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A Tribological Study of Effect of Lubricants and Lubrication Mechanisms in Rolling Process: A Review

Rahul Kumar Jain[1,2*], Ranganath M Singari[1], and R.C. Singh[1]

[1]Delhi Technological University, Delhi-110042, India, [2]GB Pant Institute of Technology, Okhla, Delhi-110020, India

*Email: rahul_jain_1980@yahoo.co.in

ABSTRACT: Rolling process had been used in every aspect of our life. Various type of section like tee, angle, channel, railway track, sheets, foils of different mate-rial are made by rolling process. Quality of product depends upon the various characteristics of rolling parameters. At the junction, key role played by lubricants for saving of energy and properties of material in contact. Re-searchers are putting continuous efforts for the tribological analysis and developing new lubricants for the rolling process according to the material. The authors had reviewed the lubricants used in different rolling processes and found out diverse range of lubricants. Various ecologically safe and effective lubricants had been reviewed. Lubrication performance testing tri-bometer for testing of tribological properties of lubricants had been re-viewed. Hydrodynamic, mixed and boundary lubrication mechanism had been found in different rolling conditions. Use of lubricants were found helpful in reducing power consumption in rolling and good quality prod-ucts, hence the cost..

Keywords: Lubricant, Ecofriendly lubricant, Tribometer, Lubrication mechanism.

I INTRODUCTION

The rolling process is a very ancient process. Small hand-driven rolling mills were in use even as early as the fifteenth century [27]. After the development of the steam engine, the practice of metal rolling assumed the huge industry shape. Today 70% of the product made by rolling or these are the feed product for other manufacturing industry.

Basically, in rolling process a sheet is rolled between two rolls and material is deformed. The tribological properties like lubrication, wear, friction is very important for economic and close dimensional products by the rolling process. Rolling lubricants play an important role in the rolling process for higher productivity and good surface quality. These may be used either in neat or with emulsion in water or oil. Main function of rolling lubricants is control of wear, friction, cooling and to flow out the debris.

The lubricating requirement of a rolling lubricant is to control the friction and wear in the contact zone between the rolls and the workpiece as new metal surface is generated. It must also function with robustness and consistency with the mill operating at high production rates. In this paper different type of mineral and environment friendly lubricants used in rolling process of different materials had been overviewed. Presence of different type of lubrication mechanism and different lubrication test also studied.

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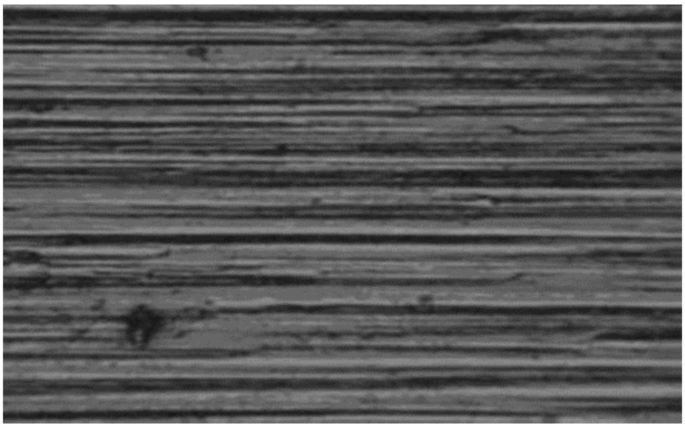
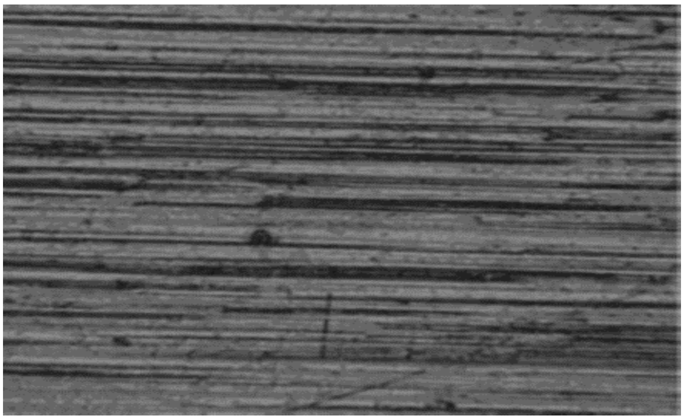
III LITERATURE REVIEW

Liu nana et al. [1] had experimented on Cu foil rolling with o/w emulsion with different oil concentration and dry and found that better surface produced at 0.02-0.05% concentration than dry rolling (see fig.1.). rolling oil with viscosity of 40- 50 mm^2/s provided better lubrication and cooling effect.



