A FRESH LOOK AT ROLLING OILS IN THE METALWORKING INDUSTRY

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Introduction

The effective use of rolling oils in the metalworking industry is generally regarded as an art rather than a science. With variations in the quality of some of the raw materials used e.g. vegetable oils, it was often difficult to predict the performance of a product from one batch to another. However, with the increasing use of synthetically produced components and better understanding of the rolling process itself, more consistent and predictable results can now be obtained.

The development of improved rolling lubricants has always been difficult because of the problem of evaluating potential mill performance of new products in the laboratory. Full scale mill tests are very expensive and time consuming and cannot be attempted unless there is a very good chance of successful results being obtained. Without meaningful laboratory methods for assessing potential mill performance, revised formulations, possibly using new additive technology, are very difficult to evaluate. Limited data can often by generated by using a laboratory "Mini-Mill" but this cannot reproduce the environmental problems experienced on a full scale, working mill.

Let us first look at the basic rolling mill configurations which are used worldwide.

Rolling Mills

Metalworking has been carried out for thousands of years by casting, hammering, forging or various combinations of these operations. Development of manually operated mills and the use of water and steam power for driving the mills led to the increase in size of the rolling process and have resulted in todays modern electrically driven and computer controlled rolling mills.

The first mills used two cylindrical work rolls and were designated 2 - High mills. At first they were unidirectional but later were made reversible by the use of DC motors. (fig 1)

The demand for a wide variety of ferrous and non ferrous materials to be rolled required the mills to have improved rigidity to successfully produce the desired end product. The 3 - High mill was the first answer to this situation followed by the use of large diameter backup rolls and a small centre roll. This was easy to utilise as a reversing mill since it was possible to alternate between the upper and lower roll bite dependent upon direction. The requirement for more stiffness in the mill then led to the development of 4 - High mills in which two relatively small work rolls are each backed up by relatively large diameter backup rolls.

The ultimate in rigidity led to the development of the Cluster mill, more commonly called 'Z' mills or 'Sendzimir' mills , where a cluster of intermediate and larger size backup rolls support each small workup roll. The Cluster mill arrangement also incorporates some horizontal support for the work roll and is most useful when very small work roll diameters are necessary or when wide mill widths are required. Such mills are frequently used for rolling stainless steel, or more exotic materials such as titanium.

A demand for higher productivity and improved surface qualities led to the development of the tandem mill which consists purely and simply of several stands normally 3, 4, 5 or 6 in tandem having the configuration of two large diameter backup rolls and two somewhat smaller work rolls. These units are very popular today and can produce widths up to 2 metres with speeds of 2,200 metres/min and a minimum thickness of 0.15mm.

Strip rolling is performed by passing the steel through one or more pairs of rolls until the required reduction and final thickness has been achieved.

Under working conditions the mill rolls are cylindrical normally, the work rolls being driven and the backup rolls rotating by friction. It is generally accepted that a decrease in diameter of the work roll results in bigger possible reductions. Surface finish of the work roll is particularly important and can noticeably alter the co-efficient of friction. Normally the smoother the rolls the lower the co-efficient of friction. The other factor tied in with work roll diameter is surface roughness which will reflect in the co-efficient of friction in the bite angle.

The rolling pressures required to provide thickness reductions in the strip cause elastic distortion of the rolls and to counteract this effect most rolls are slightly cambered. This can apply to backups and work rolls. By reducing the roll load necessary for a given reduction , rolling oils reduce the degree of camber required. Also by varying the distribution and the amount of roll coolant, the effective shape of the rolls can be firmly controlled during rolling; this method is utilised to obtain good shape when different gauges and types of material are being handled in one mill, or to correct the effect of variations in hardness and gauge.

Rolling Friction

The basic function of a rolling oil is to provide controlled friction at the roll contact points. It should reduce friction to an acceptable level which will prevent metal to metal contact and prevent any welding tendency or pickup. Where the material to be rolled enters the roll bite the roll speed is greater than the strip speed. This differential is known as backward slip, the speed differential decreases as strip progresses further into the roll bite. A point is reached in the roll bite where the strip speed and the roll speed are equivalent, the backward slip being zero. This point has been named the neutral point. The area of contact from the entry point is called the entry plane. (fig 2)

Under most conditions the roll strip leaves the work rolls at a speed slightly higher than the roll speed. This difference is termed forward slip. The speed differential increases from the neutral point to the point of exit, this area of contact between the neutral point and the exit point is termed the exit plane.

