



EXPERIMENTAL ANALYSIS OF INFLUENCE OF DIFFERENT LUBRICANTS TYPES ON THE MULTI-PHASE IRONING PROCESS

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Resume

This paper is aimed at presenting results of an experimental analysis of the different types of lubricants influence on the multi-phase ironing process. Based on sliding of the metal strip between the two contact elements a special tribological model was adopted. The subject of experimental investigations was variations of the drawing force, contact pressure and the friction coefficient for each type of the applied lubricants. The ironing process was conducted in three-phases at the constant sliding velocity. The objective of this analysis was to compare all the applied lubricants in order to estimate their quality from the point of view of their applicability in the multi-phase ironing process.

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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 molybdenum-disulphate and c) oil for deep drawing. For each type of lubricants and the blank holding force, the measurement of the drawing force was performed.

Investigation of lubricants in ironing process represents a very interesting subject for research, what can be concluded based on numerous papers being published on this topic. Andreasen et al. [6] were investigating several types of lubricants by application of a model that simulates the ironing process. In their tests were applied variable process parameters like the speed, walls thinning value, step length and

tool temperature. The special attention was directed towards the sustainability of the lubricant layer and influence of lubricant to the galling phenomenon, what was used as idea in this paper. The tribological model of van der Aa et al. presented in [7], as well as those in [3-6], served as a basis for realizing the tribological model presented in this paper, Fig. 1. In work by Stefanovic et al. [8] is presented the more extensive survey of application of the various types of lubricants for different procedures of plastic forming, as well as of tests based on which analyses of those lubricants are conducted. The special emphasis is put on the group of the new, the so-called ecological lubricants, whose application is constantly growing. The problems of the new

lubricants application and advantages with respect to classical ones are discussed in papers [9] and [10].

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 13 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 moving sliding element 10 is placed into the holder with a T-groove 9, which is moving with piston 8 and hydro-cylinder 7.

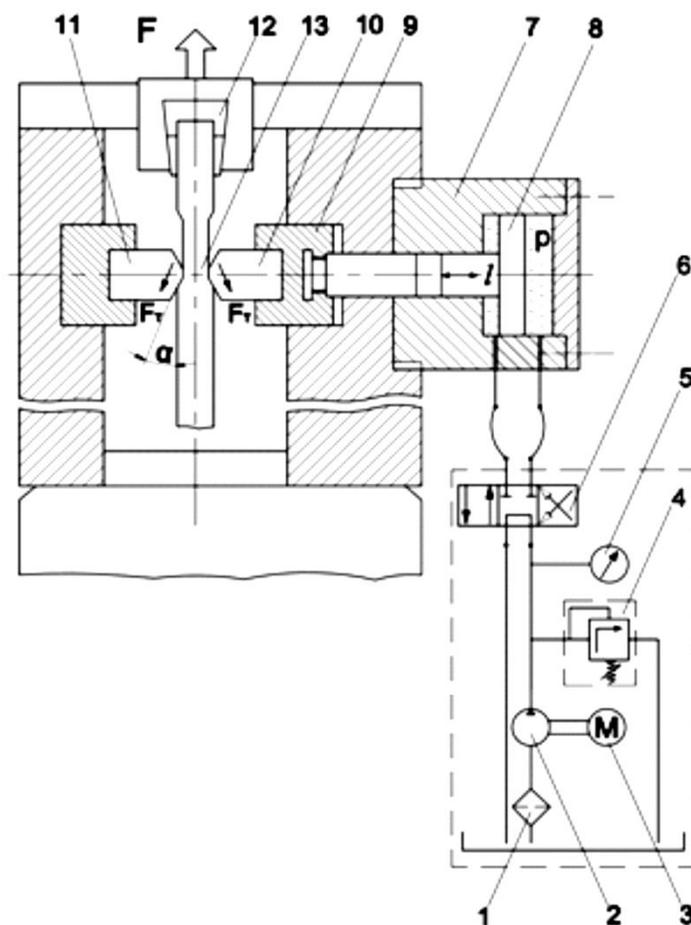


Fig. 1. Block scheme of the experimental device: 1 – Filter, 2 – Pump, 3 – Actuator, 4 – Irreversible valve, 5 – Manometer, 6 – Two position distributor, 7 – Cylinder, 8 – Piston of cylinder 7, 9 – Holder with the T-groove, 10 and 11 – Sliding elements, 12 – Jaw for sample holding, 13 – Sample.

