A Combined Effect of Elasto-Plasto Hydrodynamic Lubrication in Cold Strip Rolling

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Abstract

The aim of this study is to analysis the behavior of lubricants in cold strip rolling. An elastohydrodynamic lubrication analysis which takes account of elastic deformation of the roller while the metal strip deform plastically ,so that a relation between the E.H.L and plastohydrodynamic is used to determine the lubricant film thickness which will entrained in metal rolling operation .The viscosity variation and the variation between the pressure gradient and the speed of the roller with lubricant which is Newtonian up to some critical shear stress and thereafter behaves plastically is derived.The results are compared with the experimental one ,which shows good agreement with it.

Index terms— Elastohydrodynamic, plastohydrodynamic, cold rolling, viscosity variation

1 INTRODUCTION

n the lubrication of cold metal forming such as rolling drawing, and extrusion, lubricant films are entrained by wedge action in nominally steady processes. The pressure of the film thickness can vary from atmospheric to the order of yield stress of the work piece.

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In cold rolling as strip is reduced and elongated it changes speed relative to roll speed and must slide against the roll surfaces .The resultant friction produces forces ,which tend to retain the strip in the roll bite ,roll force and torque increasing with increase in friction. A decreases in (?), the coefficient of friction, is thus desirable to reduce power consumption and roll loads and to obtain increased strip reduction. The latter is of particular importance in the rolling of thin plate where the high loads required because considerable roll flattening. This increases frictional forces until a point is reached at which no further reduction of the strip can occur. Further increase in load merely cause further roll flattening. If (?) could be reduced by improved lubrication, the value of this limiting reduction would be increased enabling thinner strip to be rolled.

consequently the roll gap will increase during the rolling, as well as being increased slightly by the elastic roll-flattening already exist under very high loading and the mill "spring back", which is the deformation will be elastic-plastic of the mill, it is an important factor which must be taken into account when setting the roll gap for a given pass .Some reheological model was used by (Grubin and Vinogradova, [9] and Dowson and Higginson, [6] such as the ones used in elastohydrodynamic lubrication **??**Cheng,[4], (Wilson and Walowit, [13] in their plasto-hydrodynamic analysis of the strip rolling,(Aggarwal and Wilson, [1], [2] solved numerically the equations which includes the permissible velocity profiles against various relevant flow.Their results can provide neither the local variation of flow properties nor the global behavior in any real metal forming lubrication since the continuity equation has not been incorporated in their analysis. (Yuan and Chern, [14] developed a theoretical hydrodynamic lubrication analysis which takes account of temperature dependent viscosity variation along as well as across the film thickness. (Kuniaki and zhrgaug, [8] carried out a series of experiments using a rolling type tirbo meter to investigate the frictional dependence on the average velocity of the lubricant V at the contact zone inlet and the relative sliding velocity Î?"V between the roll and the work piece during deformation .

In this research undertake to gain further knowledge of the mechanism of lubrication in the roll gap by taking a model of lubricant entrainment under very high pressure using E.H.L. theory with the effect of elasto-plastic behavior of metal rolling strip which From equilibrium considerations the local velocity (u) is given by:-) 2 (1 2 1 2 c z c x p z u + ? ? ? = µ ???.(**1**)

The values of 1 c and 2 c could be obtained by taking (z=0),(u= 1 u) and(z=h),(u= 2 u). Then eq. (1) becomes:-) (2 /) (2 2 1 2 1 h z x p h z u u u u ? ? ? + ? + = µ ????.(2)

The volume flow rate per unit width (Q) is given by :-? ? = h z u Q 0 ????..(3)

Substituting eq.(**??**) into (3) gives :-Q h u dx dp h ? = . 12 _3 µ ?????(4)

Where:2 /) (2 1 _u u u + = e p ? µ µ 0 = 2.

The film thickness of the lubricant in eq.(**??**) can be represented as :

h total = h (elastic of the roller) + h (elastic-plastic deformation of the strip) ....(**??**)

h (elastic of the roller) could be delivered from E.H.L. theory :- (6) note that in eq.(**??**) we have just the elastic deformation of one surface roller.? ? ? = ds s x s p E R x h elastic .) ln( ) (1 2 2 2 ? ?????..

h (elastic-plastic deformation) could be obtained as :-p e ij d ij d ij d) ( ) (? + ? = ? ???????.(7) where ? ? ? ? d d kk ij ij e E G ij d) 2 1 (2) (? + ? = ? ????.(8)

?ij'=deviatric stress G= modulus of rigidity E= young modulus ? =poisons ratio ?ij d?kk= the component of mean stresses Also the plastic strain is:-? ? d ij p dQ d ij d = ?) (?????.(9)

Where d?=proportionality constant termed the plastic multiplier. (10) So that it can be seen that the total elasticplastic strain for the strip is:= ? ?? ij Q Plastic potential flow rate after yielding =?ij' ? ?) (ij d p ij d = ? ? ??????../) 2 1 (2 ? ? ? ? ? ? ? ij kk ij ij d E G ij d d d + ? + = ? ???.(11) Where d?ij = hi i h) (?

for the deformation of the strip.

