

RESEARCH OF THE EFFECT OF LUBRICATION ON EXTRUSION LOAD IN DIRECT EXTRUSION

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Abstract: Direct extrusion shaping creates friction on the tool surfaces due to relative motion of the tool materials. Friction increases the necessary extrusion force and causes extrusion faults by changing the material flow mechanism. A number of parameters affect the magnitude of extrusion force. Being one of these parameters, the lubrication effects the friction and therefore defines the extrusion force in friction.

In this study, the effect of lubrication on the extrusion force is theoretically and experimentally studied. In the experiments done, the parameters such as extrusion ratio, die angle and lubrication are changed and the extrusion forces are determined while the other parameters are kept constant. After a sufficient and homogeneous lubrication, the material flow becomes steady and uniform and the extrusion force is reduced.

Keywords: Extrusion, Load, Lubrication

1 INTRODUCTION

In plastic forming processes, there is always a friction formed between the tool and the material. This friction increases the shaping load and decreases the efficiency. In the extrusion processes, the friction becomes more important and effective due to the relative motions of the tool and the materials respect to each other. Friction forms deviations in material flow which causes various extrusion products. Friction also increases the necessary extrusion load. It, therefore necessitates the use of more powerful presses and causes increases in the tool dimensions.

The effect and the degree of friction changes according to the extrusion methods used. A higher friction is formed in direct extrusion, a lower friction is formed in indirect extrusion while no friction in the hydrostatic extrusion processes (Figure 1).

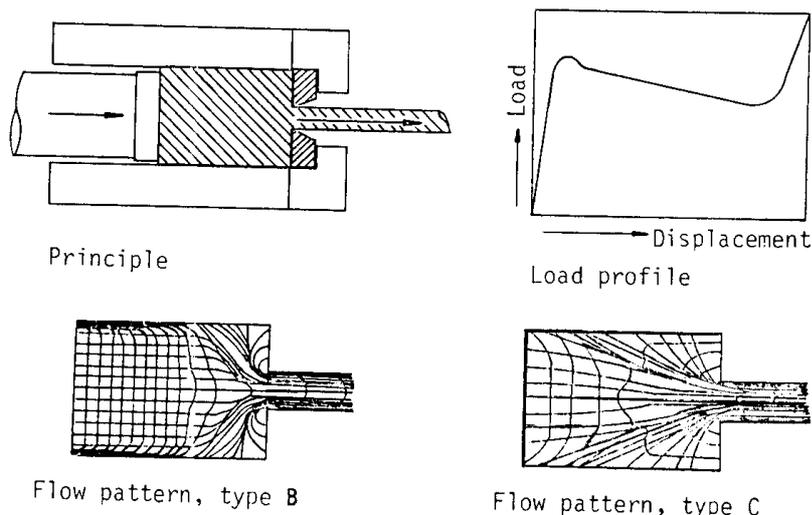


Figure 1. Direct extrusion

The friction force and coefficients change depending on the friction mechanism applied (sliding, adhering and rolling frictions) and the other related parameters. In plastic forming, the friction formed between the tool and materials is shown by t which is defined as the sliding stress in a unit contact

area. Since the area of contact between the tool and the material, determines the boundaries of the material, the friction resistance and the sliding stress can be evaluated together.

Friction mechanics is highly complicated science and many researches have been carried out on this topic. Fundamental assumptions of friction have been taken into account to obtain mathematical formulatýon. of the friction improved friction assumptions can be expressed as coulomb friction coefficient, constant friction factor and hydrodynamic lubrication.

Lubrication is the most efficient method in order to reduce the negative effects of friction. Lubrication provides a uniform material flow thus decreases the extrusion force required for the process and increases the tool life. However a lubricant which is suitable to the properties of extrusion material and the extrusion temperature should be selected and a homogeneous lubrication should be applied. Otherwise various extrusion faults can occur during process.

In this study, the effect of lubrication on the extrusion force and the material flow is studied by using a % 99.99 pure lead in the cold extrusion - experiments in lubricated and unlubricated conditions.

1.1 The effect of friction on extrusion load

The construction of the press and the tool and the calculation of the extrusion load is an important factor in evaluation of the shaping energy and the cost of the process. The parameters such as extrusion material, extrusion ratio, temperature, die hole angle, lubrication billet dimension ratio and extrusion rate affect the extrusion load. Of these parameters, the lubrication, billet dimension ratio and die angle affect the friction which on return affect the extrusion load.

The variation of extrusion load along the ram displacement and the work consumed during shaping process in the extrusion process is shown in Figure 2. The work A is consumed for filling the billet into the container, the pressing of the billet, elastic shaping of tools and for very small surface movements of the billet. The work B is consumed to start the flow of material by overcoming the friction between the billet and the dead region. The work C is consumed for overcoming the friction from the start of the flow to the end of the process. The work D is consumed for shaping of the material. A suitable and homogeneous lubrication reduces the frictions formed in the areas of B and C considerable.

