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MEASUREMENT AND EVALUATION OF FRICTION RATIOS AT DEEP DRAWING

Evin, Emil - Hrivnák,Andrej - Tkáčová, Jana
Technical University of Kosice, Faculty of Mechanical Engineering,
Department of Technologies and Materials, Slovakia

ABSTRACT

In this contribution the methodics of friction coefficient assessment at deep drawing of cylindrical cups is given. At experiment the materials EDDQ, ZStE 220 P, DDQ Zn coated, stainless sheet and lubricants ANTICORIT RP 4107 S, ANTICORIT PL 3802-39, FERROCOAT 6130, foil were tested.

1. INTRODUCTION

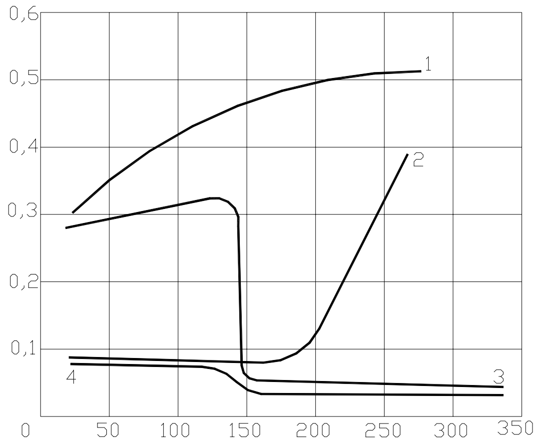
The result of deep-drawing process depends on material characteristics of sheet (yield strength, size of grain, homogeneity, microgeometry of surface, etc.), die parameters (stiffness, microgeometry of contact surfaces, radii of drawing edges, drawing gap, etc.), used machine and lubricant. During deep-drawing process, single parameters are under change and their mutual effects have influence on technological formability, that is in a great measure influenced by lubricant. The correct selection of lubricant is one of the basic factors that ensure the quality of deep drawing process. Functions of lubricant at deep drawing are often various. Generally is valid that the role of lubricant is to minimize the friction on the contact surfaces to reach the highest formability of material. Lubricants must fulfil also other functions i.e. to protect sheet against corrosion, they must be easily applicated and removed from the surfaces, they must be stable in drawing process, they may not be dangerous and their application should be cost effective. From the point of view of their impact on working conditions and environment the priority is given to lubricants without chlorine.

The requirements on lubricants for deep drawing are contrary in many cases. They can be fulfilled by adding the surface active polar substances or by high pressure active substances (EP additives) into basic lubricant. Natural oils (rapeseed oil, ricinus oil, palm oil) and synthetic oils belong among the most important polar active substances. It must be taken into consideration, that with increasing temperature in the forming zone on the contact surfaces the drop of lubricity occurs -

Fig. 1. This drop may be compensated by effective polar substances and EP additives. As it results from Fig.1 the polar active substances have positive influence on friction coefficient only to a certain temperature limit.

At development of new types of environmentally friendly lubricants for deep-drawing it is needed to define the interval of temperatures at deep-drawing because EP-additives become independently effective only from certain temperature and it will not be logical to develop lubricants with EP additives for low forming temperatures in deformation zone. At deep drawing, temperature generates in the consequence of deformation work and contact friction in the forming zone. This temperature [1] at drawing the auto body panels made of conventional low carbon steels intended for deep drawing can be to 60^{o} C and pressure of blank holder to 5,5 MPa. At drawing of high strength steel sheets temperature is to 100^{o} C and pressure to 20 MP.

μ



Temperature °C

Fig. 1 Dependence of friction coefficient on temperature at mineral oils with various additives: 1 - mineral oil, 2 - polar active substance, 3 - mineral oil with EP - additives, 4 -mineral oil with EP additives and with polar active substances [1]

2. MEASUREMENT AND EVALUATION OF FRICTION RATIOS AT DEEP DRAWING

In relation to the aims of the project the cup test was used for evaluation of lubricity. The characteristics of cup test (drawing force, limiting drawing ratio) react sensitively on the change of deep drawing conditions. For modelling of contact surfaces loading, four various blank diameters were used in the under-critical area (area without failure $D_{max} > D_1$=55 mm, D_2 = 60mm, D_3 = 65 mm, D_4 = 70 mm) and one diameter in the above critical area (area of failure of cup, $D_{max} < D_5$ = 80 mm).

