Aluminum Sheet Production: General Principles of Finishing Lines
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Abstract
Aluminium became a material which is widely used and preferable from industries and consumers. The key reason of being widely preferable is very important characteristic abilities of aluminium like low density, formability and corrosion resistance. Aluminium can be produced in different ways such as direct chill casting, high and low pressure die casting, twin roll casting. In twin roll casting, production continues with rolling operations, annealing and finishing operations. In this work, different finishing line operations like tension levelling and degreasing, slitting, cut to length line and their principles will be discussed. Every operation contains different parameters and aims to finalize the product dimensions and surface properties which is requested by customer. Another important situation is increasing the quality of product, productivity and machine usability. All equipment in finishing operations until the end of the packing which is in contact with aluminium product will be examined.

1. Introduction
Aluminium is used in various areas of industry such as transportation, packaging, architectural etc. Therefore, there are many important material properties for different end users. Finishing operations can be changed with desired dimensions and material properties of end-users requests. Some undesirable effect is occurring in inherent by casting and rolling operations. The associated surface specifications, shape tolerances and flatness specifications become replaced in the marketplace. Contamination of the surface after all process in twin roll casting products is containing some lubricants, rolling oils, surface oxides and microcracks. Surface oiliness and dirtiness has to be removed in degreasing line before the end use. At the same time sheet flatness problems should be eliminated in stretching and tension levelling operations. Flatness values to avoid any problems in the ability to take final shape, determines the end-use conditions e.g. (weldability, painting ability, formability).

In sheet metal production twisted strip, center buckles and wavy edges can occur with changes in casting and rolling parameters. Coil sets and cross bows occur due to the nature of coil structure. These shape defects have to be removed for achieving desired flatness values with stretching and levelling operations.

Transverse and longitudinal directional plastic deformation effect on outer and inner “fibres” of the sheet with same elongation. It is possible to achieve dead flat strip with this effect.

Slitting operations are very important factor for determining the quality of the product in last operations. An unsuitable slitting operations can create edge Burr. Even flatness problem can be occurred with wrong slitting operations. If it is desired to produce a high quality end product, knowledge of applicable parameters and effect in finishing operations is considerable.

2. Theoretical Basics
Fundamental issues of finishing lines in twin roll casting industries are degreasing, flatness and slitting qualities. Thus operational steps and changes should be followed in order to obtain the desired values. In this part some theoretic basics will be discussed about degreasing, flatness and slitting qualities.

2.1. Stretching and Tension Levelling Principles

![Figure 1. Center buckle while stretching operations](1)

Aluminium sheet strips are simultaneously stretched by bridle rolls with different angular velocity. The velocity changes between bridle rolls provide the desired elongation on process. The I-Unit is a powerful description of the fibre length distribution in the strip width direction. I Unit equation can be seen in below (1).

\[ I_{Units} = \pi H L^2 x 105 \]  

(1)
H: Wave Height  
L: Wave Length

<table>
<thead>
<tr>
<th>Shape Forms</th>
<th>Appearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strip Camber</td>
<td>Edge Bubbles</td>
</tr>
<tr>
<td>Long Center</td>
<td>Center Bubbles</td>
</tr>
<tr>
<td>Long Edges</td>
<td>Side Bubbles</td>
</tr>
<tr>
<td>Quarter Bubbles</td>
<td>Herringbone</td>
</tr>
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</table>

**Figure 2.** General flatness problems in production which observed after cold rolling operations [2]

Fibre length changes and this effects can be seen in Figure 3. If amount of elongation increases on the fibre region, surface area per unit volume will increase. In this case fibres will tend to create waves. Different wave types can be seen after this effect in Figure 2. These failures are occurring after uncontrolled trend in differences in casting thickness and rolling parameters.

**Figure 3.** Fiber elongation of the region in which the flatness problems [2]

This is well known that, in over yield strength operations, two regions where deformations occur such as homogenous and heterogeneous plastic zones. Stretching and tension levelling operations are generally applied in homogenous plastic deformation zones in order to achieve the best flatness values.

Stretching with bridle rolls and tension levelling operates with two different principles and two different mechanical properties of the material. The same amount of fibre elongation is the main objective. Material can be elongated in homogeneous plastic deformation zone. The principle of stretching operation is basically due to the speed difference between bridle rolls. This speed differences between the bridle rolls are provided with differential engine. Given the amount of strain is actually equivalent to the size of expansion of the material.

Coil set, crossbow edge waves can be eliminated with the speed difference is generated in the bridle rolls. If deviations from flatness increases, amount of elongation created by bridle roll is not enough. In this case equipment is preferred which is providing a narrower range of plastic deformation.

**Figure 4.** Schematic illustration of tension levelling operation. [3]

A standard leveller group consists of four main sections which are frame, work rolls, back up rolls, spindle drives, transmission gears. Back up rolls are required for work rolls bending [3]. Amount of plastic deformation increases with penetration of leveller work rolls. If contact angle increases, bending on outer fibre will more elongate than inner fibre. The shorter fibres have to elongate with pressure of work rolls. In this time longer and shorter fibres will come up to same length at the center and cross section of metal.
Contact angle between work rolls and material increases with the penetration. Internal and external elongation changes can be seen in Figure 4.