The position of a neutral point is influenced by the values of the applied forces and backward tensions. The specific roll force is described as the rolling force required per unit width of strip and its size depends upon the following parameters:

1. Incoming strip thickness
2. Drafting on the mill
3. Forward and backward tensions
4. Compressive yield strength of the strip
5. Elastic modulus of the rolls
6. Co-efficient of friction in the roll bite

In additon to controlling the friction, rolling oils must contribute to the following general requirements.

1. Leave no undersirable stain after annealing
2. Avoidance of pickup and other surface defects
3. Controlled surface finish
4. Efficient cooling
5. Reduction of roll wear
6. Protection of the steel against corrosion during and after rolling
7. Compatibility with the equipment and materials

Hot Rolling Lubricants

Cold rolling mills began using rolling lubricants extensively in the early 1930s, but research into their behavior was not undertaken to any significant extent until the late 1940s. One of the major benefits found in the early use of lubricants in cold rolling mills was that increased rolling speeds were possible, and, therefore, increased productivity resulted.

As a result of the productivity increases in cold rolling, some mills placed their attention upon increasing productivity of hot strip mills by the same method, i.e., using rolling lubricants rather than adding new facilities. These efforts, along with a natural thought process of using lubricants whenever the need arose to reduce friction and wear, were instrumental in introducing lubricant usage into all hot rolling processes, both flat and shape. The development of Hot Rolling Lubricants usage paralleled that of lubricants in general, i.e. first lubricants were animal and vegetable fats, then petroleum, and lastly new synthetic blends. The major benefits stated for HRL usage, i.e., reduced friction, reduced roll wear, increased productivity and increased formability , have been expanded to include reduced rolling loads, improved product surface, improved shape control, improved production scheduling, reduced scale formation, and reduced production costs.

A general description of HRL, or any lubricants, is any substance capable of reducing friction, heat, and wear when introduced as a film between solid surfaces. It has been shown that even water or scale can act as an HRL in the hot rolling of steel. However, these compounds are not very effective in practical usage, and in the example of scale, can have a harmful effect on the surfaces of both the rolls and the steel.

Classification of these lubricants varies from the simple, solid, liquid, grease, to lengthy, complex products. For the purpose of this discussion a compromise of these classifications can be expressed as:

1. Petroleum oils
2. Fatty oils
3. Solids and suspended solids
4. Synthetic esters
5. Soaps, pastes, and waxes
6. Blends

In all application systems involving liquids, the HRL are used under pressure, either pneumatic or pump. Application sites of all HRL are usually on the backup and /or work rolls, rarely on the metal piece. HRL have been delivered in a neat, emulsion, water-dispersion, or an emulsion/steam dispersion form. The HRL are applied onto the rolls directly or indirectly via the roll cooling water. Several types of methods are used to aid in control of HRL delivery onto the rolls, such as wipers, felt pads, or rollers. Complete HRL systems, can range from very simple to complex installations and the concentration of HRL in percent by volume varies over a wide range, i.e. 0.005-15 percent on production hot mills .

The evaluation of Hot Roll Lubricants is a difficult task and is best carried out on a laboratory hot rolling mill. Once adopted in a full scale mill, its effectiveness can be influenced by application methods, plant design, and general plant standards in health, safety and pollution.

However the benefits such as reduced roll wear, reduced friction and improved surface finish are of considerable benefit. Measurable savings in energy can also be made due to the reduction in slab temperature of the steel supplied to the mill, while maintaining the same force and horsepower level.

The effect is to reduce the furnace fuel requirements by about 9%. In the US, this saving equates to 3½ million barrels of oil each year - a significant saving. (fig 3)

Cold Rolling Lubricants

The market for cold rolled steel has changed drastically over the past few years due to world over-capacity and increased competition amongst the major steel producing countries. Since the car industry is probably the largest consumer of cold rolled sheet, this has had a marked influence on steel making techniques to cope with the need for thinner, lighter gauge sheet with better durability to meet new standards of corrosion warrantees. With the introduction of high strength, low alloy steels which can be produced by the continuous casting process together with chrome-alloy work rolls, these combinations have initiated the development of many new types of rolling oils. Particularly of the oil/water emulsion type.

A rolling oil will generally be blended from some or all of these following components.

A. Carrier/Film former
B. Lubricity additives
C. Emulsifiers
D. Antioxidants

The bulk of the product and the carrier is normally a mineral oil, ester or a blend. Mineral oils were traditionally used because they were cheap but have little to offer in the high speed rolling operations of the present.

Mineral oil molecules adhere very loosely to steel surfaces and therefore are unable to withstand the shearing stresses produced during rolling. They are only used as diluents for better lubricants or for the rolling of thicker sheet products on operations where the frictional requirements are not severe.