For experimental research these steel sheets were used: KOHAL 180 – S1, ZStE 220 P – S2, ZINKOHAL 220 – S3 and stainless sheet – S4. Measured values of surface microgeometry parameters of investigated sheets in directions 0^0 and 90^0 to rolling direction are given in Tab.1. The chemical composition and mechanical properties of used materials are given in [2].

Tab. 1 Characteristics of surface microgeometry of investigated sheets

Material	Ra [μm]		Rmax [μm]		Number of peaks Pc [Pc/1cm]		Bearing share $t_{pi75\%}$	
	0^0	90^0	0^0	90^0	0^0	90^0	0^0	90^0
S1	1,45	1,09	10,41	8,28	28	30	8,08	6,37
S2	1,17	1,24	8,81	8,98	28	27	4,77	5,6
S3	1,31	1,25	8,06	9,08	30	30	5,68	5,3
S4	0,18	0,16	2,49	1,95	0	0	1,3	0,68

For experimental research the lubricants frequently applicated in the Slovak stamping shops were used:

ANTICORIT RP 4107 S with kinematic viscosity 36 mm^2/s at temperature 40^0C is oil for protection against corrosion without barium. In comparison to conventional oils it reaches the optimum stability of film on perpendicular surfaces.

ANTICORIT PL 3802-39 with kinematic viscosity 30 mm^2/s at temperature 40^0C is oil not only for protection against corrosion, but also lubricant for forming - so called prelube oil. It does not contain Cl, Zn, Ba and therefore its removing is without problem.

FERROCOAT N 6130 with kinematic viscosity 26 mm^2/s at temperature 40^0C is mixture of mineral oils, synthetic esters and additives.

FOIL was used as ethalon lubricant ($\mu_{e0} \approx 0,05$) at assuming that foils are the best lubricants.

without lubrication - surface of die was degreased.

Other conditions of implementation of deep-drawing process of cylindrical cups are given in Tab. 2. Example of evaluation is given in Fig. 2. Limiting drawing ratio K_{max} enables us in the more complex way to evaluate the lubricity. Maximum blank diameter or limiting drawing ratio $K_{max} = D_{maxi,j}/d$ can be determined from the dependence of drawing force Fz_{ij} on blank diameter and force required for failure of cup $FL_{i,j}$ -Fig.2. Limiting drawing ratio K_{max} enables us to include also the influence of friction ratios in deformation zone and also in the zone of transport of forces (in the critical area). Measured values of drawing forces and calculated values η_{ij} and μ_{ij} are given in Tab.3

Tab. 2 Conditions of experiment

Material of die	19 732 die steel according to Slovak Standard
Material of blankholder	12 061
Material of punch	19 732
Diameter of punch with flat bottom	32,85 mm
Diameter of punch with hemispherical bottom d	33,84 mm
Radius of die edge of punch with flat bottom	4,5 mm
Radius of die edge of die	4,5 mm
Clearance - flat bottom(hemisph.bottom)	1,57 (1,075) mm
Sheet metal thickness	0,8 and 1 mm
Roughness of punch with flat bottom	Ra = 0,8 μm
Roughness of punch with hemispherical bottom	Ra = 0,8 μm
Roughness of die	Ra = 0,4 μm
Amount of lubricant	7 g/m^2