![Figure 4. Elongation differences after stretching operation. [4]](image)

Firstly, top surface of material will bend. After first roll, second roll continue to bend the other surface of the material. Number of driven rolls and diameters varies by material properties. Reduction of coil set is possible with the large diameter rolls whereas buckling can be removed with lesser diameter rolls. Roll number and diameters should be increased where flatness issues seen in soft materials such as aluminium. The deviation of flatness regions can be rectified with low pressures.

**Table 1. Leveller applications in flatness issues [3]**

<table>
<thead>
<tr>
<th>Application</th>
<th>Operator Side</th>
<th>Center of Machine</th>
<th>Drive Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural setting (in cross bows, coil sets,</td>
<td>Small Bend</td>
<td>Smaller Bend</td>
<td>Larger</td>
</tr>
<tr>
<td>crowned strips and chatter marks cases)</td>
<td>Radius</td>
<td>Radius</td>
<td>Radius</td>
</tr>
<tr>
<td>To stretch the edges (in center buckle cases)</td>
<td>Larger Bend</td>
<td>Smaller Bend</td>
<td>Larger</td>
</tr>
<tr>
<td>To stretch the center (in wavy edges, quarter</td>
<td>Large Bend</td>
<td>Smaller Bend</td>
<td>Large</td>
</tr>
<tr>
<td>buckles cases)</td>
<td>Radius</td>
<td>Radius</td>
<td>Radius</td>
</tr>
</tbody>
</table>

In all applications entry work rolls penetration must give more pressure than exit work rolls. Quarter buckles and wavy edges can be flattened with stretching center of the material, also center buckles can be flattened with stretching edges. Both applications provides all the fibre to elongate the same length [5]. This operational differences can be seen in Table 1.

### 2.2. Principles of Slitting Operation

Slitting is a very important operation due to providing desired dimensions of the customer request. Operational steps and contact equipments affect the quality of final product. Slitting quality is determined by the size of edge burrs. Burr height occuring at the edges may disturb the flatness of the final product by performing edge swelling during the winding operation. Directly welding and joining operations can lead to issues in the end use.

![Figure 5. Standard equipment in slitting lines [4]](image)

Slitting blades are positioned on the slitting shaft. The position of the knife during the slitting operation can be fitted to the desired final dimensions. In this situation shape defects of the material can be eliminated while slitting operations. For this reason, two types of rubber on slitting are used. Male and female rubbers are placed between the cutter blades. Schematic representation of the slitting operation can be seen in Figure 6.

![Figure 6. Position of blades and material while slitting operation [6]](image)

Blades and material position and mechanical changes of material while slitting operation can be seen in Figure 7. Position of blades (gap and penetration) is very important while cutting due to changes of material thickness and mechanical properties. Gap of the thick and brittle materials increases whereas thin
and ductile materials decreases. Cutting and fracture zones changes depending on the gap position and penetration of the blades. Therefore material properties has to be analyzed carrefuly before the slitting operation. Roll over, burnish and fractured zones can be changed along the blade diameter, backlash of slitting shaft and blades. Space rings can be used for decreasing the backlash. Schematic formation of standart slitting edge can be seen in Figure 8.

Figure 8. Equivalent stress and strain distribution during the cracking phase [6].

Flatness problems can occur through the width. Wavy zones has longer fiber according to the other zones. For instance if a coil has center buckles, materials length of the centerline will be longer than edges. In this situation center and edges cannot be wound with same tension and center of the coil windings will be looser than edge coils. Therefore loophole can be used for the swinging of long fiber zones. Loophole is necessary for the good winding operations.

2.3. Cut to length line components

Surface films and papering operations can be applied in the cut-to-length line. Aluminium sheets need to be electrostatically chargeable in order to be papered. One surface of film is adhesive. Intermediate rolls have to be use for properly film bonding. Cut to length lines generally contains the decoiler, leveller, film and paper covering roll, electrostatic charge machine, hydraulic rotary shear, convey table and stacker.

Figure 9. A simple cut to length line [9]

2.4. Degreasing operations

Degreasing process is applied to clear surface contaminations and oils which is coming from cold rolling and casting operation. Degreasing operations are separated as pressure water applications, solvent wiping, vapor degreasing, emulsion cleaning, acid cleaning, mechanical cleaning and alkaline degreasing operations in aluminium production. Line speed, line length and the amount of pressure are important for aluminium and surfactant contact time in degreasing operation. Solvent tanks should be sealed because of the toxic gas-free. The number of spray nozzles and nozzles angle is very important for effective degreasing operation. Nozzle angle has to be reverse direction in reference to line direction. Cleaners are many in number and vary in type and formulation. Cleaner types are separated in alkaline applications such as alkaline salts, wetting agents, sequestering agents. Synthetict detergents allow oil to be removed by displacing the oil from the surface and creating an emulsion in which the oil droplets are dispersed in water [10].

Figure 10. Simple degreasing process [10].

The level of degreasing (oiliness) operation can be determined by ink test.

3. Conclusion

In this article finishing lines and operational basics of the aluminium sheet production are discussed. There are many finishing operations which is unspecified. It is possible to produce with high added value half finished products for each end users with different finishing operations. Problematic cases which is coming from previous process can be repairable with true finishing operations.

References