

Aluminium Rolling Lubrication

Mark Foster and Chris Pargeter - Innoval Technology Ltd.

Introduction

Lubrication is an essential part of the rolling process enabling aluminium to be converted from cast slab/ingot into a usable industrial form. The rolling process makes it possible to reduce an ingot of metal, weighing up to 20 tonnes and measuring 2 m x 8 m x 600 mm thick, to plate gauges (typically 250 mm to 6 mm), sheet gauges (typically 6 mm to 250 μ m) and, ultimately, foil gauges (typically 250 μ m to 6 μ m).

In the industrialised world, approximately 50% of all aluminium alloys used is in the form of flat rolled product and over the last 35 years major changes have taken place in rolling lubricant development and understanding. It is now accepted that the rolling lubricant influences mill productivity and the quality of metal produced. The processes and lubricants involved in the rolling of aluminium are presented in Table 1.

| Process | Lubricant | Temperature ($^{\circ}$ C) | Gauge Range (mm) |
|--------------|-------------------------|-----------------------------|------------------|
| Hot Rolling | Oil-in-water Emulsion | 270 - 560 | 2 - 600 |
| Cold Rolling | Oil-based / Water-based | Ambient - 170 | 0.15 - 6 |
| Foil Rolling | Oil-based / Water-based | Ambient - 140 | 0.005 - 0.6 |

Table 1 - Aluminium rolling lubricants

The role of the lubricant is threefold: to prevent direct contact between the roll and aluminium surfaces; to extract heat generated by friction and deformation; and to transport fines and debris from the roll bite area to the filter.

When formulating a rolling lubricant the load bearing capacity, cooling efficiency and ability to provide a clean annealed product must be considered and it is essential to ensure chemical stability to minimise changes during use.

Both rheological properties and composition have a significant impact on lubricant performance. Additives are critical to friction control, preventing problems of skidding or roll bite refusals caused by too low friction or poor surface quality caused by too high friction.

Hot Rolling

During the hot rolling process lubrication and thermal control of the work rolls are achieved by spraying oil-in-water emulsions onto the rolls in controlled patterns (Figure 1). The emulsion also removes any loose debris from the roll bite area and carries it to the filter where it is removed.

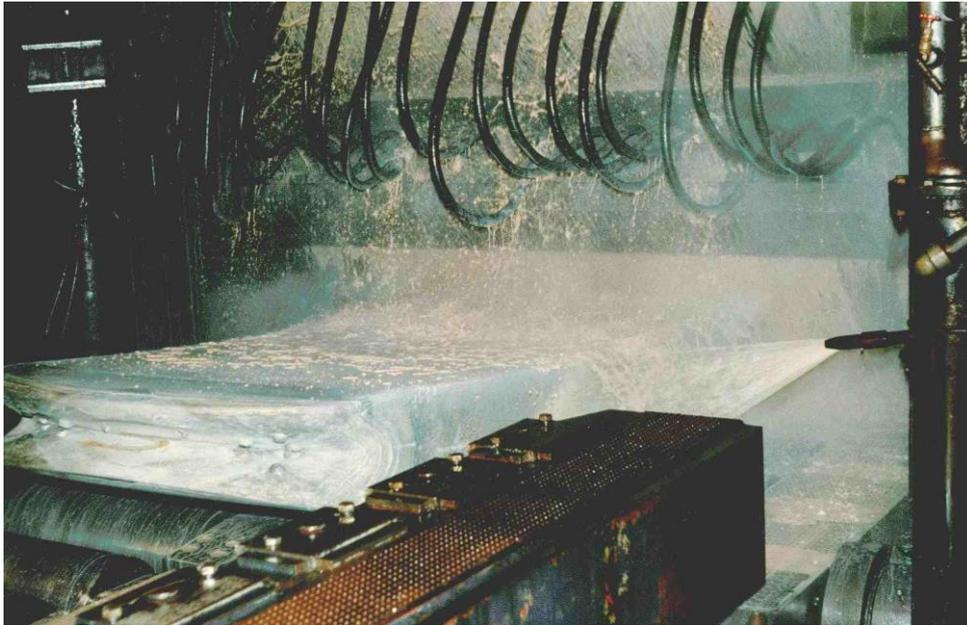


Figure 1 - View of typical hot rolling mill showing lubricant application

Emulsions are complex blends of base oil and additives, including lubricity improvers, antioxidants, emulsifiers and wetting agents. The formulation may also contain corrosion inhibitors, biocides and coupling agents that help provide stability during storage and assist the emulsification process.

Emulsifiers stabilise the surface of the oil droplets towards the continuous water phase: the two most common types of emulsifier used in hot rolling are anionic and non-ionic in nature. Anionic emulsifiers are principally metal or alkanolamine soaps, while non-ionic emulsifiers are ethylene oxide condensation reaction products. The polymerised ethylene oxide chain length determines the degree of water solubility and the amount of oil separated at the roll bite.

