Abstract

Aluminium is most widely used non-ferrous metal and one of the most abundant of all elements in the Earth’s crust. Due to its properties such like low density, formability, corrosion resistance; it has a wide range of application areas like automotive, construction, aerospace and aviation, marine, medical and food. Aluminium products are classified into three categories according to their production technique: extrusion, rolling and cast aluminium products. Like aluminium itself, rolling it also has a very short history, whereas the last decades are the times that rolling technology is matured. Since demands and aluminium industry is growing continuously, need for producing fast and efficiently pushes the rolling lines to increase the productivity. Together with productivity, good quality; specifically, consistency in thickness, good flatness and surface appearance are expected to be superior in the competitive environment. This work aims to give the principles of rolling aluminium based on theoretical and practical knowledge; specifically, in terms of flatness control mechanisms, thermal effects and their management.

1. Introduction

Aluminium sheet production starts with Direct Chill Casting (DC) of ingots or with Twin Roll Casting (TRC) method. The ingots which are cast by the conventional DC method are then mainly subjected to preheating and hot rolling operations. With TRC method, aluminium cast coils are directly produced from liquid aluminium alloys by eliminating a few steps compared to DC. TRC coils are then processed by cold rolling operation in order to achieve desired thickness. Hot rolling is used for producing plate and strip, where cold rolling is used for strip, sheet and foil. Plate is the form of aluminium which its cross section is a rectangular and its thickness is 6,3 mm or more. The aluminium products which its thickness is between 0,20 and 6,3 mm are named as sheet. Below 0,20 mm thickness, the flat product is called as foil [1].

Rolling, as a metallurgical process is reducing the thickness of material by passing it between two counter rotating cylinders. During the process, the materials are elongated but it does not show a significant amount of spreading transversally. Rolling is a widely used process because of its high productivity. Technical meaning of hot rolling is rolling the metal material at a temperature higher than its recrystallization temperature, so that the material is avoided from strain hardening during the process. Cold rolling is a rolling process which is occurred at room temperature where the material shows strain hardening. Although it is named as “cold” rolling, the material is heated up by deformation to approximately 100°C and a high amount of coolant is used during the process in order to have a thermal equilibrium [2]. Cold rolling, as its expected to be, requires more energy where it provides a very good surface quality and physical tolerances. Finish rolling operations of materials are completed by cold rolling.

Figure 1. Grain structure change during cold rolling [2]

Rolling process breaks and offsets the lattice planes of the material and increases the dislocation number, which results in material to resist the deformation and making it harder and stronger. Rolled material shows an elongated grain structure (Figure 1).

2. Types of Cold Rolling Mill

Strip rolling can be done with different type of mills (Figure 2). Reversing rolling mills are used for coil weights up to 5 tons, there non-reversing mills are used...
for normal coil weights between 10-15 tons. For higher coil weights and higher production volumes, multi-stand tandem mills are used.

Choosing the correct type of cold mill depends on the exact range of products that is desired to be produced. Cold mills are classified into few categories according to their thickness ranges and speeds. To determine the optimum type of roll stack configuration, some specific requirements of the down gauging process like material hardness, gauge range, rolling speed and strip width should be known.

The simplest design, two high mills are no longer used because of their inability to control the roll gap geometry and minimum thickness it can produce is 0.20 mm (Figure 3).

Four high mills are most widely used mills with their hydraulic negative and positive bending cylinders. Many rolling mills are today still designed in the traditional four high configurations. These are able to produce high-quality products, especially if the materials are not wide range. Nevertheless, 4-high mills are inherently limited by the range of actuator effects and by their capabilities for fine control across the strip width, for both profile control and flatness control. These controls near the strip edge become more problematic when there is a need to deal with frequent product changes, while running at maximum reduction and speed to achieve good plant productivity. This is known both through plant experience and through process models, which take into account the mechanical effects of roll bending and flattening under load, the material properties of the strip being rolled, and the thermal transients occurring as the heat balance alters in the roll gap. For this problem, 6 high mills are accepted to be as a solution [2].

Six high rolling mills have the most effective system to control the roll gap with their work roll or roll drives with axially shift or tiltable intermediate rolls, with positive and negative roll bending capacity. Because of this capabilities, these mills are mainly used as universal strip rolling mills.

3. Flatness Control

The rolled materials final flatness is depended on the characteristics of the starting material (cast coil, hot rolled material, etc.) and features of the mill. If the materials flatness is not good, some parts of the strip are longer and results in buckling. Buckling may occur on centre or edges. This defect can be eliminated by tension levelling where the strip is stretched sufficiently so that short parts are extended to the point where they have the same length of the long parts and the out of shape disappears (Figure 4). Paying attention to the ingoing products flatness is significantly important for the final shape.

