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LUBRICATION AND THE CHOICE OF LUBRICANTS FOR DEEP-DRAWING

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ABSTRACT

The role and the importance of lubricants and lubrication in the process of metal forming are complex, and have been the object of many researches. In deep-drawing of thin sheets, the tribological conditions influence the forming process in a very complex manner and on equal terms with other elements of the forming system (machine, tool, material). The comments on the significance of the optimal choice of lubricant for deep-drawing, the methods and procedures for the evaluation of the technical quality of the lubricant are given in this paper. For two basic procedures of research, so called "complex " tribological models-stretching and pure deep-drawing-and many investigated lubricants, the results are given from different categories: limit relations in forming and presentation in forming limit diagram. The compared results for stainless and low-carbon steel sheets, in drawing of axis-symmetrical and square-section parts, are given.

1. INTRODUCTION

The right choice of lubricants in metal forming, especially in deep-drawing, includes implicitly that the role and importance of lubrication should be ragarded as equal as others elements of forming system. In selecting lubricant and a lubrication zone, the following demands must be fulfilled [1], [2]:

- the existance of the desired friction resistance in all part zones (control of metal-flowing);
- the decrease of metal to metal contact in critical zones, leading away of heat and the decrease of tool wear;
- obtainment of the desired quality of the part surface.

This should be completed by the characteristics of lubricants regarding the manner of application and the easiness of removing, coordination with the following forming process , protection from corrosion in parts storing, Fig 1.

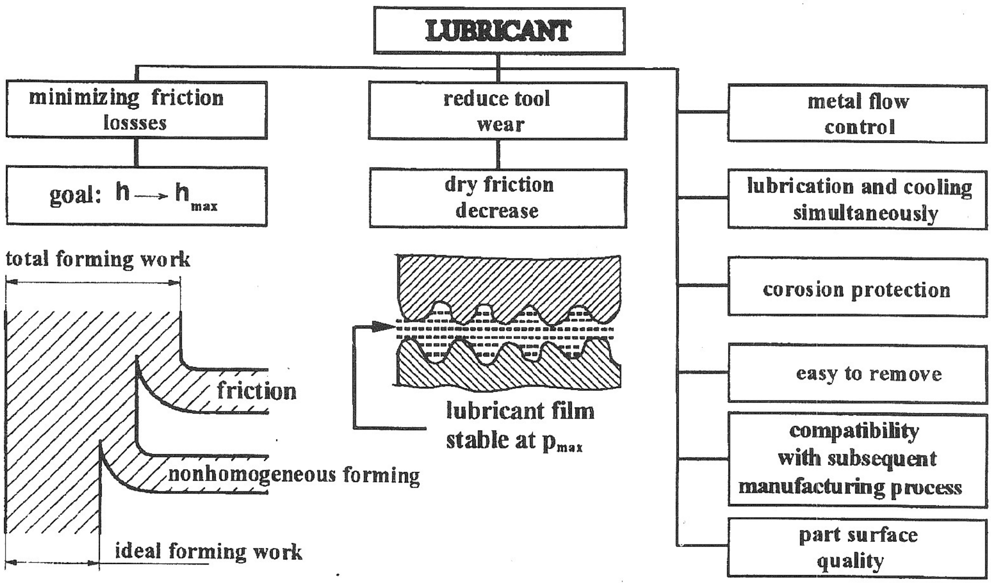


Fig.1. Schematic summary of the functions of a lubricant

It has long been recognized that, concerning the elements of complex geometry, in different zones, very different schemes of forming could exist: pure deep-drawing, stretching, bending with tension and so on. In tribological researches, these areas are described by special models [3].

The results of tribological researches, which are also partly related to the evaluation of the technological characteristics of lubricants for deep-drawing, can be basically divided into three groups. The first group includes physical indicators - friction force and coefficient, roughness parameters, etc, the second one includes macro indicators in forming - force and the depth of drawing, etc-and the third one includes the parameters of realized stress-strain fields - strain distribution, presentation in forming limit diagrams (FLD). The third group parameters are the most complete, but most difficult to be determined [4].