Much work has been done to standardise the oil particle size in oil in water emulsions. Conventional products have an oil particle size of 2μ to 35μ. These larger particles eventually coalesce to become free oil and quickly reduce rolling efficiency.

Newly developed products have the ability to provide standardised droplets of around 15μ and which remain very stable for long periods.

The emulsifier is probably the most important constituent of a rolling oil since it can determine the following: -

(a) Speed of plating
(b) Amount of plated oil
(c) Adhesion performance of plated oil

It has already been suggested that it is the quantity of the adhered oil which determines the hydrodynamic film thickness, important at higher speeds.

Balancing the emulsifier system, to obtain the desired results, is still very much an art based on science. The reason for this is probably the variable and random raw materials which must be utilised, for commercial reasons, rather than pure chemicals. The types available are multitude and potential combinations too numerous to enlarge upon here. (fig 4)

Biocides are not widely used since the temperature of operation (normally 45-60°C) is sufficient to inhibit their growth and expansion. Small amounts, for bacteriostatic purposes, of a broad spectrum type may be added. If there is a serious problem, identification of the microbes followed by external treatment of an efficient biocide is recommended. In this application GLUTARALDEHYDE, a recent innovation in the metalworking industry, may be particularly effective. Bacterial action and their by-products could totally destroy the efficiency of a rolling emulsion.

Rolling Oils for Sendzimir Mills

Sendzimir Mills offer a high degree of precision in rolling ferrous and non-ferrous materials. They are frequently used for the production of stainless steels and here, mineral type rolling oils are preferred as they provide better surface brightness after annealing compared with soluble types. In addition, they should also have good oxidation stability for long life and have a viscosity of 12.0 - 17.0 cSt @ 40°C. The relatively low viscosity also assists cold startability as the rolling oil is frequently used to lubricate roll bearings also.

More emphasis has recently been placed on the selection of the base oil to be used and Hydro-finished and Hydro cracked base oils are often selected for their particular distillation range.

Here it is interesting to note that Japanese requirements for rolling oils on similar mills are frequently different from those of the US or Europe although the quality of the rolled product is very similar.

Conclusion

The science of Rolling Oils is becoming a very complex subject requiring much effort to apply it successfully to modern rolling mill applications. At the some time, the metalworking industry continues to research on improved materials and rolling techniques, all of the which put extra demands on the rolling oil supplier.

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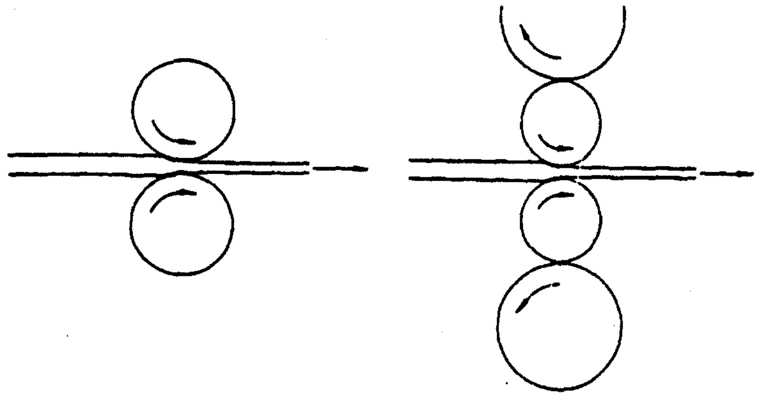
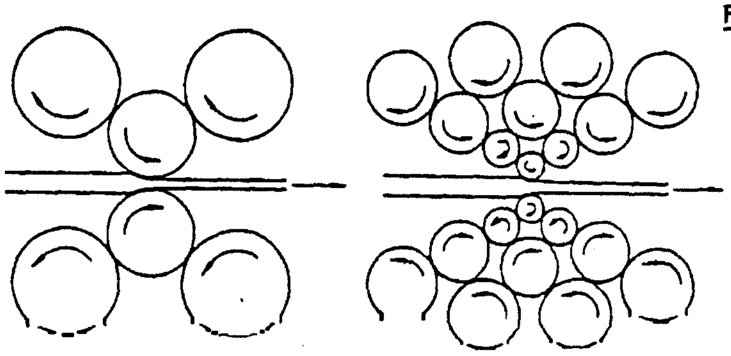


