Computing of Lubricant Film Thickness in Cold Rolling Process

Sadiq Muhsin Ihmood

Mechanical Engineering Department

College of Engineering
Thi-Qar University
sadiqmuhsin@yahoo.com

Abstract

The aim of this work is to study the effect of the following parameters :reduction in thickness , length of contact, rolling radius, viscosity of lubricant oil, and roll speed on the lubricant film thickness which are pointed to as an independent variables. In order to illustrate the effect of these parameters, three types of lubricants ,A(Commercial rolling oil, known as Roll oil 981), B (Forming cutting oil called Exx cut 225, with additive) and C (Forming cutting oil called Exx cut 225). Were selected also three values for roll radius (55,65,and 75 mm), with three values for roll velocities (0.5, 1, and 1.5 m/s), and finally five values for reduction in thickness (75, 80, 85, 90, and 95%) were examined to cover all inquires in this work.

The study shown that an increase in roll radius leads to increase in lubricant film thickness . At high reduction, the lubricant film thickness becomes very small, and requires the use of high viscosity lubricant.

Keywords : Cold rolling ; lubricant film thickness**.**

حساب سمك طبقة سائل التزييت في عملية الدرفلة على البارد

المستخلص

الهدف من هذا البحث هو لدراسة تأثير المتغيرات الاتية : التخفيض في السمك, طول التلامس, نصف قطر الدرفيل, لزوجة سائل التزييت, وسرعة الدرفيل على سمك طبقة سائل التزييت والتي يشار إليها بأنها عوامل غير معتمدة.ولكي نوضح تأثير هذه المتغيرات, تم اخذ ثلاثة أنواع من سوائل التزييت (Roll oil 981), (Exx cut 225, with additive) و (Exx cut 225), كذلك ثلاث قيم من نصف قطر الدرفيل(55,65, 75 mm), مع ثلاث قيم من سرعة الدرفيل (0.5, 1, 1.5 m/s). و خمسة قيم من التخفيض بالسمك تم اختيارها لتغطية كل التساؤلات في هذا البحث.

بينت هذه الدراسة أن الزيادة في نصف قطر الدرفيل ستؤدي بالضرورة الى زيادة سمك طبقة سائل التزييت و عند نسب التخفيض العالية جدا فإن سمك طبقة سائل التزييت يصبح صغير جداً وهذا يستلزم استخدام سائل تزييت ذا لزوجة عالية.

1. Introduction

In cold rolling process, the role of lubricant is to reduce the friction coefficient, guarantee the surface quality of products, and increase the tool life.Zhrgang et al[1] have carried out a series of experiments by using a rolling type tribometer to investigate the lubricity of the volatile lubricants at high speed forming. Experimental results show that the friction coefficient decreases with increasing working velocity for both SPCE and A3004, in any lubricant. With an increase of reduction in thickness the friction coefficient decreases for SPCEbt and increases for A3004.

Saxena[2]showed that the film thickness increases with an increase in R/h (roll radius to the strip thickness at the inlet ratio) .Zhrgang et al.[3] illustrates that with increasing rolling velocity, for a smooth work piece, the rubbed portions became slight, the slip bands became more marked and the friction coefficient decreases .The experiments of Kevin and John[4], showed that the viscosity of the oil in the emulsion did not have a major effect on the load .Increasing speeds cause a reduction of the loads at higher roll roughness but with the smoother rolls no speed effect was observed . Huart et al.[5] have done experiments to optimize the contact condition in cold rolling, the simulation of trapping shows the role of lubricant in cold rolling .The lubricant fills the cavity, and avoids a total flattening of the asperities .

K. Loaisil et al.[6] designed a new heating system to simulate interface temperature which has a decisive effect on lubricant behavior. These optimizations permit to analyze contact temperature, forward slip and lubricant influence on friction, iron fine pollution and surface aspects. A great influence of temperature and lubricant on friction and wear has been put forward. An increase of the coulomb friction coefficient associated with a decrease of the iron fines quantity have been shown with an increase of temperature.