2. THE ELEMENTS IMPORTANT FOR THE CHOICE OF LUBRICANT

The specific tribological problems are also caused by different part dimensions, materials, sheet thickness and its surface characteristics. However, the basic form and type of forming have the greatest influence. It is particularly important to pay attention to the interpretation of the effects of some forming types influence in cases when they occur at same time. The most important tribological influential factors are: the contact pressure in blank holder zone, the relative sliding speed, heating of parts, the intensity of heat transfer onto the tool, the quantity of lubricant etc.

The speed of sheet sliding in the contact zone of die and holder in deep-drawing is the same as the speed of press-slide, but it is considerably smaller in the case of stretching. The heat primarily develops in those part zones in which large deformations, increased speeds and high local pressures are achieved (for example, the zones which slide across the draw bead, etc). In this conditions of lubricative film interruption, well-known "galing" phenomenon and sheet and tool surface damage may occur.

The control of friction conditions in deep-drawing is most successfully achieved by using the lubricant which has the correct combination of shear strength and film thickness, wherefore the qualities of a lubricant in conditions of boundary lubrication are of particular significance. In such conditions, the lubricant must have the considerable film strength in order to prevent interruption and enable metal to metal contact. However, the certain sheare resistance in the lubricant layer is also necessary, in order to reduce the friction forces.

For example, in operations of deep drawing, the value of the total strain and strain distribution depends primarily on viscosity and lubricant stickness, and less on separately composed additions. At the high viscosity, the application of a lubricant can be problematic, and therefore the dry lubricative films can be problematic, and therefore the dry lubricative films can be used. The choice of lubricant in particular case depends on a part type-for example, parts with slight change of profile, or parts with strong change of form.

In ordinary deep-drawing, the difficulties occur when high pressures upon the blank holder are necessary, or when very precise outlines are being drawn. In such a case we must use the lubricant with special additions for high pressures or dry films with carefully controlled thickness.

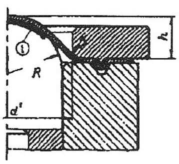
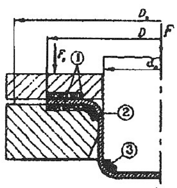
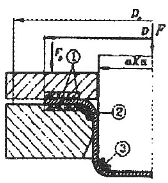
The particular problems appear in case of multi-operational deep drawing, long lasting storage, differential lubrication etc.

According to the Fig.1, it is practically impossible to give a simple universal rule for the selection of a lubricant because of many tribological factors and some other kinds of problems. The adequate literature offers some generally defined references to the lubricant selection, defined on the basis of the type of material being drawn, part geometry, manner of application, storage, cleaning etc [5].

3. EXPERIMENTAL DETAILS

In previous papers the thorough analysis of tribological models in deep-drawing has been performed, and systematic selection of important parameters has been conducted, according to the structure of outputs from some tribological researches. According to the degree of complexity, the defined tribological models are: basic - sliding of the thin sheet between the flat surface of die and holder, sliding by bending with tension across the die edge, sliding across the draw bead, and complex-two-sided stretching and pure deep-drawing [3]. Each of these models can be successfully used in the evaluation of lubricants, in correspondence with characteristics and aim of research.

Table 1

Models	Experimental Procedure				Indicators		
	mater.	lubricant	speed	geometry	force	depth	distribution
Stretching  STR	Č4580 Č0147	Lub.1 Lub.2 Polyeth. + oil Dry	20 mm/min	R=25 mm D_o=120 mm d_o=50 mm	F_{FR}	h_{FR}	$\varphi_1=f(loc.)$ $\varphi_1=f(\varphi_2)$ FLD
Pure deep-drawing  PDD	Č4580			D_o=100 mm p_H=4,27 MPa F_H=2,5 kN d_o=50 mm	F F_{FR}	h h_{FR}	$\varphi_3=f(loc.)$ $\varphi_1=f(\varphi_2)$ FLD
	Č0147			D_o=100 mm p_H=2,05 MPa F_H=1,2 kN d_o=50 mm			
Deep-drawing  DD	Č4580			D_o=90 mm p_H=6,9 MPa F_H=3 kN a=40 mm			
	Č0147			D_o=95 mm p_H=2,36 MPa F_H=1,2 kN a=40 mm			