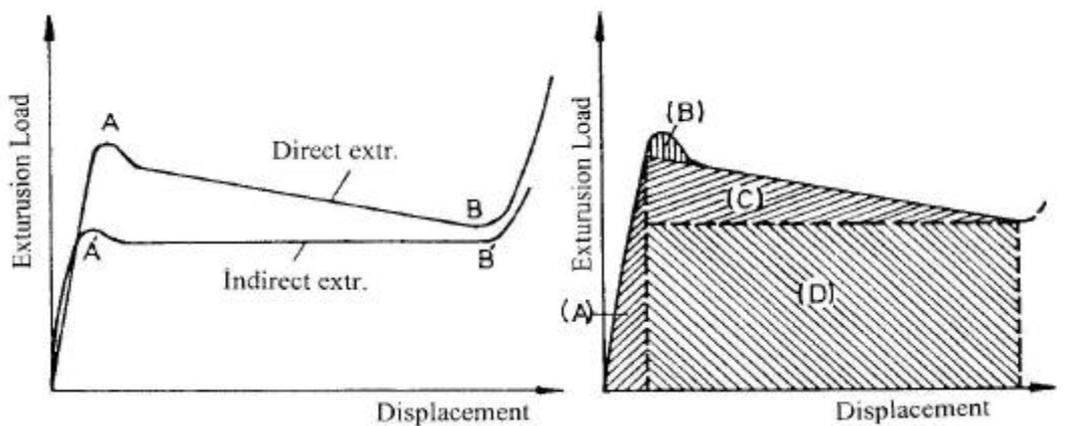


Figure 2. Load profile and the work assumed for direct extrusion.

Many methods have been developed to calculate extrusion load. Effectiveness of those methods depends on analysis of the methods, theoretical approaches and sensitivity of the results. It is a known fact that elementary analysis is the most important method amongst others since it is easy to approach and to apply for a case.

Total extrusion load can be defined as follows by means of elementary analysis method and assumption of coulomb friction coefficient:

$$F_t = A_0 \times \mu \times k_d + \pi \times D_0 \times L_0 \times \mu \times k_f$$

A_0 : Billet section, μ : Coulomb friction coefficient, D_0 : Billet diameter,
 k_f : Yield stress, L_0 : Billet length, k_d : Deformation resistance

Where the first term is a load to express deformation of material, internal friction and die friction. The second term can be described as a force between billet and the containers. μ can be defined as an effect of friction factor on friction force and depends on material type and lubricating condition. If

homogeneous lubrication is provided μ is taken as 0.05 \pm 0.15 at low temperature, otherwise μ is assumed between 0.35 and 0.45 without lubricating.

1.2 Lubrication

The effect of friction on the material flow and the extrusion load can be reduced partly or completely by applying a suitable and homogeneous lubrication. Thus a more uniform material flow can be obtained and the extrusion load is reduced. Meanwhile the wearing of the tool surfaces becomes minimum and a better surface quality of the products is obtained. In the extrusion process of Al profiles without lubrication the friction loss can reach to % 35 and the extrusion load is increased by % 50 [6].

In the extrusion applications of Al , the lubricants are used die lubricant, lubricant-graphite mixture, molybdenumdisphide, soft soap and wax, the latter two are used tube extrusion. Copper oxide is a very efficient lubricant for extrusion of the copper alloys. Calcium grease is used for extrusion of Cu alloys and Pb and also used in the cold extrusion process.

Different methods are applied in order to solve the problems occurred by friction and temperature in the hot extrusion process. These methods are cold extrusion, hydrostatic extrusion and glass lubricated extrusion. In all of these methods, a uniform and lubricated material flow are observed. In the cold extrusion of Al alloys the fat and sulphur mixture can provide good results and coating of the billet with zinc-phosphate is suggested. Since many of the lubricants lose their properties at high temperatures, glass is used as a lubricant material. T. Altan and co-workers have used glass as a lubricant for the extrusion of steel at 1000°C and obtained good results. Glass lubricant is coated on the surface of billet by dipping and rolling [8].

It is also suggested by the researchers that the materials having high plasticity properties can be used as lubricants for the materials having very low plasticity properties.

2 EXPERIMENTAL STUDY

In this study, % 99.99 lead is used in the extrusion experiments by using direct cold extrusion methods using conical die. A hydraulic press of 500 tons having % 2 accuracy is used in the experiments. The faulty results occurred during material flow are observed by inspecting the process at different extrusion conditions.

2.1 Experimental specimens

The specimens are prepared from % 99.99 purity soft lead. The billets of 60 mm diameter and 90 mm length (L/Do = 1.5) are obtained in cylindrical form and separated along the symmetry plane. A web of coordinate grid –lines are dented on both surfaces of the pieces in 0.5 mm depth and 0.6 mm width each being 5mm apart. The coordinate grid-lines are then filled with fine graphite powder and the separated two pieces of specimen are put together in its original form.