In this paper, the effect of some parameters like reduction in thickness, length of contact, rolling radius, viscosity of lubricant oil, and roll speed on the lubricant film thickness have been investigated. Computing of lubricant film thickness, roll separating force, length of contact and slide/roll ratio as a function of the process parameters are used to satisfy the objective.

2. Cold rolling process

Cold rolling is a metalworking process in which the metal is deformed by passing it through rollers at a temperature below its recrystallization temperature .Cold rolling increases the yield strength and hardness of a metal by introducing defects into the metal's crystal structure.

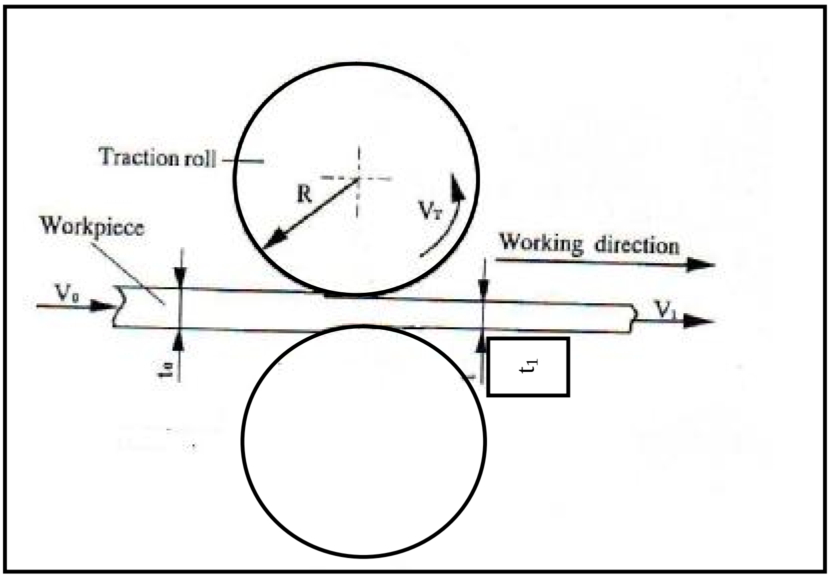

Figure (1) . A schematic diagram of the rolling process.

The gap between the rotating rolls is less than the thickness of the entering strip $\mathbf{t_0}$, therefore a friction force is necessary in order to bite the strip and to pull it through the rolls.A metal strip passing through the rotating rolls is squeezed, and it elongates while its cross section area decreases .

The amount of deformation **"r"** achieved in a flat rolling operation (thickness reduction)is determined by the relationship [3]:

$$r = (t_o - t_1)/t_o \quad (1)$$

A machine used for rolling metal is called (Rolling Mill) .A typical rolling mill consists of a pair of rolls driven by an electric motor transmitting a torque through a gear .A force applied to the rolls in vertical direction is called (Roll Separating Force).

3. Material and lubricants

The strips are of stainless steel 304 .The strips are nominally 1 m long, 10 mm wide and 0.8 mm thick .Three oils are used A, B and C, the properties of the lubricants are given in Table (1) .

Table (1). Properties of the lubricants .

Lubricants	Viscosity (Pa.s)	Pressure-Viscosity coefficient (1/Gpa)
A	0.00507	11.28
B	0.0173	13.9
C	0.02186	14.58

The program conditions are given in Table (2).

Table (2).Program conditions.

Reduction in thickness(r%)	75, 80, 85, 90, 95
Rolling velocity V_T(m/s)	0.5, 1, 1.5
Slide/roll ratio δ	0.4, 1.42, 1.85
Traction roll radius (mm)	55, 65, 75

The lubricant film thickness, length of contact, angle of entry and the roll separating force are reported.