For the evaluation of the influence of tribological conditions in deep drawing, the parameters of the third group are the most complete; they represent the " internal "indicators of the forming process, and in the course of determination of them, it is necessary to know the critical deformation zone. The parameters of this group are grapho-metrically determined, along with the knowledge of all elements of complex deformation analysis: strain distribution in critical section, the distribution in forming limit diagram (FLD), defining of elements of the deformation history, strain path etc.

The paper also includes some results of lubricants evaluation by complex tribological models: stretching, pure deep-drawing of axis-symmetrical piece and deep-drawing of the square section piece, according to the Table 1.

The lubricants selection has been performed by using two different groups of steel-sheets intended for the forming by deep-drawing: Č0147 (AKDQ)-low-carbon steel-sheet and Č4580 (AISI 304)- stainless steel-sheet. The characteristics of these materials are given in the Table 2.

Table 2

Material	**R_P** **[Mpa]**	**R_M** **[MPa]**	**R_P/R_M** -	**A_{80}** %	**n** -	**r** -
Č0147	220,9	321,8	0,69	37	0,22	1,407
Č4580	309,2	655,8	0,47	33,6	0,351	1,017

Many lubricants for deep-drawing from different manufacturers have been investigated; here results are given for two best samples (Lub.1 and Lub.2). The cases of completely clean surfaces (dry) and the usage of polyethylene foil with lubricant (Polyeth.+oil), have been taken as special cases. In course of investigation by stretching, only the zone under the punch is being lubricated, whereas in deep-drawing the annular surface in both holder and die zone is being lubricated.

The basic and oldest criterion of formability in stretching-the biggest fracture depth, can also be used in quantitative evaluation of lubricant which is being used. In course of that, there are often no important differences in the fracture forces. However, deformation analysis provides a considerably better approach in the interpretation of the results. Strain distribution in main sections with ordinary presentation in the system of main line strain represents the basic of such analysis. Quantification in the evaluation of the distribution forms is enabled by the characteristic indicators of strain distribution at the limiting or common forming depth, such as distribution gradient in critical zone, coefficient of distribution favourableness, the reserve of plasticity [6], the pick locality and the width of necking zone etc [7].

4. RESULTS AND DISCUSSION

In Fig.2 and Fig.3, the depths in the course of fracture and adequate main strain distributions for different experimental conditions, are given. in order to achieve better lubrication, the deformation should be homogeneous, with the rupture place near the piece pole.

The connection between achieved deformations and those ones which are possible to the utmost, with many strain paths, is shown by the distribution in forming limit diagram. In the course of that, the other main tangential deformation is being taken into consideration, and it highly influences the value of the major deformation, Fig. 4 and Fig. 5.