(a)



(b)

Fig.1. Surface topographies of copper foil after rolling: (a) no lubrication, (b) initial oil concentration= 0.02%,[1]

Lenard and Zhang [2] Studied lubricant mechanism with different SAE oil and observed that at low speed it was boundary lubrication regime and at higher speeds it was mixed lubrication mechanism with lighter oils. In heavier oils it was hydrodynamics lubrication regime.

McConnell and Lenard [3] found experimented with different lubricants on low carbon steel strips and observed the lubricants with synthetic hydrocarbon were better as these produced the lowest roll forces, roll torques and the lowest coefficient of friction. At most, boundary or mixed lubrication regimes were observed.

Nonaqueous mineral oil were used as the base oil with a few percent of higher alcohol or fatty acid ester as boundary lubricant by S. Kondo [4]in cold rolling of aluminum alloys. Low viscosity oil was found better and fatty acid ester provided better rolling stability.

Lu and Chuang [5] studied the effect of surface roughness on lubrication. experiment Better lubrication condition were found in initial strip transverse roughness.
The roll loads and roughness of rolled strip reduced when lubricants including water, neat oils / emulsion, were used in rolling than the dry condition in cold rolling of low carbon steel [6].
At high speed of Aluminum strip rolling higher concentration of emulsion were better than the neat oil as surface quality was better [7].
Paraffinic oil with additives (4-5%) were used in cold rolling of Aluminum Alloy 3003 by Gjonnes for investigation of surface topography after rolling [8].
Liu et al. [9] done strip drawing test with three lubricant mineral oil without additive, mineral oil with additive of Sulphur and phosphorous and water-oil lubricant with additives of Sulphur and phosphorus active substances. Coefficient of friction reduced in the lubricant with additives.
Three lubricants denoted by “no additive”, “additive sulfurized castor oil (SCO) 2%” and “additive borate ester containing nitrogen (BECN) 2%” with base oil i.e. mixture of 35% mineral oil, 25 % coconut oil were tested by a four-ball tribo-tester as per Standard ASTM D2783 and on two high rolling mill in cold rolling of steel strip. Alkylphenol ethoxylates were used as emulsifier by Sun et al. [10]. It was observed that both the test provided the consistence results but coefficient of friction was more realistic in cold rolling setup.
Sun et al. studied the effect of ferrous particles on the tribological properties of 4% commercial lubricant emulsion with deionized water in cold rolling of IF steel. Load carrying capacity of the lubricant increased up to 3.9 % when was size of ferrous particles were equal or less than 0.3 micrometer[11].
Effect of lubricant viscosity on rolling mill load was analyzed by Dick and Lenard on rolling of ASTM A366 steel. Three type of emulsion, 10% Kutwell-40 in H_2O ,10% Walzoel FM 82, 5% Petronate HLB in H_2O and 10% oil FSG M3, 5% Petronate HLB in H_2O were used. The effect of the viscosity was apparent at higher velocities and reductions but was negligible at lower speeds and lower reductions [12]
Rolling load were reduced after using lubricants as analyzed by Nad and Lenard [13]
The effect of boundary additives was investigated by Lenard on the rolling parameter in rolling of aluminum strip. Mineral oil was used as basic oil and lauryl alcohol, stearyl alcohol, lauric acid and stearic acid were used as additives. Lauryl alcohol caused the largest reduction of the roll separating force while stearyl alcohol was the most effective in reducing the roll torque. The coefficient of friction reduced most when lauryl alcohol was used [14].
A lubricant was developed by Tang et al. by using an industrial white oil as the base oil, for cold rolling of zirconium alloy. Anti-wear agent, anti-foam agent, additives, antioxidants, detergents and dispersant were added. The lubricant was tested for physical, chemical properties, and characteristic of lubrication and found meeting with requirement of cold rolling of the alloy [15].
Tribological performances of an emulsion with four different concentrations of an emulsifier were studied. The tribological properties, including the friction coefficient, the electrical contact resistance, the wear loss was examined with different concentrations of emulsifier. The emulsion with a dilute ratio of 50:1 was found most favorable of the four emulsifier concentrations because it leads to the lowest friction coefficient, the smallest wear loss and the worn surface [16].
Pin on disc tribometer was used for investigation of effects of sliding speed and lubrication on the tribological behavior of stainless steel analogous to steel rolling with sunflower oil as lubricants and phosphorous as extreme pressure additives. When lubricants were applied, friction was reduced, and stability of sliding process improved that leaded to the stainless-steel surface quality. Hydrodynamic effect also observed. Lubricant additives, oil film improver and extreme pressure improved the performance of pure base oil and reduce the wear rate of the stainless steel [17].
Chun and Lenard [18] studied synthetic ester-based lubricants with different emulsion concentration in hot rolling of Aluminum 1100 H14 strips. Coefficient of friction reduced when the concentration of emulsion increased. Hydrodynamic lubrication regime was approached in the process. Surface were found better as emulsion concentration increased.
Polybutene based low viscosity, paraffin oil emulsions were used in rolling of Aluminum 1100 H14. Emulsion were prepared by stirring using Poly oxyethylene laurel alcohol as emulsifier [19].
Volatile lubricants given the same performance as the paraffinic mineral oil in rolling of mild steel sheet and Aluminum A3004 [20].
Colza based emulsion, synthetic ester and mineral oils were evaluated for lubrication behavior in hot rolling with simulation on testing machine [21].