The additives are polar in nature which enables physical/chemical bonding onto the roll surface, providing load bearing and protecting the freshly generated aluminium surface. In general, increasing additive polarity provides more effective lubrication. Commonly used additives are organic acids and esters. Modest amounts of organic acids in formulations significantly affect the surface quality of the rolled sheet although, during use, they generate metal soaps that can influence emulsion stability. Esters are less reactive and relatively stable and are now extensively used in formulations. Some formulations contain extreme pressure additives that help

minimise surface defects caused by localised welding of the aluminium to the steel roll.

Consistent lubricant performance must be established and maintained to ensure effective cooling and protection of the freshly generated surface whilst minimising roll wear and avoiding slippage and refusals.

Cold & Foil Rolling

The majority of cold and foil rolling operations use oil-based lubricants, although some mill systems can accommodate water-based alternatives. The base oil represents more than 90% of the total lubricant volume and acts as a solvent for the load bearing additives and a roll-cooling medium. The base oil viscosity has a significant effect on the quantity of lubricant entering the roll bite and hence the rolling operation. A typical cold rolling mill lubrication system is shown in Figure 2.

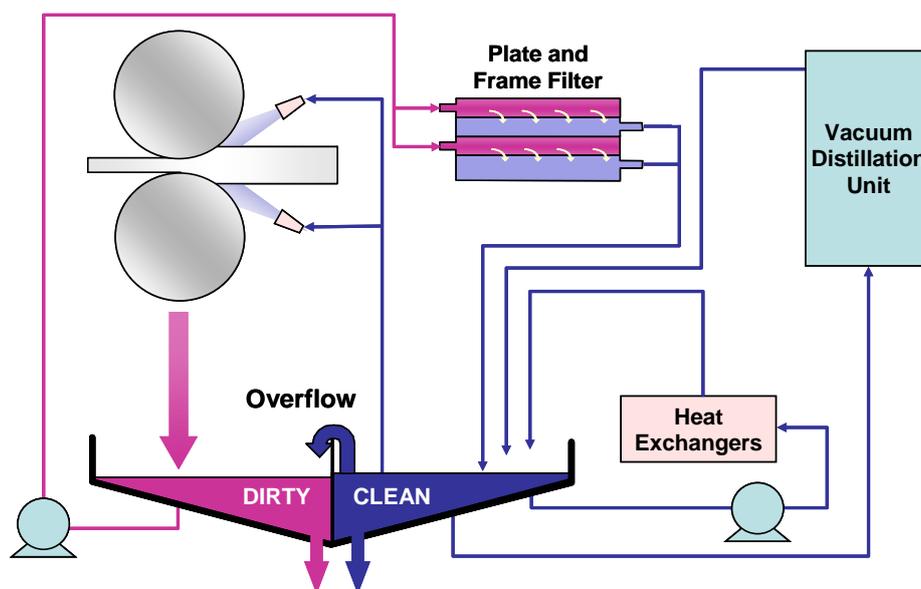


Figure 2 - Schematic diagram of cold mill lubrication system

Traditional cold rolling lubricants comprise a base oil, load bearing additives and anti-oxidants. The base oil must have a suitable viscosity for the mill duty and a narrow boiling range to minimise both evaporation during use and the risk of staining during annealing of the rolled strip. Refining processes help to ensure compliance with several American Food and Drug Administration standards and have the advantageous effects of increasing flash point and reducing odour.

Load bearing additives must provide the required level of load bearing capacity and frictional control whilst not producing staining during annealing. These additives are organic compounds which contain a polar functional group e.g. acids, alcohols and esters. The presence of these polar groups causes the molecules to be attracted and adsorbed onto metal surfaces. The adsorption process is greatly enhanced when

aluminium undergoes deformation due to the highly reactive freshly-formed aluminium surface. Typically, load-bearing additives are used at relatively low concentration levels.

Water-Based Cold Rolling

Water-based lubricants have several advantages over oil-based lubricants, including greater heat transfer properties, providing increased cooling of rolls, lower cost, non-flammability and reduced hydrocarbon emissions. However, the use of water increases the risk of surface staining, generation of metallic fines, and noise from the operation of containment systems. A larger lubricant volume and more elaborate filtration are required with water-based lubricants and there is also a reduced tolerance to process variations.

Mills that operate water-based lubrication use a combination of surface active components in the formulation and complex containment/shielding systems incorporating a combination of air wipes, vacuum removal and screens to eliminate water staining. Problems of water/strip contact increase as mills become wider and rolling speeds increase.

Water-based lubricant formulations include emulsions of oil-based formulations, solutions in which the load bearing additives are water soluble at room temperature but insoluble at roll bite temperatures and systems where the lubrication and cooling functions are separated by applying oil-based lubricant on the entry side and cooling water on the exit side of the mill.