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 drawing force is being done over the total length of the punch travel of approximately 60 mm, by the corresponding measuring chain.

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 modelled 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 sliding 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 a 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 of the friction coefficient values, caused by simplifications in the basic model, were avoided [3].

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 $\sim 10 \mu\text{m}$ thickness with oil for deep drawing, lubricating greases based on MoS_2 and oil for deep drawing (kinematic viscosity $100 \text{ mm}^2/\text{s}$ at $40 \text{ }^\circ\text{C}$ and density 0.93 g/cm^3 at $20 \text{ }^\circ\text{C}$).

For lubricant of the form of phosphate coating with oil and the grease based on MoS_2

were applied holding forces $F_D = 15 \text{ kN}$, while for the case of oil the holding force was $F_D = 10 \text{ kN}$. The sliding velocity applied was 100 mm/min . The highest value of the drawing force was realized for the case of testing the lubricant based on MoS_2 , during the second and third phase of ironing, Fig. 3b.

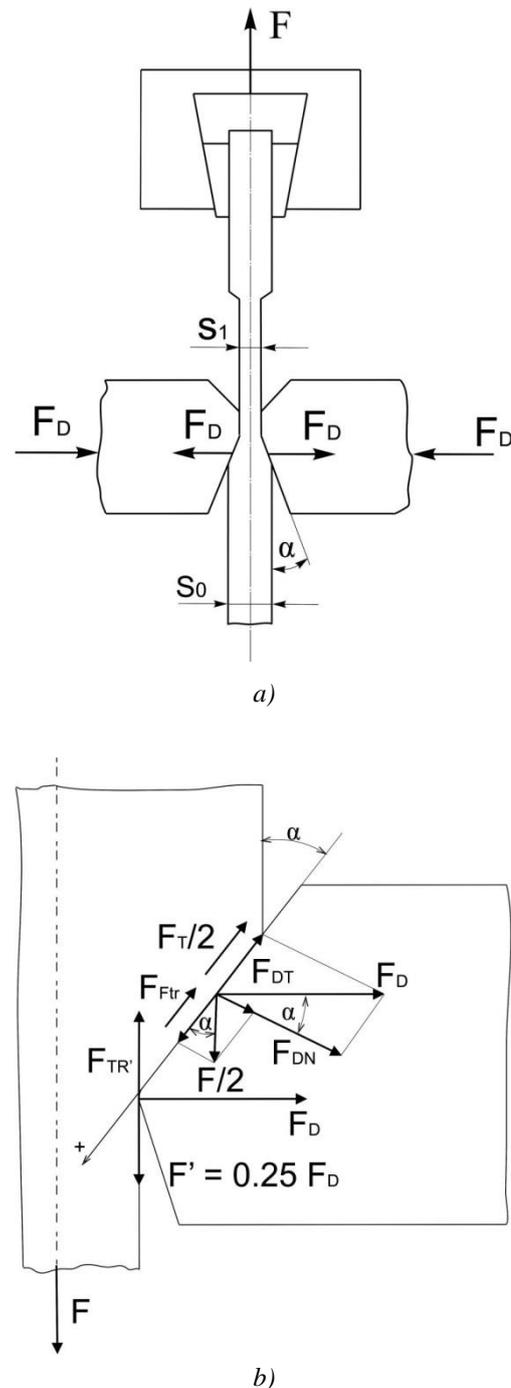


Fig. 2. The tribological model: a) scheme of the contact between the sliding element and samples; b) Scheme of the forces' action.