4. Results and discussion

Figure (2) shows the variation in the lubricant film thickness with increasing reduction in thickness, the lubricant film thickness decreases for any lubricant .The result in this figure compared with the results of Mizuno form[3] and a good agreement was found.

The effects of the length of contact on the lubricant film thickness are shown in Figure (3) .It is quite apparent that increasing length of contact increases the lubricant film thickness .The results of the dependence of the roll separating forces on the reduction are given in Figure (4) . The results indicate that, as expected, the roll separating forces increase with increasing reduction.

The magnitude of the lubricant film thickness is shown in Figure (5)as a function of slide/roll ratio (δ), with an increase of slide/roll ratio, the film thickness increases for any lubricant .Figure (6) shows the variation in the lubricant film thickness with rolling radius, the lubricant film thickness will increase with increasing rolling radius.

The increase in rolling velocity and hence, the relative velocity between the roll and the strip, is expected to entrain more of the lubricant, leading to lower frictional resistance, lower load on the mill and high lubricant film thickness .This is observed in Figure (7).

5. Conclusions

1) The film thickness decreases with increase in reduction, but increases with length of contact and rolling radius.
2) The roll separating force increases with increases in reduction.
3) With an increase in rolling velocity, the lubricant film thickness increases.

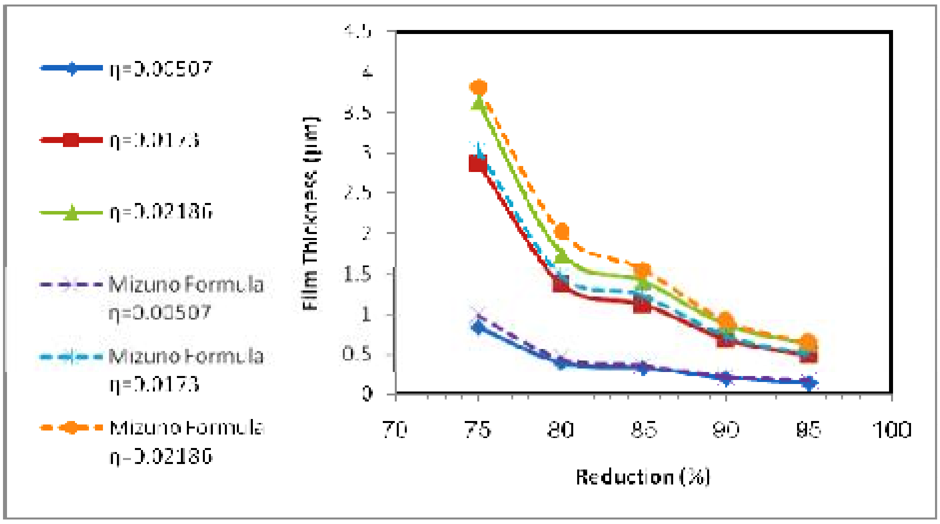

Figure (2). Variation of film thickness with reduction, R=55 mm, V_T=0.5 m/s.