The efficiency of change of friction ratios η_{ij} at using lubricant is expressed by ratio of drawing force $F_{z\,i,j}$ obtained at use of i-lubricant to force $F_{z\,e,j}$ obtained at use of ethalon lubricant [2]:

$$\eta_{i,j} = \frac{Fz_{i,j}}{Fz_{e,j}} \qquad (1)$$

Total drawing force consists of components of force for deformation and components of friction forces – Fig.3:

$$Fz_{ij} = Fzid_j + T_{1i,j} + T_{2i,j} \qquad (2)$$

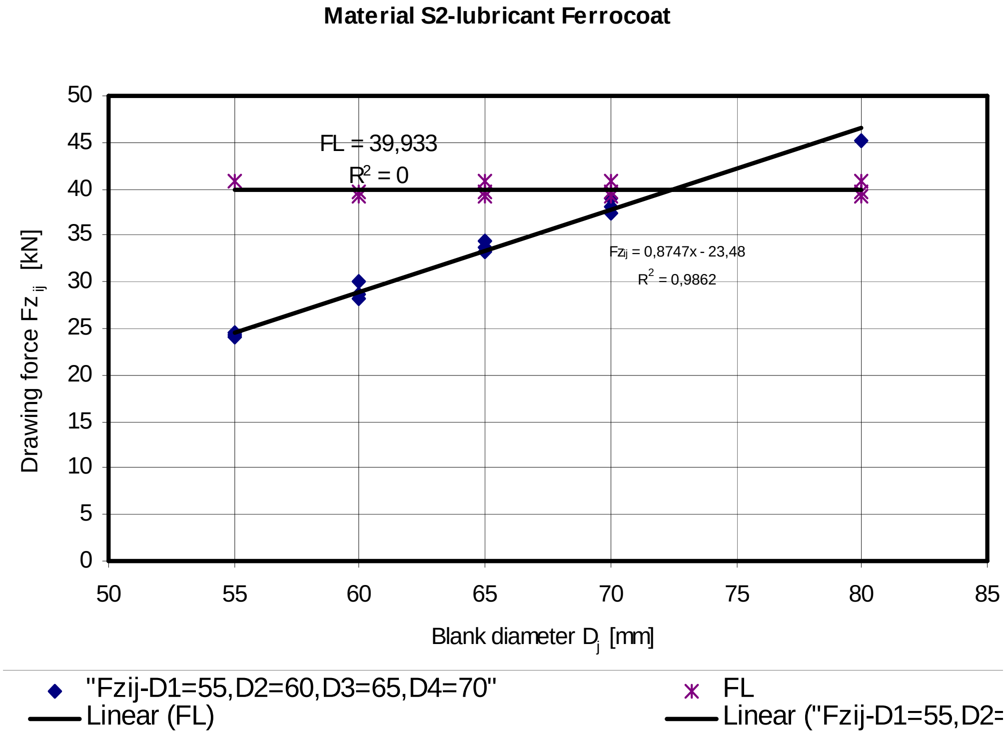


Fig. 2 Dependence of drawing force $F_{Zi,j}$ on blank diameter $D_{i,j}$ at material S2

Total drawing force is sum of drawing force at use of ethalon lubricant and friction forces (their increment or decrement):

$$Fz_{i,j} = Fz_{ej} + T_{1ij} + T_{2ij} \qquad (3)$$

where:

$Fz\,id_j$ – ideal drawing force (force for deformation)
Fz_{ij} – total drawing force
$Fz_{e,j}$ – drawing force at the use of ethalon lubricant (foil)
$T_{1i,j}$ – friction force betwen blankholder-steel sheet-die
$T_{2i,j}$ – friction force on drawing edge of die

$T_{3i,j}$ – friction force between sheet and cylindrical part of die (if drawing gap is higher as sheet thickness than its value is zero)

$T_{4i,j}$– friction force on drawing edge of punch (this force has positive influence on formability)

