test was performed in universal testing machine.

In cold rolling the aspect ratio of grains changed adjacent to the rolling direction and also along with the strain energy used in recrystallization. During annealing energy of deformation shows major role. After cold rolling grain refinement mostly depends upon the temperature and the grain size before deformation. In tensile testing of cold rolled strip the tensile strength increased upto 950 Mpa with only 4.4% of strain. Due to dislocations in the microstructure when undergoing plastic deformation in cold rolling, there was increase in hardness and strength before annealing process. There was also sharp increase in ductility and in tensile strength.

In this the specimen which was annealed consisting of refined microstructure gives tensile properties of better finished steel with increase in ductility. Yet, increase in strain reflects improved formability. The study of these parameters helps in the improvement of quality of metal sheets being cold rolled.

REFERENCES

1. *Rituper, R.: Beizen von Metallen, Leuze Verlag, Saulgau, (1993)*
2. *Karner, W.; Hofkirchner, W.: Modern pickling and acid regeneration technology, in: MPT International 2/1996, Düsseldorf, p. 92-96, (1996)*
3. *International Iron and Steel Institute: Recycling and Disposal of Spent Materials from Acid Pickling and Coating Lines, Brussels, October, (1987)*
4. *Hensel, A.; Poluchin P.; Poluchin, W.: Technologie der Metallformung, Freiberg, (1990)*
5. *Dahl, W.; et al. (eds.): Umformtechnik Plastomechanik und Werkstoffkunde, Verlag Stahleisen, Düsseldorf, (1993)*
7. *Rasselstein Hoesch GmbH: Process Routes - Firm Information, Neuwied, (1996)*
8. *N.J.Petch, J.I.S.I., vol. 173, (1953) 25-28.*
9. *K.H. Schroder: A BASIC UNDERSTANDING OF THE MECHANICS OF ROLLING MILL ROLLS File: SCHROEDER_ROLLS_010703.DOC*
10. *George Dieter. Mechanical Metalurgy. McGraw-Hill, 3rd edition, 1986.*
11. *John G. Lenard. Primer on Flat Rolling. Elsevier, 2007*