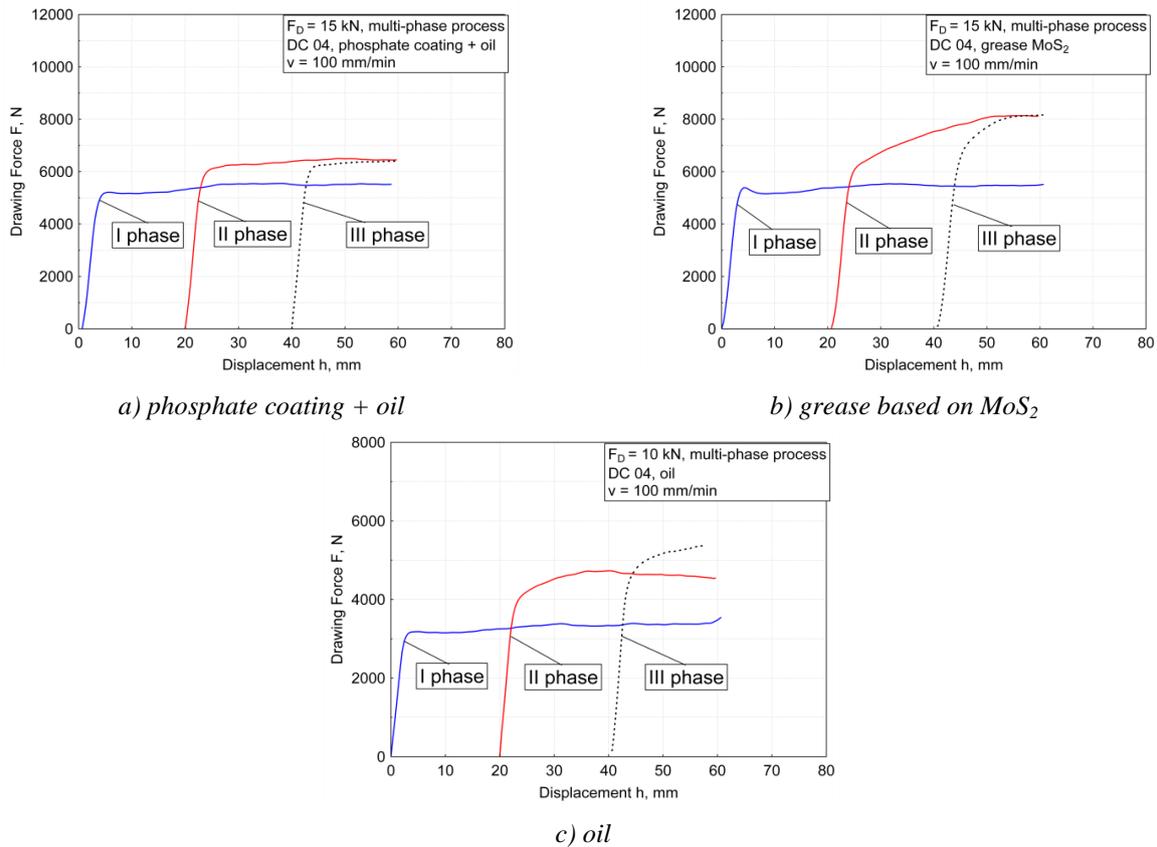


Fig. 3. Diagrams of drawing forces.