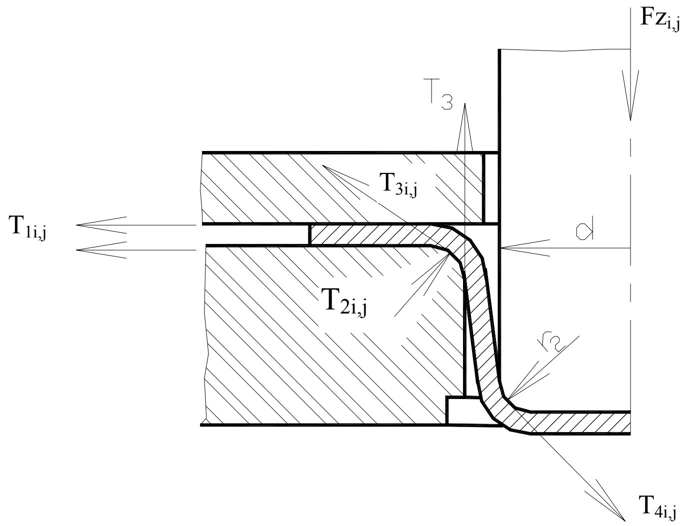


Fig. 3 Scheme of friction forces at deep drawing

After expressing the components of friction forces and arrangement we obtain the increment of friction coefficient:

$$\Delta\mu_{ij} = \frac{\eta_{ij} - 1}{1{,}16 + k} \tag{6}$$

where: $k = Fp_{ij} / F_{z\,i,j} = 0{,}1$

F_p - blankholding force

then the total friction coefficient is:

$$\mu_{ij} = \mu_{ej} + \Delta\mu_{ij} \tag{7}$$

Tab. 3 Measured values of drawing forces and calculated η_{ij} and μ_{ij}

M	D_i	Drawing force $Fz_{zi,j}$ [kN]	$\eta_{i,j}$	Friction coefficient

	[mm]	Used lubricant									$\mu_{i,j}$			
		1	2	3	4	5	1	2	3	5	1	2	3	5
S1	55	20,01	19,115	20,300	18,820	20,320	1,06	1,02	1,08	1,08	0,1	0,06	0,11	0,11
	60	23,82	23,219	24,092	22,394	24,287	1,06	1,04	1,08	1,08	0,1	0,08	0,11	0,12
	65	27,62	27,322	27,883	25,967	28,253	1,06	1,05	1,07	1,07	0,1	0,09	0,11	0,12
	70	31,43	31,426	31,675	29,541	32,22	1,06	1,06	1,07	1,07	0,1	0,1	0,11	0,12
	80	35,10	35,2	34,953	34,367	35,283	-	-	-	-				
	D_{max}	75	75	74	77	73								
S2	55	23,85	24,502	24,349	23,690	25,056	1,01	1,03	1,03	1,08	0,06	0,08	0,07	0,1
	60	28,68	29,207	28,993	27,999	30,056	1,02	1,04	1,04	1,08	0,07	0,08	0,08	0,11
	65	33,5	33,912	33,636	32,307	35,056	1,04	1,05	1,04	1,09	0,08	0,09	0,08	0,12
	70	38,33	38,617	38,28	36,616	40,056	1,05	1,06	1,05	1,09	0,09	0,09	0,09	0,12
	80	39,76	40,07	39,93	39,1	39,4	-	-	-	-				
	D_{max}	71	71	71	72	69								
S3	55	19,41	19,013	19,692	16,451	19,333	1,18	1,16	1,2	1,18	0,19	0,17	0,21	0,19
	60	23,11	23,298	23,756	20,41	24,083	1,13	1,14	1,16	1,18	0,15	0,16	0,18	0,19
	65	26,81	27,583	27,819	24,368	28,833	1,10	1,13	1,14	1,18	0,13	0,15	0,16	0,2
	70	30,51	31,868	31,883	28,327	33,583	1,1	1,12	1,13	1,19	0,11	0,15	0,15	0,2
	80	35,09	35,22	34,933	34,362	35,633	-	-	-	-				
	D_{max}	76	74	74	78	72								
S4	55	34,66	36,283	35,423	30,562	35,079	1,13	1,19	1,16	1,15	0,16	0,2	0,18	0,17
	60	44,54	46,333	45,54	39,704	45,413	1,12	1,17	1,15	1,14	0,15	0,18	0,17	0,16
	65	54,42	56,383	55,656	48,845	55,746	1,11	1,16	1,14	1,14	0,14	0,17	0,16	0,16
	70	60,66	60,36	61,6	56,083	61,267	-	-	-		-	-	-	-
	D_{max}	68	67	68	69	68								

