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Faculty of Mechanical Engineering
Department of Materials Engineering

1953 – 2013
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SEMDOK 2013

18th International of PhD. students' seminar

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dean of the Faculty of Mechanical Engineering of the University of Žilina in Žilina

Terchová, Slovakia
30 January – 1 February, 2013

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INFLUENCE OF LUBRICANTS ON THE MULTIPHASE IRONING PROCESS

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Abstract

In this paper are presented results of experimental investigations of the type of lubricants influence on the ironing process. The tribological model was adopted, based on sliding of the metal strip between the two contact elements. Variations of the tensile force, contact pressure and the friction coefficient were investigated for each of the applied lubricants, in the three-phase ironing process, at constant sliding velocity. The objective of these investigations was to compare the applied lubricants and to estimate their quality from the aspect of their applicability in the ironing process.

Keywords: *Ironing, Tribological model, Friction coefficient, Contact pressure, Tensile force.*

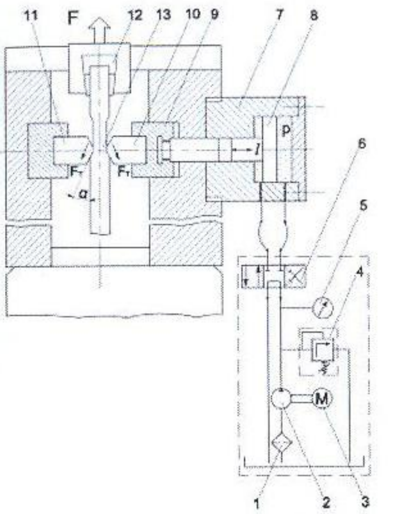
1. Introduction

The ironing process in cold conditions is frequently characterized by high contact pressures and local load of the tool, especially in the case of the multi-phase process. In such conditions, the lubricant has the decisive influence on plastic forming. Absence of lubricant would cause the direct contact of the machined piece and the tool, what would significantly disrupt the stability of the forming process. Lubrication, as a measure of reducing the damaging influence of friction, enables increase of the deformation and deep drawing degree, [1]. Application of lubricants eliminates or decreases the harmful phenomenon of galling, [2], wear of the tool's working surfaces and improves the quality of the machined piece surfaces.

Based on the adopted tribological model [3, 4], the original device was developed, based on sliding of the thin sheet samples between the side elements (die) in three phases. The contact surfaces between the sample and the die were separated by the layer of lubricant. The three types of lubricants were applied: a) lubricant in the form of the zinc phosphate coating with oil, b) lubricating grease based on molibdenum-disuplhate and c) oil for deep drawing. For each type of lubricants and the blank holding force, the measurement of the tensile force was performed.

2. Experimental device and the tribological model

For experimental investigations a device was constructed which models the symmetrical contact of the thin sheet with the die during the ironing process [3, 4] (Fig. 1). The metal strip is being placed into the holding jaw 12. The jaw with the sample is moving from the bottom towards the top, by the mechanical part of the device. The sample is being acted upon by the side elements 10 and 11, which simulate the die and perform the ironing. The moving sliding element 10 is placed into the holder with a T-groove 9, which is moving with piston 8 and hydro-cylinder 7. The sliding element 11 is fixed. During the ironing process the recording of the tensile force is being done at over the total length of the punch travel of approximately 60 mm, by the corresponding measuring chain.



1 – F ilter
2 – Pump
3 – Actuator
4 – Irreversible valve
5 – Manometer
6 – Two position distributer
7 – Cylinder
8 – Piston of cylinder 7
9 – Holder with the T-groove
10 and 11 – Sliding elements
12 – Jaw for sample holding
13 – Sample

Fig. 1. Block scheme of the experimental device

Tribological model, used in this experiment, was developed based on an idea presented in [3]. In the large number of cases, the tribological models can not completely simulate real processes [4]. Due to that, the more detailed analysis of the process being modeled is necessary. The applied model enables realization of the high contact pressures (Fig. 2a). The basic idea in realization of this device was to provide for determination of the friction coefficient at the contact surface between the siding element and the sample, based on what the estimate of the lubricant became possible (Fig. 2b). Calculation of the friction coefficient requires analysis of forces that act on the contact surface at certain angle, as well as on the input portion of the side element (Fig. 2b). In that sense, it was proposed, based on observations about the classical approach deficiencies [4], to take into account forces F' and $F_{TR}^{'}$ in the input zone. Then, the inaccuracies were avoided of the friction coefficient values. Caused by simplifications in the basic model [3].