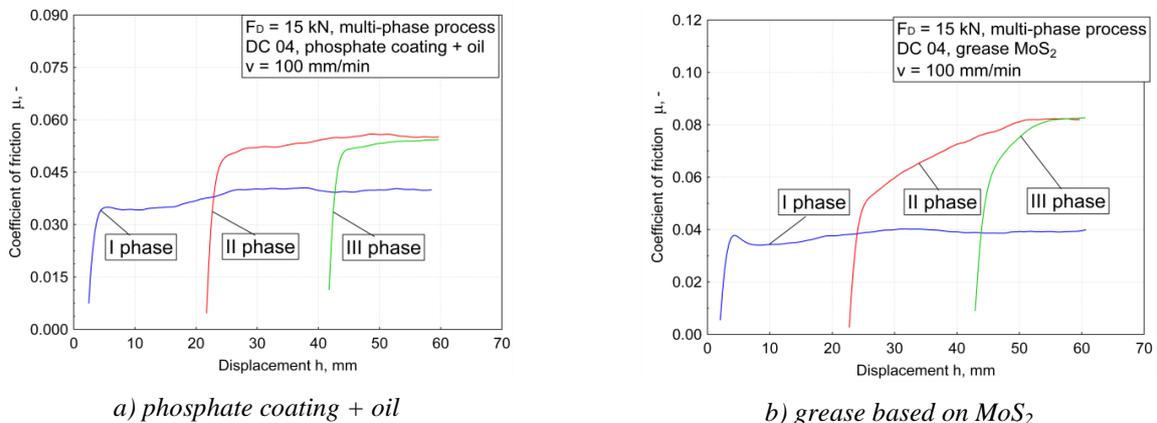


Fig. 4. Diagram of the friction coefficient for different lubricants.

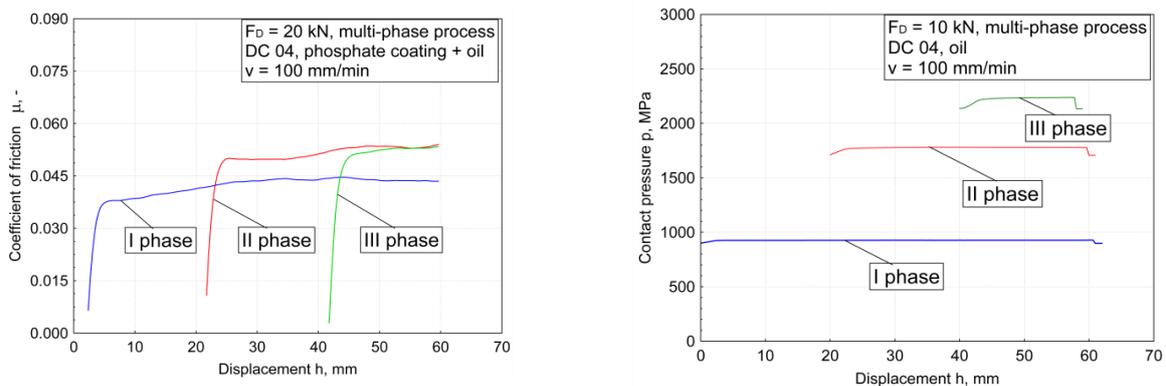


Fig. 5. Dependence of the friction coefficient on displacement for the lubricant in form of the phosphate layer with oil at $F_D = 20$ kN.

Fig. 6. Diagram of contact pressures during the oil investigation phases.

Table 1

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

Lubricants and conditions	Maximal 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

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 drawing forces were obtained, Fig. 3c. The lowest values of drawing forces were obtained when the lubricant in the form of phosphate coating was applied, Fig. 3a.

Investigation of lubricants based on MoS₂ 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 MoS₂, 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, Fig. 4a, were noticed lower values of the friction coefficient, durability of the phosphate coating and negligible appearance of galling. It is also very interesting to analyse dependence of the friction coefficient on displacement for the case of lubricant in the form of the phosphate coating with oil, at the drawing force of $F_D = 20$ kN, Fig. 5. Comparing this presentation with Fig. 4a one can easily conclude that, in this case, increase of the drawing force weakly influences variation of the friction coefficient with this type of lubricant. Based on that, the conclusion can be drawn that the phosphate layer of lubricant with oil is convenient for application for the higher drawing forces, as well.

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. 6 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 drawing forces, friction coefficient and contact pressures, one can conclude that the oil for deep drawing is 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 MoS₂ 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 drawing 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.

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