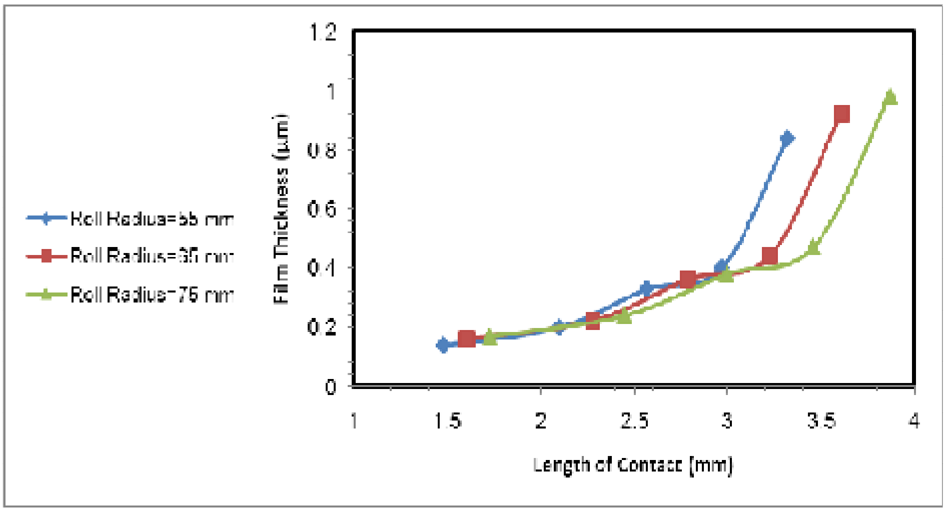

Figure (3).Variation of film thickness with length of contact , V_T=0.5 m/s , η=0.00507 Pa.s .

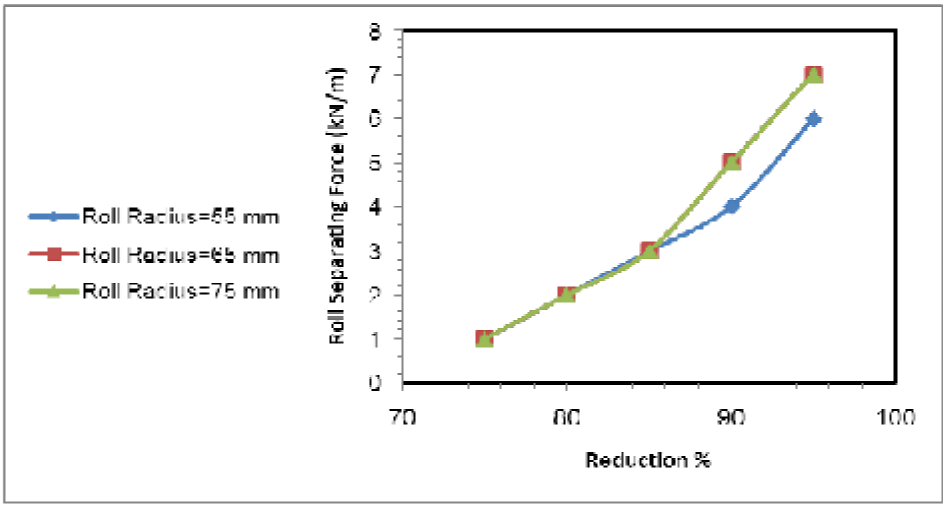

Figure (4). Variation of rolling separating force (kN/m) with reduction , V_T=0.5 m/s , η=0.00507 Pa.s .

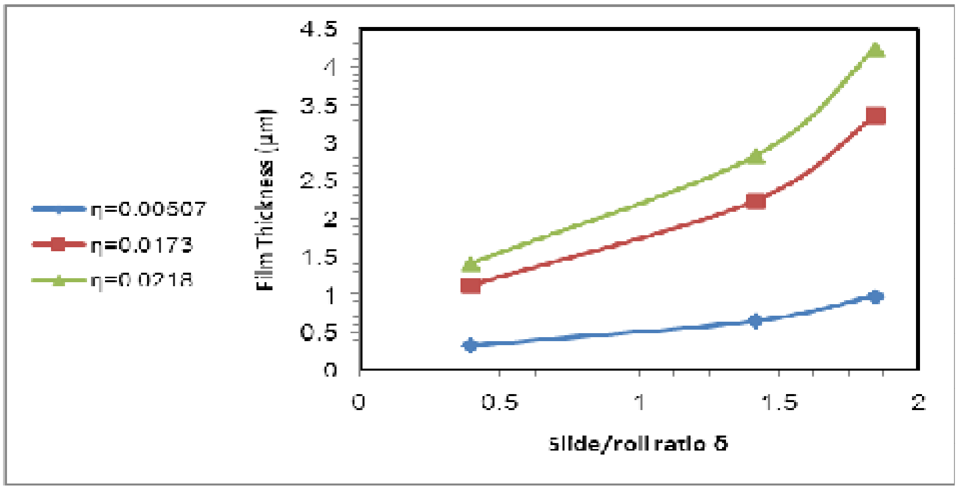

Figure (5).Variation of film thickness with slide/roll ratio, r=%85, R=55 mm.