Blends of polyoxyalkylene modified alkanolamines, with negative coefficients of solubility in water with temperature and phosphate esters that reduce surface staining are also commercially available.

Lubricant Maintenance

During use rolling lubricants become modified and contaminated in a number of ways:

- Evaporative loss of the more volatile components which raises the flash point, viscosity and initial boiling point.
- Aluminium and iron debris produced by frictional wear.
- Formation of metal soaps by the reaction of some load bearing additives with roll and strip surfaces.
- Oxidation and/or polymerisation due to exposure to high temperature and pressure.
- Contamination with other lubricants used on the mill causing increased viscosity, changes to frictional characteristics and the generation of surface staining.

To ensure lubricant performance is maintained and changes must be monitored and controlled. Some of the main parameters to be monitored are shown in Table 2.

| Monitoring Parameters | | |
|-----------------------|------------------|------------------------|
| Hot Rolling Emulsions | | Oil-based Cold Rolling |
| Oil Concentration | Emulsifier Level | Additive Level |
| Oil Phase Viscosity | pH | Soap Level |
| Additive Level | Tramp Oil | Viscosity |
| Soap Level | Bacteria | Ash Level |
| Emulsion Droplet Size | Biocide Level | Gum / Heavy Ends |

Table 2 - Rolling lubricant monitoring parameters

Rolling mill systems are designed to ensure the required volume of clean lubricant is supplied to the mill at the required temperature, pressure and flow rate.

There should always be clean lubricant available for supply to the mill under all conditions. As a result, the filtration system must be capable of filtering more than 100% of the flow to the mill and there should be a constant overflow from the clean to the dirty side of the lubricant tank. Lubricant temperature is controlled by heat exchangers and oil-based lubricants can be passed through a vacuum distillation unit for removal of contaminants (Figure 2).

Environmental Control

Mills are fitted with oil recovery systems to reduce the amount of lubricant lost to the environment via the mill exhaust system. Several types of recovery systems are available but the most efficient and widely used system is the counter-flow oil washing process.

Spraying oil-based lubricants at high velocity against the hot rolls of the mill generates oil vapour and fine droplets and is accompanied by the risk of fire (Figure 3). It is therefore essential that mills are fitted with fire control equipment and all operating personnel trained in its use. High capacity fume exhaust units prevent the build-up of potentially dangerous oil-air mixtures. Mill fire fighting equipment usually comprises carbon dioxide stored under pressure in gas bottles or at low pressure in bulk storage systems. Some mills have both high and low pressure equipment installed.

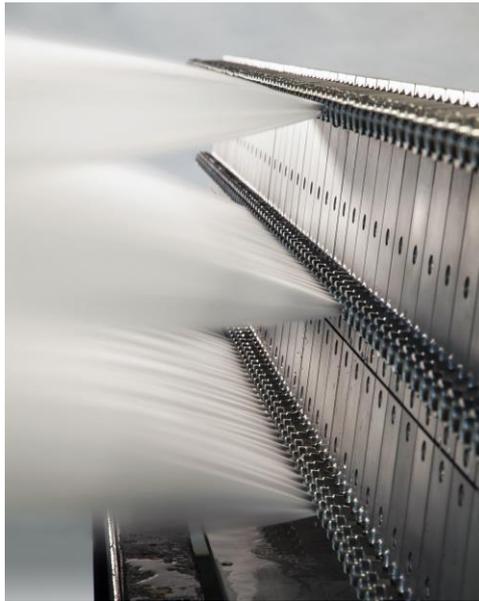


Figure 3 - Rolling mill coolant sprays (Courtesy of Lechler Ltd.)

A major advantage of using carbon dioxide to extinguish mill fires is that it does not interfere with the subsequent operation of the mill or contaminate the lubricant. After a fire has been extinguished, the carbon dioxide is replenished and the firefighting equipment reactivated. Any mechanical problem on the mill (possibly the cause of the fire) can be corrected and rolling recommenced.

Summary

The three main functions of a lubricant in aluminium rolling are: to prevent excessive contact between the rolls and aluminium surface; to remove heat generated by friction and deformation; and to carry fines and debris from the roll bite area to the filter.

The majority of hot rolling mills are lubricated and cooled by oil-in-water emulsions, whilst the majority of cold and foil rolling mills are lubricated and cooled by oil-based lubricants.

In hot rolling the major component of the emulsion is water, with less than 10% oil phase, whilst in cold and foil rolling the base oil is the major component, accounting for more than 90% of the total lubricant volume.

In all rolling lubricants the base oil functions as a solvent for the additive components which provide load bearing capacity and controls friction in the roll bite.

Lubricants must be adequately monitored and maintained to ensure optimum performance.