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Effects of geometrical and material parameters on rod extrusion process

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ABSTRACT

In this study, effects of die angle and billet and die materials on stresses, deformation, load requirement and die yielding in rod extrusion process are studied using simulation techniques. Based on these results, rod extrusion process can be optimized to reduce load requirement and die failures. © 2015 Trade Science Inc. - INDIA

KEYWORDS

Extrusion;
Stress;
Strain;
Yielding;
Finite element.

INTRODUCTION

Extrusion is an important metal forming process having wide application in industrial and domestic sectors[1]. Some of the common extrusion products are rods, tubes, channels, I sections etc. A good quality extruded product results after optimizing process, geometrical & material parameters. Geometrical parameters are die angle, extrusion ratio, Material parameters are die and billet material strengths. Processing parameters are friction, temperature and production speed. Laboratory experimentation of extrusion considering these parameters are difficult and time consuming. Application of FE simulations of extrusion process is getting wide popularity in recent years due to its ease, economy and short duration.

Gouveia et al[2] carried out finite element analysis of cold forward extrusion using both the updated Lagrangian and the combined Eulerian-Lagrangian finite element formulations. Lee. et al.[3] reported a three-dimensional steady-state finite element analysis of square die extrusion by using automatic mesh generation. Knoerr. and Altan[4] conducted finite element analyses of extrusion using commercial software DEFORM in order to obtain information of metal flow, temperature, strain, and stress for more effective die and process design. Lee Geun-An et al[5]. presented the finite element investigation of the wear and elastic deformation of dies in metal forming. Hur K.D. et al.[6] presented a design method for cold backward extrusion and proposed a design method that makes the elastic deformation of the pre stressed die as small as possible for precision cold forging. Ales Mihelic et al.[7] reported their investigation on tool design optimization for steady-state extrusion process, using finite element discretization and non-linear mathematical techniques. Ventaka Reddy et al.[8] analysed axi-symmetric steady state cold tube extrusion of strain hardening material using Galerkin finite element formulation. Li et al.[9] studied hot extrusion of titanium aluminum alloy using FEM and experiments.

Although large number of literature on the topic are available, integrated study combining effects of geometrical and material parameters are rare. In this study, effects of these parameters on rod extrusion process are studied using simulation techniques. Effects of die angles, material and billet strengths on stress strain distributions, load requirements and die yielding are critically examined.

GEOMETRY

Three half die angles considered in the study are 30^0, 45^0 and 60^0. The billet and rod diameters are 80 and 40 mm respectively. In this way extrusion ratio is 4. The thickness of the top die wall is 20 mm.

MATERIAL PROPERTIES

Following material properties for die and billet are considered-

(a). Billet

(a). Yield strengths: 60,80,120 MPa
(b). Hardening exponents: 0

(b). Die

(a). Yield strengths: 800,1000,1200 MPa
(b). Hardening exponents: 0

Both materials are modeled as rigid plastic.

FINITE ELEMENT SIMULATION

Considering varying geometrical and material parameters total 27 cases are framed. Billet is considered as deformable and punch and die are considered as rigid bodies. FE modeling is carried out using 4 noded axisyemmetric elements. A typical FE model is shown in Figure 1. There are 390 elements and 451 nodes in each model. Displacement boundary condition is given to the punch, which is applied to the billet through contact algorithms. Die and billet interaction is accounted through contact boundary conditions. Negligible friction between the contacting bodies is accounted. Mean strain energy criteria, based on the authors previous work [10], is used for mesh adaptivity. FE simulations are carried out considering large deformation algorithms using MSC.MARC software [11]. Simulation is done in 280 incremental steps. Large displacement and large strain plasticity procedures are adopted in the simulation.

RESULTS & DISCUSSIONS

Results of the FE simulations can be described under following heads:

Strain distribution

A typical strain distribution in the extrude rod is shown in Figure 2. It can be observed that very high strains in excess of 2.5 exist. Maximum strain in the die and billet materials with respect to billet strengths for the three dies are shown in Figure 3, 4 &.5. It can be observed that more fluctuations in the die strains occur when die strength is low. Which saturates with increase die strengths. There is not much effect of billet strengths on the maximum strain.

