An Experimental Study of The Effect of Process Parameters on The Extrusion Pressure and its Impact on The Die Life

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Abstract: In this work an experimental study of the effect of process parameters on the extrusion pressure and its impact on the life of a hollow die having a bearing shape of roman section/Channel is carried out. The aluminium used here is of a grade 6061-O and the die material of high density steel. Upon extrusion of aluminium from the die- variable factors (Temperature, pressure, lubrication, die angle) affecting the life of the die are noted down and a brief analysis is carried out. A relationship is determined between the experimental and the theoretical data.

Index Terms: Extrusions, aluminium, die life, extrusion pressure, theoretical model, Boron nitride aerosol, extrusion temperature.

1. INTRODUCTION:

Extrusion is a process used to extrude and create objects of a fixed cross sectional profile. Extrusion dies are used in the process of extrusion and classified into two types- Hollow and solid dies. In this particular experiment of extrusion process we use a hollow die with a bearing area of 115.37mm2. The various apparatus and equipment used in the extrusion process consists of a horizontal extrusion press.straightners, billet heaters, die heater, die oven, lubricant and support tools. The lubricants used to calculate the difference and change in die life are- boron nitride aerosol and standard graphite solution. The life of the die could also be maximised by reducing extrusion pressure by varying the other parameters. A theoretical determination of analysis could be obtained by an equation which includes the yield strength of aluminium and other factors. The practical value is analysed by considering the live data which includes the extrusion temperatures and ideal pressure of the hydraulic fluid of the press. The final theoretical and practical values are used to calculate the extrusion pressure and hence deduce the change in die life.

2. EFFECT OF LUBRICANT ON THE EXTRUSION PROCESS:

2.1 Graphite

The most widely used lubricant for aluminium extrusion is Graphite solution having properties which exhibit high temperature and oxidising effects. They contain jellying agents and fungicides.Graphite solution causes emission of black smoke which is evident at high working temperatures; it is also observed that the frictional coefficient of lubricant increases with the increase in temperature. It is structurally composed of plains of polycyclic carbon atoms that are hexagonal in orientation and is best suited for lubrication in a regular atmosphere. Water vapour is a necessary component of the graphite solution because it reduces the bonding between hexagonal plains of graphite to a lower level than the adhesion energy between substrate and the graphite. Graphite is characterised into two main group's: Synthetic graphite which is a high temperature sintered product and natural graphite it is derived from mining and has an ore quality.The higher the carbon content and the degree of graphitisation the better the lubricity and resistance to oxidation.

2.2 Boron nitride

Boron nitride is an excellent dry lubricant that maintains its lubrication properties even under extreme conditions. It is a solid lubricant. Boron nitride has platelet like micro-structure. Its low co efficient of friction is due to the fact that the platelets slide easily upon one another. Of all solid lubricants, Hexagonal boron nitride has the highest temperature resistance in air. It can be used at high temperature such as 9000C. Other lubricants suffer oxidation at much lower temperature. Boron nitride's co-efficient of friction remains virtually unchanged over wide temperature range. It is far superior to other lubricants especially at high temperature. The boron nitride active ingredient is a fine particle size of the hexagonal form of the compound. It is naturally lubricious and stable even at elevated temperature in aggressive environments. The inert and non-wetting nature of the boron nitride particles makes it an excellent surface coating for used in Aluminium extrusion.

Thegraph [Fig 1] depicts the variation of coefficient of friction with respect to the rise in temperature. It indicates that at elevated temperature, the co-efficient of friction of boron nitride aerosol decreases whereas the co-efficient of friction of

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graphitesolution increases. Hence, the wear rate decreases on the use of boron nitride aerosol.