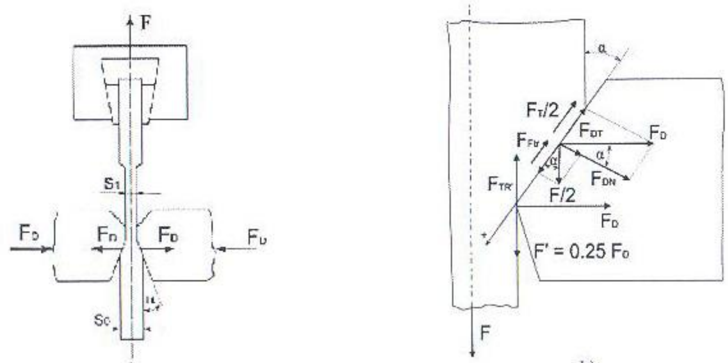
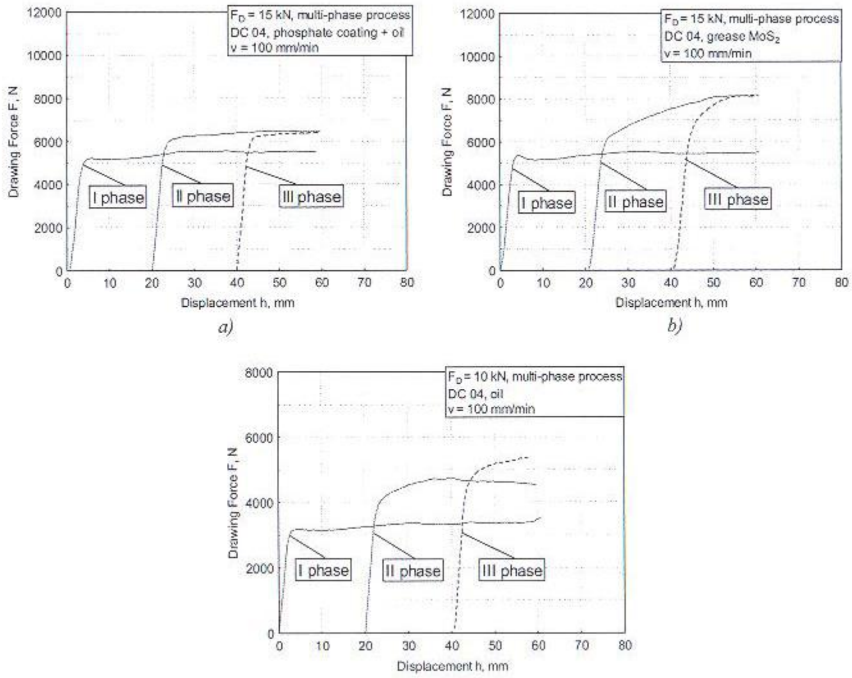


Fig. 2. The tribological model: a) scheme of the contact between the sliding element and samples; b) Scheme of the forces' action.

3. Experimental results

In experiment were used samples made of steel thin sheet DC 04 (EN 10027.1), with thickness of 2.5 mm and width of 20 mm. The following three lubricants were applied: zinc phosphate coating with ~ 10 μm thicknesses with oil for deep drawing, lubricating greases based on MoS_2 and oil for deep drawing (kinematic viscosity 100 mm^2/s at 40 °C and density 0.93 g/cm^3 at 20 °C.

For lubricant ion the form of phosphate coating with oil and the grease based on MoS_2 were applied holding forces F_D = 15 kN, while for the case of oil the holding force was F_D = 10 kN. The sliding velocity applied was 100 mm/min. The highest value of the tensile force was realized for the case of testing the lubricant based on MoS_2, during the second and third phase of ironing (Fig. 3b). Investigation of oil at holding forces F_D > 10 kN resulted in impossibility of performing the ironing process, due to very strong friction. Thus due to applied holding force of 10 kN the lower values of the tensile forces were obtained, Figure 3c. The lowest values of tensile forces were obtained when the lubricant in the form of phosphate coating was applied (Fig. 3a).



c)

Fig. 3. Diagrams of tensile forces: a) phosphate coating; b) grease based on MoS_2; c) oil

Investigation of lubricants based on MoS_2 resulted in more prominent friction (Fig. 4b) with respect to phosphate coating with oil (Fig. 4a). Reasons for that were in disruption of the lubricating layer, based on MoS_2, on the contact surfaces between the die and the sample and proneness to appearance of galling [2]. Contrary to that, with lubricants in the form of phosphate coating with oil, Figure 4a, were noticed lower values of the friction coefficient, durability of the phosphate coating and negligible appearance of galling.