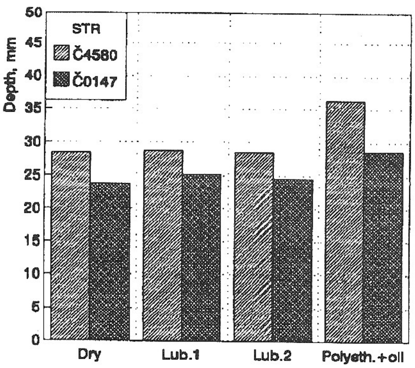


Fig.2. Drawing depth in stretching

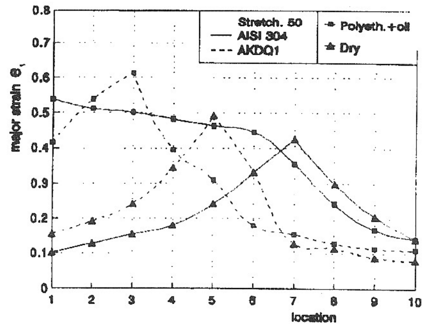


Fig.3. Strain distribution in different contact conditions

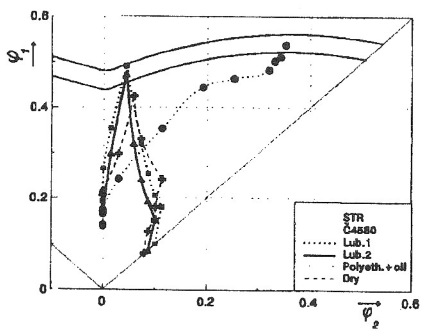


Fig.4. Strain distribution in FLD for Č4580

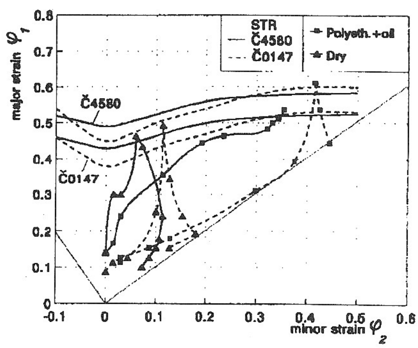


Fig.5. Strain distribution in FLD

The deformation force and the achieved depth with high values of limiting drawing ratio are the classic indicators of the influence of friction in pure deep-drawing. The achieved drawing forces in different contact conditions, according to the experimental conditions in Table 1, are given in Figure 6. Comparative distributions for different materials, contact conditions and tribological models are given in Fig.7 and Fig.8. Big differences in quality of examined materials influence the obvious differences in the influence of tribological conditions on the piece flange. Material C.0147 does not grow harder intensively as stainless does, and therefore the localization zone becomes narrower and restricted to the fields nearest to rupture place. High deformation gradients and high degrees of major deformations are thus achieved, but the realized fracture depth is smaller.

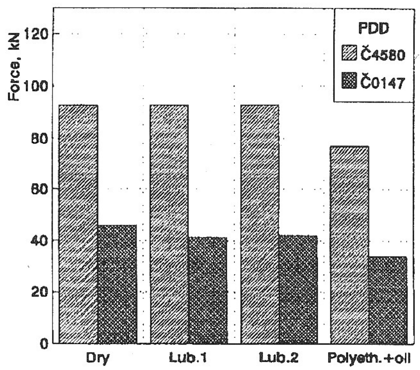


Fig.6. The biggest forces in drawing of ∅50

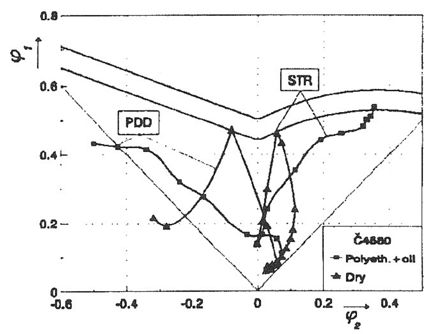


Fig.7. Strain distribution in FLD for Č4580

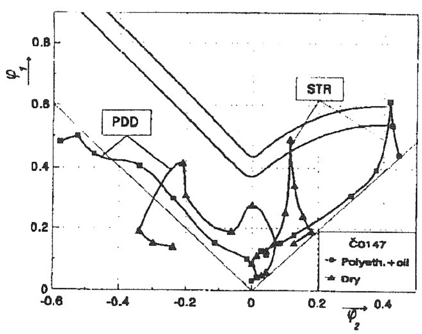


Fig.8. Strain distribution in FLD for Č0147

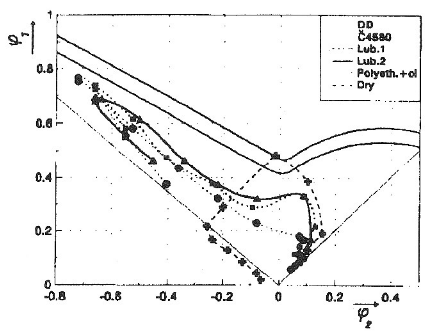


Fig.9. Strain distribution in FLD for Č4580

Distribution in deep-drawing square pieces 40x40 are given in Figures 9 and 10, and distribution in drawing axis-symmetrical piece ∅50 with flat punch are given in Fig.11. In such drawing conditions, localization occurs on the place of rounding of punch, in conditions when $\varphi_2=0$.