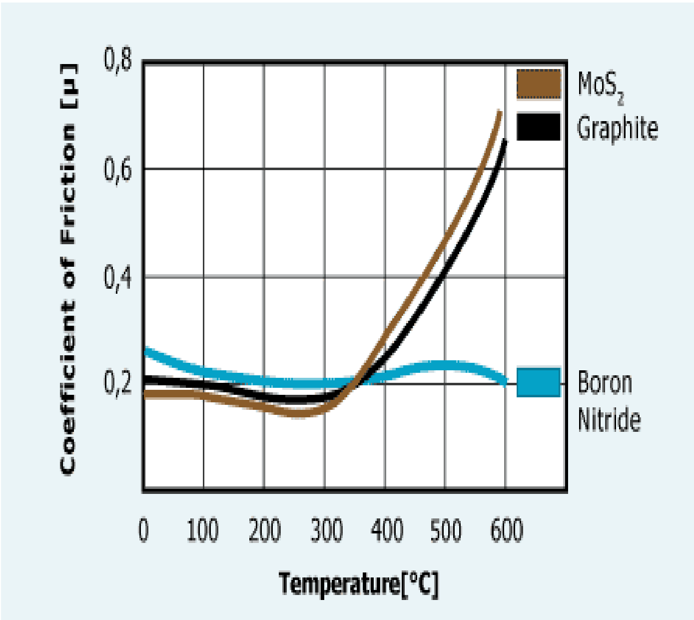

Fig 1: Temperature vs Coefficient of Friction graph for Boron Nitride and Graphite.

Temperature	BrNi(μ)	Graphite (μ)
420°C	0.21	0.25
460°C	0.23	0.31
480°C	0.25	0.36
520°C	0.25	0.36
560°C	0.23	0.51
600°C	0.20	0.63

Table 1.Temperature vs Coefficient of Friction table for Boron Nitride and Graphite.

3. Experimental Study under real life conditions:

The specifications of the apparatus used in this experiment are-

1) Hydraulic press-20 tons

2) Straighteners- manual

4) Billet - Aluminium 6061-O.

Length-21cm

Diameter-9cm

Area-63.58cm2

5) Billet heater- Oil fire type

6) Die oven- Baffled oven type.

7) Lubricant- Boron nitride aerosol.

Type of Die: Hollow Die

Bearing area-115.37mm2.

Weight-1.14kg/cm2|

Material- High density steel.

3.1 Practical analysis of extrusion pressure:

The practical analysis is carried out with the aid of live readings obtained while performing extrusion. The indicative values obtained here are ideal pressure/fluid pressure,which is the pressure exerted on the ram, Billet temperature is in the range of 4200C – 6000C and coefficient of friction(μ) could be obtained from the graph for relative temperatures accordingly .The die angle and the reduction ratio are constant. The equation for determining the extrusion pressure is :

Extrusion pressure(Pt) at various temperatures= load on piston/area of billet

Load on piston at given temperature= Pr*Area of piston

1. Diameter of piston(D)= 8cm
2. Area of piston- π/4)D2= 50.26cm2
3. Die angle(α)= 830
4. Area of billet(ab)= 63.58cm2
5. Load on piston at given temperature= Pr x Area of piston

420oC – 235 x 50.26= 11806.4kg

460oC- 220 x 50.26= 11057.2kg

480oC- 200 x 50.26= 10052kg

520oC- 190 x 50.26= 9549.4kg

560oC- 180 x 50.26= 9046.8kg

600oC- 150 x 50.26= 7539kg

6. Extrusion pressure(Pt) at various temperatures= load on piston/area of billet.

Pt at 420oC- 11806.4/63.58 = 185.69kg/cm2

Pt at 460oC- 11057.2/63.58= 173.9kg/cm2

Pt at 480oC- 10052/63.58 = 158.1kg/cm2

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Pt at 520oC- 9549.2/63.58 = 150.1kg/cm2

Pt at 560oC- 9046/63.58 = 142.2kg/cm2

Pt at 600oC- 7539/63.58 = 118.5kg/cm2

Bearing cross-sectional area(at) = 11.5cm2

3.2Theoretical analysis of extrusion pressure:

Extrusion pressure is determined by the equation **Pt = (yt [1+ Tanα/μ](-rμcotα-1))** here the value of r (the reduction ratio) which is the area of cross section area of the billet/cross sectional area of the bearing. The reduction ratio is constant throughout the process of extrusion. The variation of yield strength of aluminium with the rise in temperature is the prime factor effecting the extrusion pressure,which varies from 2.0MPa – 6.8MPa over a range of temperature varying between 4200C – 6000C.The extrusion process is carried out with the die set up at an angle of 830 which remains constant throughout the process. The coefficient of friction of boron nitride aerosol which is a variable parameter varying from 0.20 - 0.25 over a range of temperature varying between 4200C – 6000C.

Temperature	Yield Strength (MPa)
420^0C	6.80
460^0C	5.58
480^0C	4.82
520^0C	3.91
560^0C	2.64
600^0C	2.00

Table 2: Temperature vs Yield Strength table

3.3Reduction ratio(r) = ab/at

= 63.58/11.5

r = 5.52

Pt = (yt [1+ Tanα/μ](-rμcotα-1))

3.4 Calculations

Extrusion pressure at various values of yt and μ(boron nitride aerosol) is obtained below as per the above equation.