Monitoring of contact pressures variations was also significant for comparison and evaluation of lubricants. The highest contact pressures were reached in application of oil, Fig. 5 and Table 1, at F_D = 10 kN, what is in accordance with more severe contact conditions during tests. In Table 1 are presented comparative results of maximal contact pressures for each type of lubricants, for each phase of ironing. Values of contact pressures vary depending on the process phase, type of lubricant and holding force. The contact pressure represents the significant tribological indicator, besides the friction coefficient.

4. Conclusion

Based on presented results of tensile forces, friction coefficient and contact pressures, one can conclude that the oil for deep drawing in not convenient for application in the multi-phase ironing processes and high values of the holding force, due to expressed proneness to appearance of galling and easy extrusion of lubricant from the contact zone. Lubricant based on MoS_2 has more favorable characteristics than the oil, because it can be applied at somewhat higher holding forces and it has better layer durability than oil. At higher contact pressures the extrusion of lubricant from the contact zone can occur, as well as increase of the contact pressure, thus application of this lubricant is limited in that sense. The coating of phosphate layer has the most favorable properties, based on lower values of the tensile forces, contact pressures and the friction coefficient. Those are the reasons for application of the phosphate coating in the ironing processes. Problems of application of the phosphate coating, however, are in the phosphatization process, which is toxic both for humans and the environment. That has caused development of the new, ecological, environment friendly lubricants.

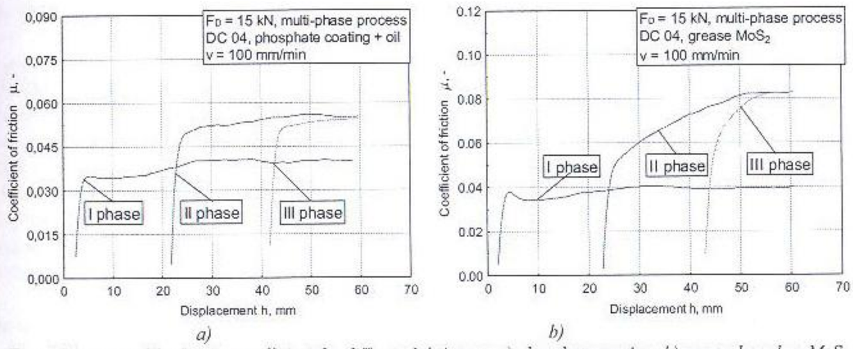


Fig. 4. Diagram of the friction coefficient for different lubricants: a) phosphate coating; b) grease based on MoS_2

Table 1

Maximum values of contact pressures in phases of ironing for all the lubricants

Lubricants and conditions		Max. pressure p [MPa]		
		I phase	II phase	III phase
Phosphate coating	DC 04, F_D=15 kN	756.709	1109.645	1109.044
Phosphate coating	DC 04, F_D=20 kN	693.506	886.9654	958.84
Grease MoS_2	DC 04, F_D=15 kN	735.727	1033.798	1075.302
Oil	DC 04, F_D=10 kN	927.868	1781.418	2238.812

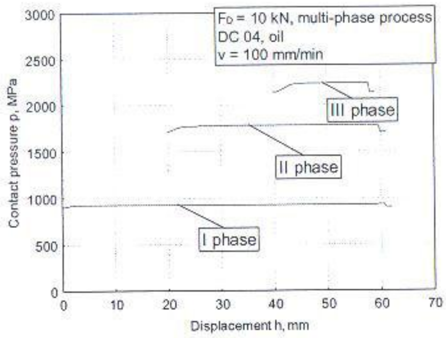


Fig. 5. Diagram of contact pressures during the oil investigation phases

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