Knowing that the value of d? are variable for each element which is dependent on the strip flow rate Q and can be obtained as in the numerical method. **??**6)

2 III.

3 THEORETICAL SOLUTION

and then we return to step (2) to find new h(i).

IV.

4 NUMERICAL METHOD

The multilevel technique which have been used by (Lubrecht, Tennapel and Bosma, [10], (Conry and Cusano, [5], (Venner and Tennapel, **??**12] is used in solving this problem by dividing the work zone into 120 nodes with equal mesh size (Î?") where (Î?") = ?(i+1) -?i .This mesh size is used in discretization of Reynolds equation. The elastic film thickness is discredited as : where:(hi) elastic =) . 1 ( ) 2 (k(i,j) = (i -j + 1/2)Î?"(ln| i -j + ½ Î?") -1 -(i -j -½)Î?"(ln|i -j -1/2|.Î?") -1)

5 Mixed hardening

To cope with the directional change of friction at the neutral point (or region), the relative velocity Î?" v of the roll to the strip (see Fig. 1) is approximated by: fig (1) : shows the strip rolling with lubrication])) ( ) ( ) ( ) [(2 1 (2 1 2 1 2 2 + + + + + = ? h h h h V U V U v h h h R u U ? ? sin + = h h h R v V ? ? cos ? = 1 1 1 sin + + + + = h h h R u U ? ? 1 1 1 cos + + + ? = h h h R v V

? ? so that the direction of the frictional shear stress need not prescribed , because the relative velocity Î?"v is always positive over the roll surface and the position of the neutral point (or region) is determined as a result of minimization of the functional.

The hardening behavior of most materials seems to be a combination of both isotropic and kinematics type of hardening .Sanda c.t, [11] used in his paper the effect of mixed hardening results in a modification of the yield surface which is written as :f(0) ( ) = ? ? ? ? ? ? y b ij ij ???..(18)

The terms and dk are respectively obtained by assuming a kinematics hardening law. For eq (11) it can be immediately written as :[ ] ? ? ? d df d d D d + ?= ? . 1 ?????(19)

where D is the usual matrix of elastic constants ? = = xy zx yz z y x ij T f f f f f f d df a ? ? ? ? ? ? ?

,A=H which is the hardness function of the strip material.

V.

6 RESULTS AND DISCUSSION

In Fig. **??**3-a) shows the distribution of the pressure along the contact zone for (14%) percent reduction of steel strip using oil H (see table **??**), ? = 1.64 m/s , h = 5.75 mm, R = 0.14 m, t/?1 = 0.024.In this figure there will be a comparison between theoretical and experimental result (done by **??**ow ,Kannel , and Bupava, 1975) which show some agreement between them . The elastic strain of the elasto-plastic material causes in the entering a decrease in the pressure and the stresses can be felt downstream a distance related to the relaxation time of the material and the velocity Î?"v while in the next region in the work zone before reaching the neutral point the value of Î?"v will be decreased and the plastic deformation begin causes very high pressure and the elastic deformation of the roller which introduced in the E.H.L. equations gives the fluctuating of the pressure in this zone . After the neutral point to the exit region the pressure will be dropped to some value and then returned to increase and this is because Î?"v will be increased also causes the elastic part of the metal strip decreases the pressure roll.

In Fig **??**3-b) shows the variation of film thickness along the contact zone. In the region between(8-11)* m the film thickness increased with decreasing in the pressure then it full very rabidly with increasing the pressure and then increased after the neutral point and then decreases.

The agreement between the practical and theoretical results is more pronounced in Fig . **??**4-a) which could be shown that at high reduction (30 percent) of steel strip by using oil c give a decrease in the pressure at point (30* m) and a sudden increases in the film thickness as shown in Fig (**??**-b) . This mean that at high reduction the using of elasto-plastic model with E.H.L. condition affect the pressure distribution and give more accurate results. **??**) it shows the relationship between the coefficient of friction and the speed of rolling at high reduction (30 percent) by using oil H and C. The coefficient of friction decreases with increasing the roll speed for values between 17-19 m/min and then will increased. This is because the effect of the relative speed on the pressure distribution and then on the viscosity of the lubricant in the contact zone.

VI.

7 CONCLUSIONS

1. The aim of this research is to used the E.H.D lubrication with plastohydrodynamic of cold sheet rolling for determining the effect of lubrication on the pressure distribution and film thickness along the contacts zone .

2. The varaiation of the relative velocity ?v that have been calculated along the contact region give the position of the neutral point which variuas with the percent reduction of the strip and the viscosity of the oil . 3. The results shows that for heavy viscosity and low percent reduction of strip , the pressure distribution and film thickness along the contact region will be agreement with an experimental one for plastohydrodynamic lubrication while for high reduction and low viscosity the mixed theory of E.H.L and plasto-hydrodynamic lubrication be more accurate . 4. The effect of speed of the roller with lubricant on the coefficient of friction and then on the critical shear stress under plastic deformation of the strip have been investigated . [1] [2] [3]

Figure 1:

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.1 VII (A)

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