Shirizly and Lenard [22] studied the effect of lubricant on rolling mill loads, testes were done with five different conditions involved dry rolling, distilled water. Oil emulsion and a forging oil in hot rolling of low carbon steel strips. Sufficient reduction in mill load and improved surface quality was observed when oil in water emulsion were used. 1: 1000 oil-in-water emulsion concentration was found the best.
Nano lubricants (TiO_2) with 4% concentration were evaluated in hot rolling of steel sheets. These lubricants were effective in reducing the mill load and improving the surface quality of strips [23].
Dandan et al. [24] had reported that Palm oil had been used as lubricants by many researchers in metal forming.
Neem seed oil performed better in the experimental study of cold rolling of Aluminum strips than the coconut and diesel oil mixture [25].
Coconut oil showed the increased tribological and rheological properties when Cuo and Sio_2 nano particles were used as additives [26].
Last non seizure load (LNSL value) of the emulsions was measured by four-ball tribo-tester, following the standard GB/T12583- 1998 [1].

III CONCLUSION

It can be concluded that rolling lubricants played an important role in rolling of metal. Presence of emulsion and lubricants between the roll and strips reduced coefficient of friction, therefore longer roll life, better surface quality of strips and it also reduced power consumption. As additive and emulsifier affected the rolling parameters so analysis for levels of boundary additives through spectroscopic and chromatographic techniques, and, for emulsions, monitoring of pH and conductivity of the water phase along with concentration and particle size measurements for the oil phase is necessary. The appearance and performance of the finished product was influenced by the amount and nature of residual lubricants on the metal surface. Mostly mineral oils had been in use in rolling lubricant but recently, there has been increased emphasis on products where the petroleum oil content has been replaced by products from renewable resources, from selected crops such as palm, coconut, soybean oil, sunflower. Vegetable oils had some challenges like oxidation stability but researches are going on to use them with some additives. It will be very beneficial for environment as well as rural areas. Products high in oleic content and low in linoleic and linolenic content would seem to afford the best compromise. Various lubricant mechanism like boundary, mixed and hydrodynamic mechanism has been observed during rolling in deformation zone as the rolling condition changed. Four ball tester and pin on disc are the type of tribometer which has been used in analyzing the tribological performance of lubricants.

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