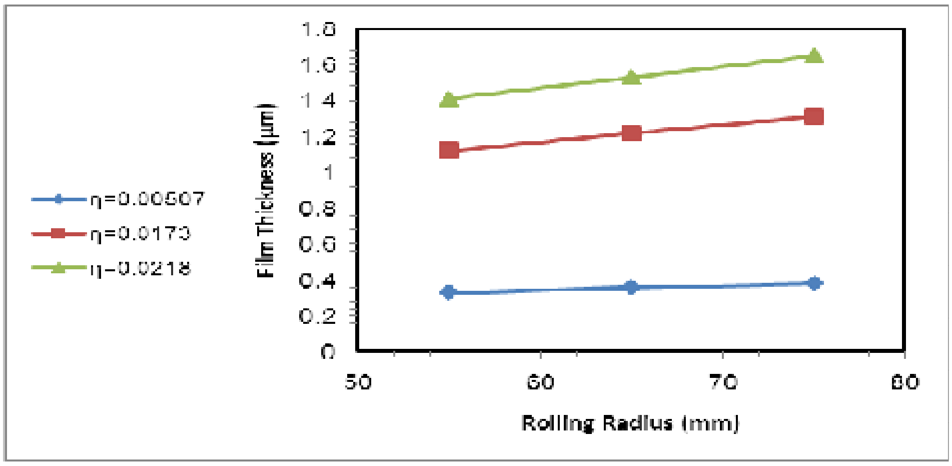

Figure (6) .Variation of film thickness with rolling radius (mm), r=%85, V_T=0.5 m/s.

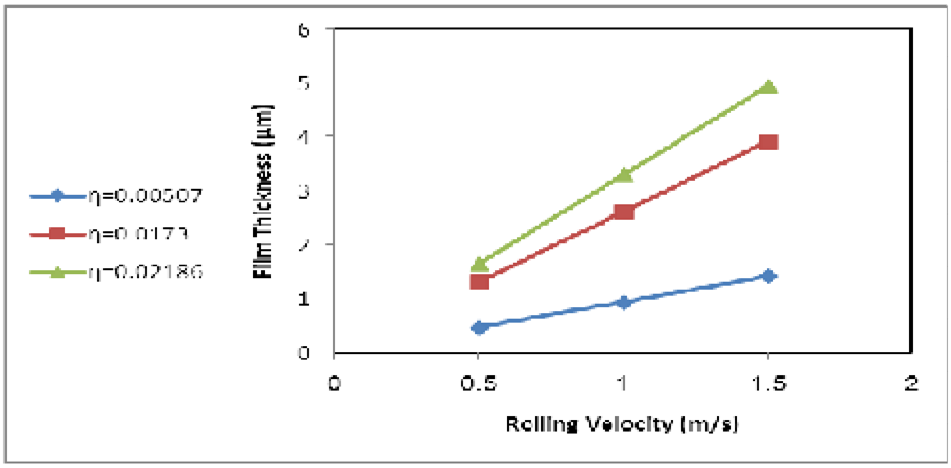

Figure (7). Variation of film thickness with rolling velocity (m/s), r=%80, R=75 mm.

6. References

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7. Nomenclature

r reduction in strip film thickness

R roll radius

t_o strip thickness at inlet

t_1 strip thickness at outlet

V_o strip velocity at inlet

V_1 strip velocity at outlet

V_T roll velocity

Greek letters

δ slide/roll ratio

η viscosity of lubricant