Mills are supported by automations in order to measure the outgoing shape of the strip and then instructed the mill controls. High performing flatness measurement and control is a critical success factor for flat rolling mills. Outgoing shape is measured by a shapemeter roll (Figure 5). This deflector roll stands between work roll and winder roll at exit side. It measures the tension of the strip and sends the signal to the actuators in order to control the work roll bends and lubricant sprays.
Flatness is need to be controlled for different reasons. One of them is to maintain total gauge performance and to attain the thickness control anywhere on the strip. The reason to have a good flatness is to enable high recovery on multi slit products and to ease downstream processing. Lubrication systems provide lubrication to the rolling process, correct rolling friction, prevent sticking and surface quality. On the other hand, coolant systems control roll temperature, vary roll thermal chamber to control the strip profile and strip flatness by removing heat from the energetic rolling process. The purposes of both two systems are different but the type of fluid used may be the same for simplicity. The both system helps to wash away the debris [5].

4. Lubrication and Cooling

For cold rolling oil based kerosene lubricant and coolant with additives can be used. A typical cold mill cooling arrangement with only entry side sprays are shown in Figure 6. Top backup roll has a wiper roll to prevent coolant carryover onto the exit side. Coolant system takes the signals from the shapemeter and long parts of the strip are adjusted by alteration of the distribution of the rolling lubricant. So these hot parts of the roll are cooled to prevent nonhomogeneous long rolling.

Additives must be non-staining during annealing. Effectiveness of additives decreases with concentration and above concentration upper limit, almost no performance improvement can be achieved. Depletion by filtration is proportional to additive concentration. If the lubricant breaks, herringbone effect seen on strip (Figure 7).

5. New Technological Possibilities

5.1. Flatness and Profile Prediction Systems

The most important weak side of currently used profile control systems is latent reaction because of the shapemeter position which it stands after work rolls. The signals that become visible after subsequent operations. Rolled strip is coiled at the exit side with containing all these gathered impurities and cooling emulsion. Because of this, there is always a loss of valuable rolling emulsion which could probably be used again. For a high quality of rolled material it is necessary to have a clean and high quality surface besides of the final geometrical shape and thickness tolerance of the strip. Removal of cooling emulsions or oils from the rolled strip in rolling mills are presently done with different techniques but the widest one of them is blowing off oil by high air pressure which is blowing directly onto the strip. To have an efficient result, positions and blowing angles of the nozzles are very important.

Lubricants are applied to keep the surfaces of work roll and the strip separated by a film layer for mainly two reasons. One of them is the lubricant that has a lower shear stress comparing with the strip. This results into the generated friction forces by shearing of the lubricant lower than the shearing of the strip. Thus less load power is needed for deforming the strip. The second reason is damaging the surface is reduced so that a good surface quality can be achieved. Requirements of low friction and good surface finish dictates the rolling operation to be performed in mixed lubrication regime. Mixed lubrication is the intermediate regime between boundary lubrication and hydrodynamic friction where there is some asperity contact but also some hydrodynamic actions [6]. For cold rolling process, boundary additives are required.
command the actuators of work roll bending and tilting systems arrive after the related region of the strip is passed. If there is an inconsistent flatness profile on in-going material, it is hard to get a proper profile on the out-going strip. For this reason, there has been efforts to predict the materials flatness behaviour depending on in-going material and cold rolling mill's capabilities. In Figure 8, the graph drawn by a prediction software shows the strip profile with different bending forces. Also there are improvements on fine edge profile control by adapting hot oiling on edges or partially inductive heating applications.

5.2. Automatic Setup Operation Controls

To produce high quality strip, it is very important to control the process properly which directly affects visual quality of the strip, mechanical properties and flatness. On the other side, competitive market requires always more efficient production. For this reason, process and set up automatization is a necessity. Automatic roll change system is a good example for this aim. In many plants, the work rolls are still changed by operators manually which is time consuming. Using automatic roll change system eliminates the safety risks of manual operation and decreases operation time. Also there are some improvements in coil feeding system which eliminates human effort and possible edge damages.

5.3. Improvements for Cooling Systems

During rolling process of aluminium, attention to work roll spray cooling has significant effect on flatness and profile controlling performance. Good dimensional and profile quality of strip depends on the spray actuator besides on the control system. This is why the cooling system is accepted to be a critical part of the process. To optimize the coolant flow and its pattern, a modelling software can be used [9]. With this model, the nozzle configuration and flow must be calculated from the heat input to the roll (Figure 9).

5.4. Clean/Green Systems Adaptation to Rolling Process

Rolling mills that use oil as a coolant and lubricant emit large amounts of oil in their exhaust. Due to environmental concerns and regulations, it is important to purify the exhaust air of aluminium cold rolling mills. In cold rolling operation high amounts of oil is used to ensure that the foils do not adhere to the rollers, to provide a good surface quality and to dissipate the heat. About 1% of the employed rolling oil evaporates thereby and is absorbed in the exhaust air [10]. The recovery system separates and recovers the hydrocarbons from the exhaust. Besides environmental benefits, the system also provides economic advantages by preventing the loss of rolling oil with exhaust.

6. Conclusion

The object of this paper was to give a brief information of basic concepts of aluminium cold rolling. Aluminium, which is a widely used metal, can be produced by several ways but rolling is a very important production process and rolled products constitute almost half of all aluminium products. Due to the growing market, quality expectations are increased. Besides ingoing material, type of the cold mill used and its properties and capabilities is significantly important for the final strip quality. Also it is intended to summarize the new technological possibilities for cold rolling process.

References


[5] Aluminum Rolling Technology Course Notes, 13-17 May 2013, Banbury, UK