According to Fig.9, fracture appears in case of unlubricated contact surfaces. However, when using both lubricants, high degrees of deformation are achieved, in course of which unstable deformation may occur. At the same time, this is the zone of intensive thinning.

According to Fig.11, with regard to high values of holder pressure (p_H=4,27 MPa) , the drawing is possible only in conditions of lubrication by foil.

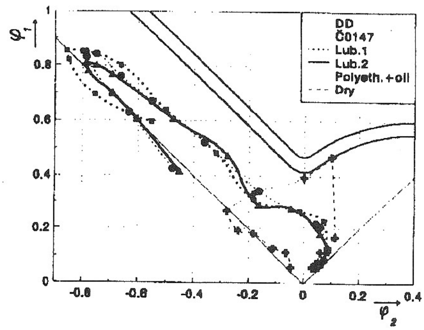


Fig.10. Strain distribution in FLD for Č0147

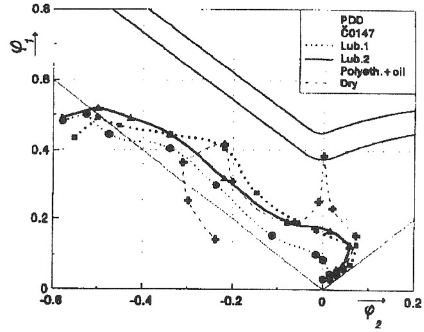


Fig.11. Strain distribution in FLD for Č0147

5.CONCLUSION

Complex tribological models of deformation and deep-drawing, can be successfully used in the evaluation of technological qualities of lubricants for deep-drawing, and they are the most complete indicators of deformation analysis. The applied methodology is efficient even in the conditions of more difficult lubrication which exists in forming of stainless steel-sheets.

Besides the usual indicators for this kind of research, the elements of deformation analysis with presentation in forming limit diagram are given too. The extreme importance of conditions for lubrication in realization of so called " complex " tribological models for different kinds of steel-sheets for deep-drawing, is pointed out.

There is no significant difference between the examined lubricants, while the Lub.1 lubricant is of much higher viscosity and its application is more difficult. Investigations in production conditions, the results of which are not given here, besides the analogous deformation analysis also include the tests of storing, stability at increased speeds and temperatures, the possibility of easy cleaning, etc.

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PODMAZIVANJE I IZBOR MAZIVA ZA DUBOKO IZVLAČENJE

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REZIME

Uloga i značaj maziva i podmazivanja u procesima plastičnog deformisanja metala su složeni i predstavljaju predmet brojnih istraživanja. Pri dubokom izvlačenju tankih limova, tribološki uslovi na izuzetno kompleksan način utiču na proces deformisanja, ravnopravno sa uticajem ostalih elemenata obradnog sistema (mašina , alat, materijal). U radu se komentariše značaj optimalnog izbora maziva za duboko izvlačenje, pokazuju metode i postupci za ocenu tehnoloških kvaliteta maziva. Za dva osnovna postupka ispitivanja (tzv. "složeni" tribo-modeli)-razvlačenje i čisto duboko izvlačenje i više ispitivanih maziva, navode se rezultati iz različitih kategorija: granični odnosi pri oblikovanju i prikazi u dijagramu granične deformabilnosti. Posebno se daju uporedni rezultati za nerđajuće i niskougljenične čelične limove, pri izvlačenju osnosimetričnih i komada kvadratnog preseka.