

# Optimization of the rheological characteristics of lubricants for reducing power losses

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*Keywords: Power saving, lubricants, viscosity, journal bearings, tribology*

## 1. Introduction

The aim of the paper is to introduce the optimization of rheological characteristics of lubricating oils that are used in some process industry during machining. In several cases, the machines employed are organized in several “stands” forming “lines” and are equipped by several spindles supported by journal bearings, fed by the same oil, but operating at different rotational speed [1]. Often, the geometry and the size of the bearings and the loads acting on them are also different [2-3].

## 2. Methods

Typically, the spindles supported by the bearings rotate at increasing speeds from the feeding of the blank material to the outlet of the machined one (see Figure 1). The power loss on the single spindle is different from the others, not only for the different rotational speed, but also because the oil, which feeds the single bearing, has different temperature and, thus, different viscosity. At present, standard mineral oils for mechanical use are employed.

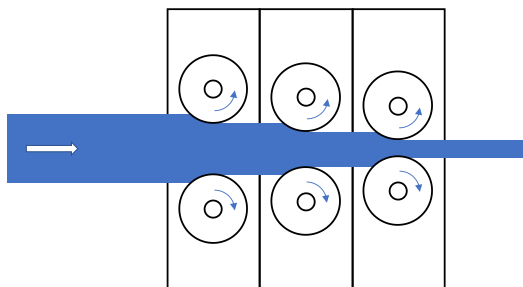


Figure 1: Spindles of roll forming process.

Owing to the large power loss in these kinds of plants, an attractive idea for power saving is, therefore, to formulate a lubricating oil which, globally along the entire line, has the best rheological characteristics (mainly in terms of viscosity) depending on the actual rotational speed of all spindles. In this way, the power dissipated during the machining process can be reduced while maintain-insufficient oil-film thicknesses in the various journal bearings of the spindles.

The modelling of the line is made, by means of a TEHD model (see Figure 2 and Figure 3), developed by using Matlab [4], for the calculation of the power dissipated in each journal bearing and the lubricating oil characteristics are defined by means of a multivariate optimization on the parameters of viscosity, temperature and thickness of the oil film.

### 2.1. Power loss calculation

The bearings of the machine operate in a wide range of conditions in terms of load and rotational speed. The

bearings in the first stage run at low speed and high load whereas the bearing in the last stand operate at high speed and low load (see Figure 1).

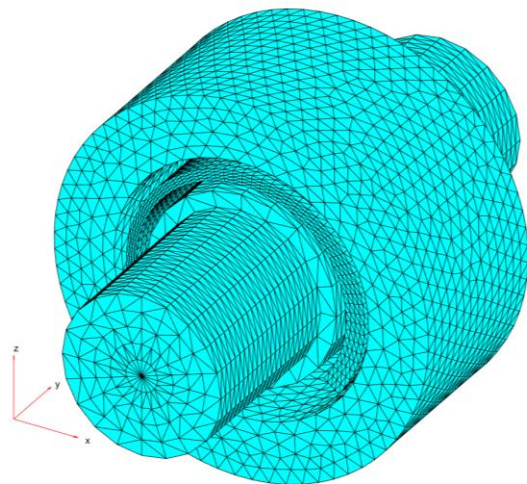


Figure 2: 3D mesh used for the thermal problem in the TEHD model.

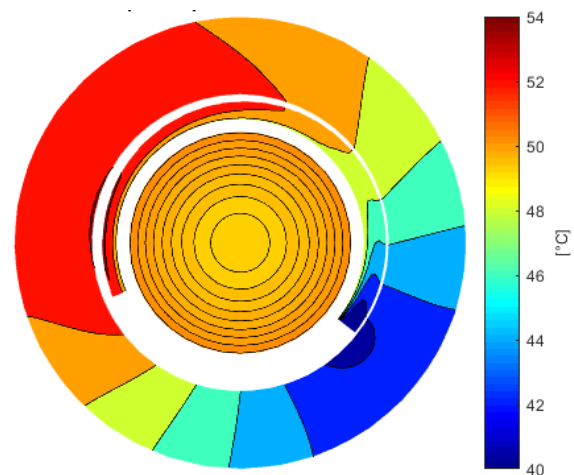


Figure 3: temperature distribution in the cross section (middle plane) of the bearing.