2-HIGH ROLLING MILL

4-HIGH ROLLING MILL

Figure no. 1



6-ROLL CLUSTER MILL

20-ROLL SENDZIMIR MILL

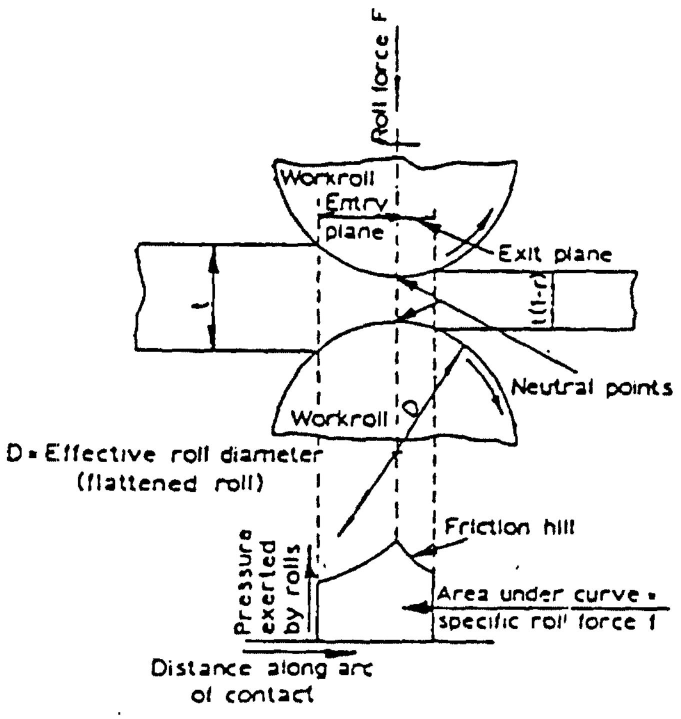


Figure no. 2

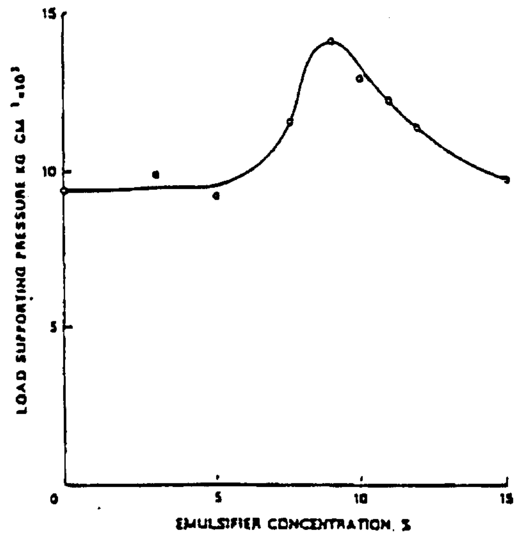


Figure no.3

Effect of emulsifier content on load-carrying properties of a soluble cold roll oil

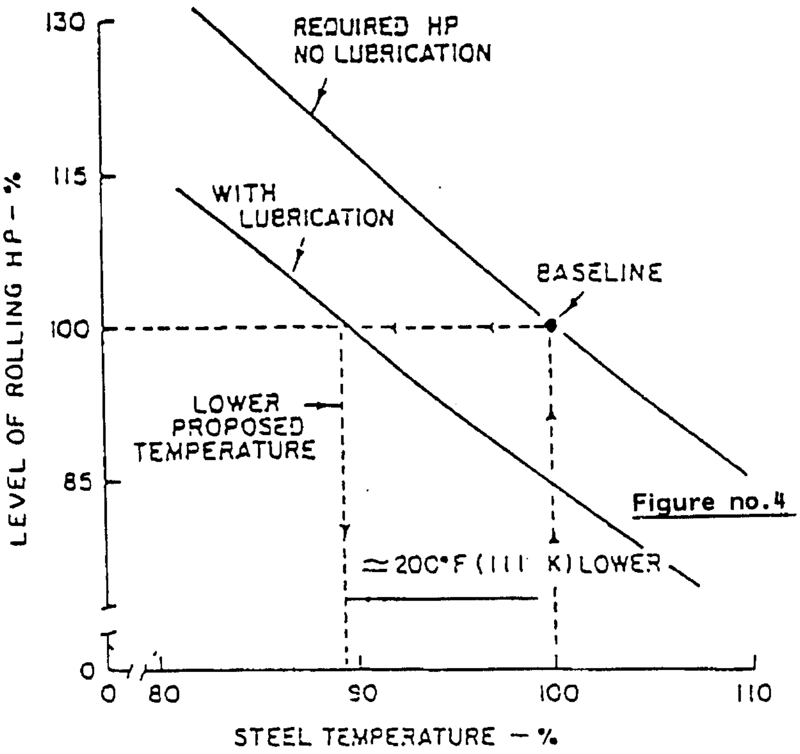


Figure no.4

-Relative effect of steel temperature on rolling horsepower with and without roll lubrication.