3. CONCLUSIONS

Obtained results are following:

1. Parameter $\eta_{i,j}$ enables us to express the lubricity in given conditions of deep drawing (deformation, drawing speed, microgeometry of contact sorfaces) because it is derived from technological characteristics of deep drawing process.
2. Friction coefficient $\mu_{i,j}$ or its increment in relation to ethalon $\Delta\mu_{i,j}$ can be used directly at numerical simulation as input parameter. By this way determined friction coefficient values for single lubricants enable us to improve the recommended values of friction coefficients given in manuals Tab.- 4 [3].

Tab. 4 Values of friction coefficients recommended for various friction couples

Material of friction couple	Friction coefficient μ	
	Dry surface	Lubricated surface
Steel – steel	0,15	0,05 – 0,15
Steel – cast iron	0,18	0,05 – 0,15
Steel – brass	0,15	0,1 - 0,15
Cast iron – brass	0,15	0,07 – 0,15
Brass – brass	0,2	0,07 – 0,2

3. With regard to constantly increasing application of zinc-coated sheets for stampings (automobile industry, consumption goods) obtained results spread the database of friction coefficients for friction couple steel - zinc.

Acknowledgement
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MERENJE I ANALIZA TRENJA KOD DUBOKOG IZVLAČENJA

Evin Emil, Hrivnák Andrej, Tkáčová Jana

REZIME

Pravilan izbor sredstva za podmazivanje je jedan od veoma važnih uticajnih parametara na konačan ishod procesa. Sredstvo za podmazivanje mora da ispuni jedan broj zahteva od kojih su najvažniji: smanjenje trenja kao i deformacione sile, povećanje ravnomernosti deformisanja, povećanje obradivosti, povećanje veka alata, zaštita lima od korozije. Pored toga sredstvo za podmazivanje treba da ima osobinu lakog nanošenja pre i lakog odstranjivanja nakon deformacije. Ovim uslovima treba dodati i ekonomski aspekt kao i aspekt zaštite čovekove sredine. Ovaj rad, koji je nastao u okviru istraživanja na evropskom projektu "ENFORM IC15-CT 98-0824", obrađuju problematiku vezanu za maziva sredstva kod dubokog izvlačenja, imajući u vidu pre svega zahteve zaštite čovekove sredine.

Istraživani su sledeći slučajevi podmazivanja:

1. *Anticovit RP 4107 S sa kinematskom viskoznošću od 36 [mm^2/s] na temperaturi od 40^{o}C*
2. *Anticovit PL 3802-39 sa kinematskom viskoznošću od 30 [mm^2/s] na temperaturi od 40^{o}C*
3. *Ferrocoat N 6130 sa kinematskom viskoznošću od 26 [mm^2/s] na temperaturi od 40^{o}C*
4. *Folija je korišćena kao etalon sredstvo (μ_e = 0,05)*
5. *Bez podmazivanja*

Autori uvode parametar η_{ij} i definišu ga kao:

$$\eta_{ij} = \frac{F_{Zij}}{F_{Zej}}$$

F_{Zij} – sila dubokog izvlačenja za analizirani slučaj

F_{Zej} – sila dubokog izvlačenja za slučaj etalona (folija)

Kao rezultat rada određene su vrednosti koeficijenta trenja za različite kombinacije partnera u procesu trenja

Obzirom na sve veću primenu pocinkovanih limova (automobilska, prehrambena industrija, ...), dobijeni rezultati daju doprinos proširenju banke podataka za kombinaciju partnera čelik – cink.