The maximum power loss for the reference oil is obtained in the last stands that runs at high speed. Conversely the minimum oil-film thickness is obtained in the first stage of the forming machine.

Therefore, the design of the new oil will be a trade-off between the reduction of power loss that can be easily obtained by reducing the viscosity of the oil in the last

stage and the limit of the minimum oil-film thickness reached in the first stages of the line.

The behaviour of all the 40 bearings in a steel roll forming machine has been simulated for different oil properties given by the two kinematic viscosities at 40 °C and 100 °C. The aim of the analysis is the reduction of the power loss. The percentage variation of the power loss with respect to the reference oil, that is the actual oil used in the system is shown in Figure 4, where the black dot represents the reference condition. It is possible to note that the highest power loss reduction can be obtained by reducing the viscosity of the oil. However, the two viscosity parameters are not independent themselves. Real oils show a behaviour represented by a limited range of the viscosity index that relates the kinematic viscosities.

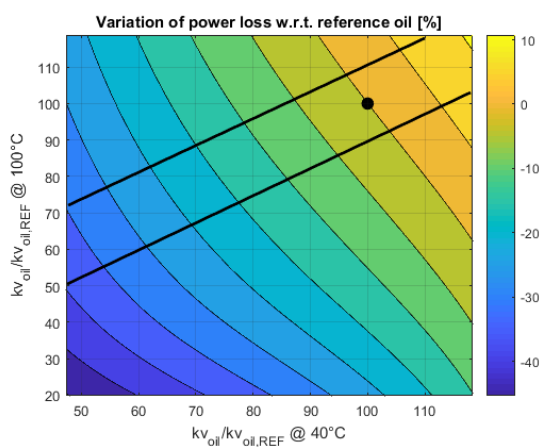


Figure 4: Variation of power loss with respect to the reference oil.

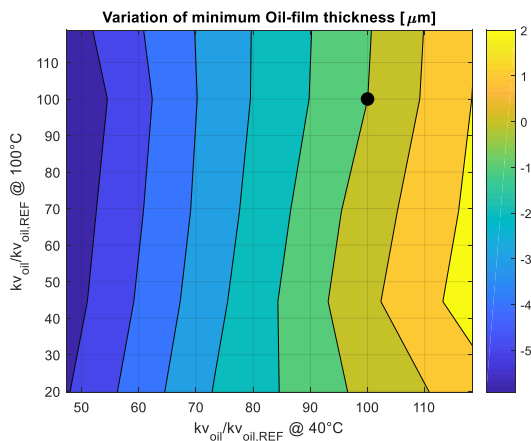


Figure 5: Variation of minimum oil-film thickness with respect to the reference oil.

The two black lines in Figure 4 represent the boundaries of the new energy saving oil. Conversely, the reduction

of the oil viscosity leads to a reduction of the minimum oil-film thickness as shown in Figure 5.

The value of the minimum oil-film thickness is critical for the bearings in the first stand that operate at high load and low speed. Furthermore, the reduction of the oil viscosity in the range given by the black lines in Figure 4, in general, do not increase the maximum temperature in the bearings.

### 3. Conclusions

The reduction of the total power loss due to shear stresses in the oil of the bearings of a steel roll forming machine has been investigated in this paper.

The analysis has been performed by simulating the behavior of all the bearings by means of an accurate TEHD model. The reduction of the power loss can be obtained by the reduction of the oil viscosity. The following conclusions can be drawn:

- the maximum power loss is obtained in the bearings operating at high rotation speed;
- the bearings operating at low rotational speed are critical because they show the minimum oil-film thickness;
- the minimum oil-film thickness is mainly a function of the kinematic viscosity at 40 °C;
- the maximum oil temperature increases for an increase of the kinematic viscosity at 100 °C and a reduction of the kinematic viscosity at 40 °C ;
- the overall power loss of the machine can be reduced of 30% by using an oil with kinematic viscosities at 40 °C and 100 °C that are about half the values of the reference oil.

### 4. References

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