- At T=420^oC;

yt=6.8; μ=0.21;

Pt = (6.8[1+ Tan83/0.21](-5.52 (0.21)(cot83)-1))

= 270.52 – 2.04

= 268.47kg/cm2.

- At T=460oC;

yt=5.58; μ=0.23;

Pt = (5.58[1+ Tan83/0.23](-5.52 (0.23)(cot83)-1))

= 203.16 - 1.04-1

= 201.12kg/cm2.

- At T=5200C;

yt=3.91; μ=0.25;

Pt = (3.91[1+ Tan83/0.25](-5.52 (0.25)(cot83)-1))

= 131.28 – 1.05-1

= 129.23kg/cm2

- At T=480oC

yt=4.82; μ=0.25;

Pt = (4.82[1+ Tan83/0.25](-5.52 (0.25)(cot83)-1))

= 161.84 – 1.05-1

= 159.79kg/cm2.

- At T=560oC;

yt=2.64; μ=0.23;

Pt = (2.64[1+ Tan83/0.23](-5.52 (0.23)(cot83)-1))

= 111.84 – 2.04

= 109.80kg/cm2.

- At T=600oC;

yt=2.00; μ=0.20;

Pt = (2.00[1+ Tan83/0.20](-5.52 (0.20)(cot83)-1))

= 97.14 – 2.04 = 95.10kg/cm2.

3.5 Comparison between analytical and practical approach of studyat various temperatures:

Temperature	P_t(Theoretically obtained)	P_t(Practically-Obtained)
420^{0}C	268.47kg/cm^2	185.69 kg/cm^2
460^{0}C	201.12kg/cm^2	173.9 kg/cm^2
480^{0}C	159.79 kg/cm^2	158.1 kg/cm^2
520^{0}C	129.23 kg/cm^2	150.1 kg/cm^2
560^{0}C	109.80 kg/cm^2	142.2 kg/cm^2
600^{0}C	95.10 kg/cm^2	118.5 kg/cm^2

Table 3

- The below graph represents the theoretical and practical values of extrusion pressures obtained at various temperatures:

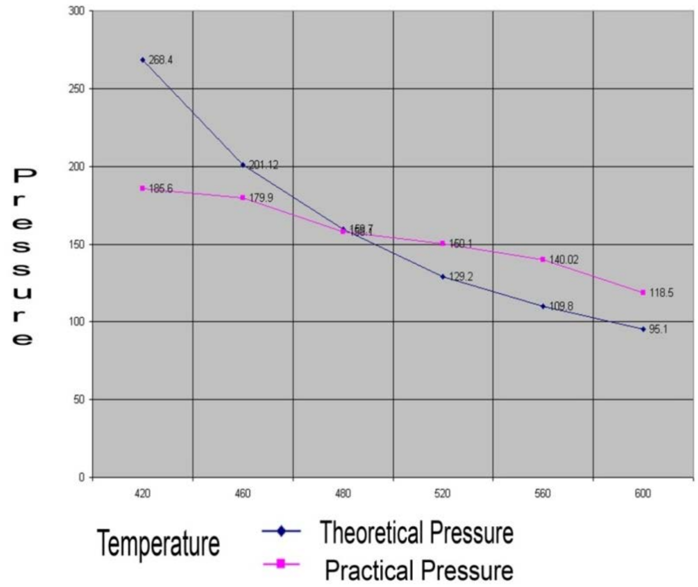

Fig 2: Pressure vs Temperature graph comparing Theoretical and Practical pressure

Temperature in ^{o}C

Pressure in Kg/cm

4. Conclusion

- From the observed data, we can conclude that Extrusion process could be carried out at a temperature between 5200C and 5600C for a minimum extrusion pressure.
- At 5600C the pressure ofextrusion is lowest.
- Life of the Die can be improved by maintaining a constant pressure(obtained from the data) and by applying Boron Nitride aerosol as a Lubricant.
- The temperatures suggested here are for a specific bearing area. However this range is suitable for extruding large varieties of hollow channels.
- The usage of boron nitride decreases the smoke emission which helps in reduction of air pollution.

The variation in the pressures observed in the comparison between the theoretical and practical analysis is due to variation in the operational conditions and the ambient temperatures.

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