Table 1. Experiment Conditions

Material	Extrusion Ratio	Die Angle		Extru.Velocity (mm/s)	Lubricant
		Lubrication	Unlubrication		
Pure Lead	10	30 ⁰ , 60 ⁰ , 75 ⁰ , 90 ⁰ , 120 ⁰	30 ⁰ , 60 ⁰ , 75 ⁰ , 90 ⁰ , 120 ⁰	1	Calcium Grease
% 99,99	5	30 ⁰ , 60 ⁰ , 75 ⁰ , 90 ⁰ , 120 ⁰	30 ⁰ , 60 ⁰ , 75 ⁰ , 90 ⁰ , 120 ⁰	1	

2.2 Experimental conditions

In order to study the effect of lubrication on the extrusion force and the material flow , 30 experiments are designed at lubricated and unlubricated conditions with different extrusion ratios and at different die conical angles at ambient temperature. The experimental results are given in Table 1. In lubricated experiments, calcium grease is spread on the die surface and die bed , on the front plate and container surfaces. In the unlubricated experiments, all of these surfaces are cleaned with cleansing agent petrol and all of the lubricant is removed completely. The specimens are extruded to 50 mm only.

2.3 Experimental results

The material flow lines present on the extruded billets are taken as photographs and the load-displacement diagrams are plotted. The effects of the process parameters on the extrusion load and material flow are inspected.

Table 2. Extrusion Loads are obtained by the experiments

Extrusion Ratio	Die Angle	Extrusion Load (kp)	
		Lubrication	Unlubrication
10	30°	42600	48300
	60°	41400	45050
	75°	39900	44400
	90°	37400	44200
	120°	39800	44700
5	30°	34550	41400
	60°	33200	40800
	75°	30350	38900
	90°	20800	38400
	120°	29800	40300

The effect of the lubrication is especially concentrated on the flow lines and sliding regions when compared to the unlubricated case. Since the friction in the container the material flow at the circumference of the billet is resisted and sliding occurs. The friction at the die surface and the die bed increased the dead region which caused the the amount of remaining material. In the unlubricated extrusion experiments, the deviations in the material flow also effect the extrusion load. The extrusion load required and the load consumed for friction becomes greater in the unlubricated case compared to the lubricated experiments. The load decreases with increase in the die angle until the die angle is 120° and the load starts increasing with the die angle after this value (Figure.3 and Table 2). With 120° die , dead region is formed also on the surface of the die bed which increases the friction and the extrusion load.

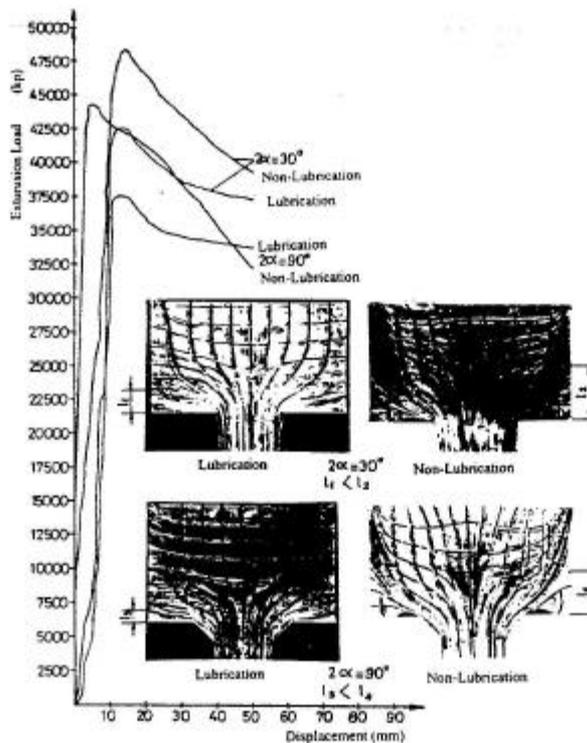


Figure 3. Effects of lubrication and die angle on extrusion load and material flow in direct extrusion.

3 CONCLUSION

1. In unlubricated process, the friction distorts the uniformity of material flow and increases the extrusion load.
2. In unlubricated process, the dead region grows and the remaining material increases.
3. In both lubricated and unlubricated processes, the flow deviates from ideality as the die angle decreases which also increases the extrusion load, whereas when the die angle increases, flow becomes uniform and the load is reduced.
4. When friction is reduced by lubrication, the lowest extrusion load and the most suitable material flow are obtained with 90° die angle.

According to the results obtained, the uniformity of material flow and the minimum value of the extrusion load are to be obtained when a suitable lubricant is selected and applied homogeneously.

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