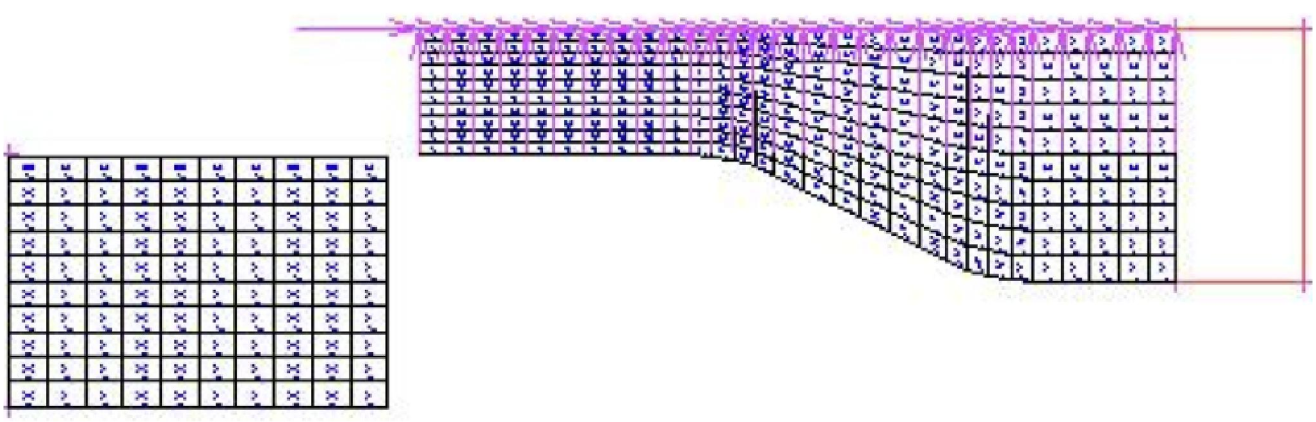

Figure 1 : FE Model for rod extrusion

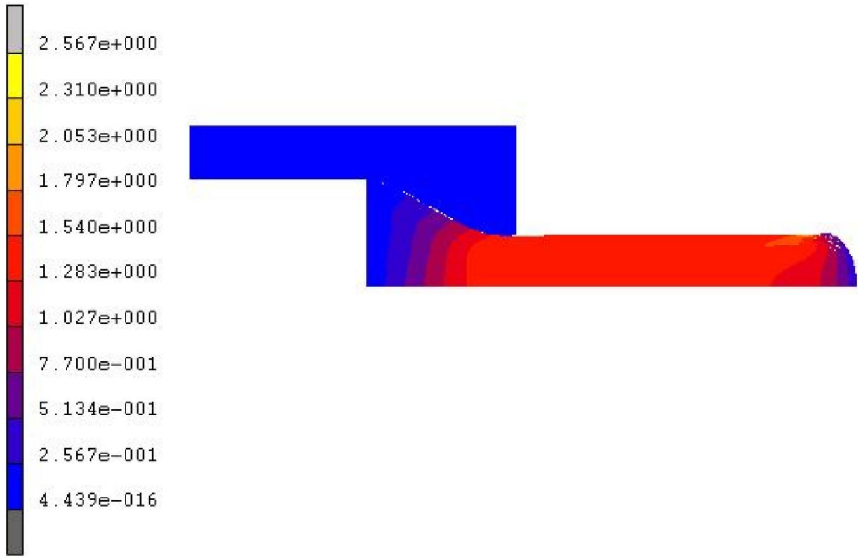

Figure 2 : Equivalent plastic Strain for rod extrusion

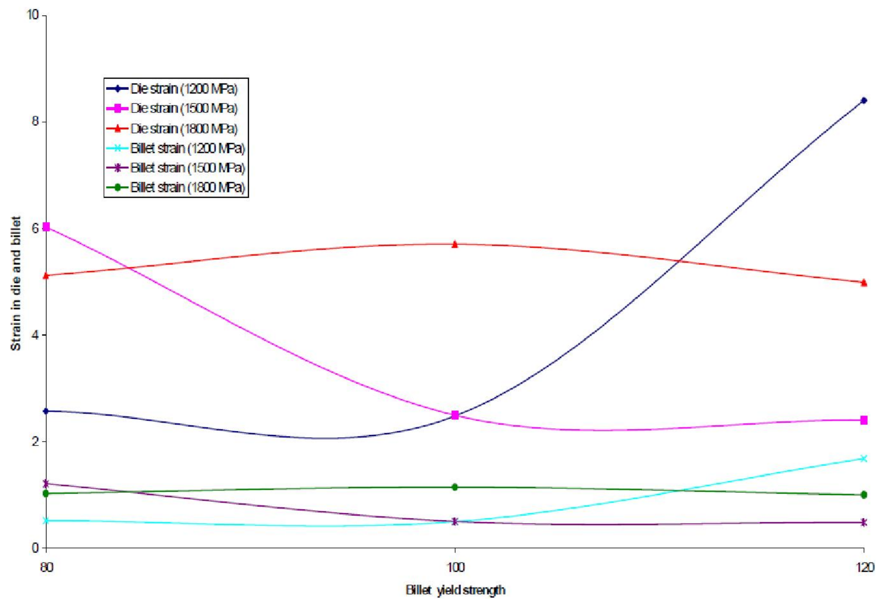

Figure 3 : Die & billet strain in 30^0 die

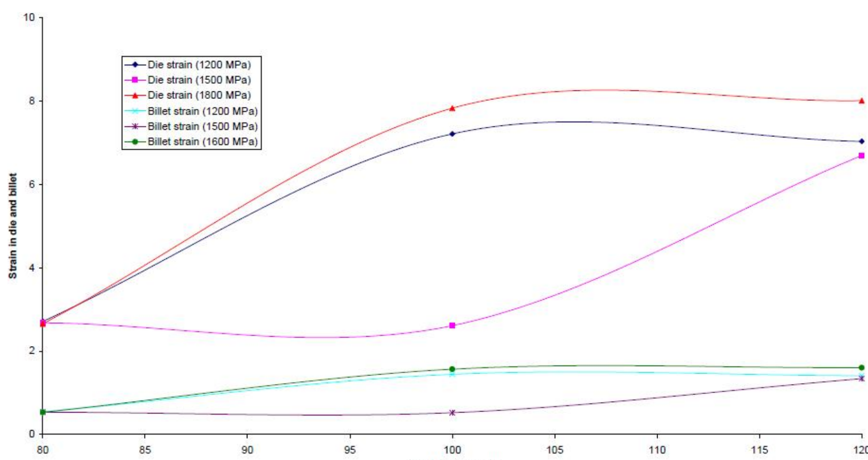

Figure 4 : Die & billet strain in 45^0 die

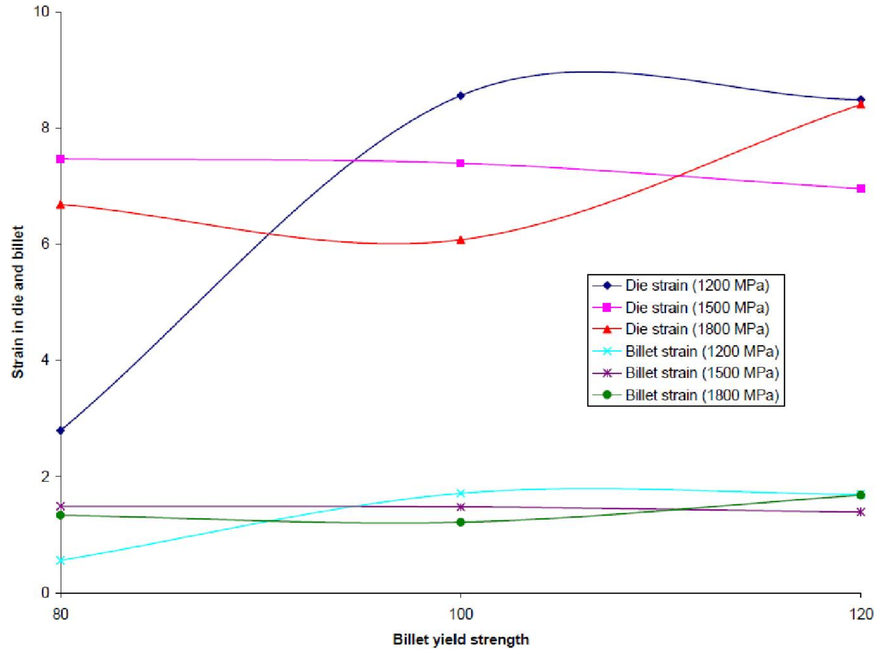

Figure 5 : Die & billet strain in 60^0 die

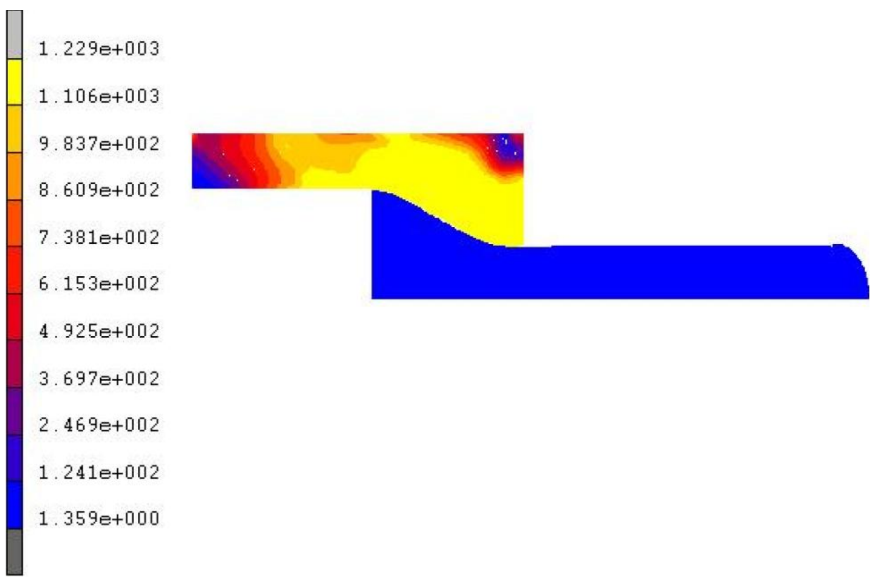

Figure 6 : Equivalent Von mises stress (MPa)

Maximum strain depends on die strengths. In 45^o die minimum strain is observed at minimum billet strength at all the die strength. Hence this will be optimum die with respect to fracture strain, especially in soft materials like aluminum, magnesium and lead. Almost in all the cases strain is maximum at maximum billet strength.

Stress distribution

A typical stress distribution in the extruded rod is shown in Figure 6. It can be observed that very high stresses in the order of yielding of the materials exist. This is invariably true for all the 27 cases. Based on the stress criteria die yielding is also calculated and given in TABLE 1,2 & 3. Most of the cases die yielding is more than 90%.

Load requirement

Maximum load for different dies considering different material properties are given in TABLE 1,2 &3. Maximum load requirement for all the cases is around 100MN, which is quite high. The mini-

TABLE 1 : Die yielding and peak load (30^0 die)

S.No	Yield strength of billet (MPa)	Yield strength of die (MPa)	% yielding of die	Load (MN)
1	80	1200	93.8	20.7
2	100	1200	93.6	21.2
3	120	1200	95.1	78.3
4	80	1500	90.6	69.7
5	100	1500	93.5	20.7
6	120	1500	94.7	20.6
7	80	1800	96.1	58.8
8	100	1800	97.03	67.8
9	120	1800	95.3	63.5

TABLE 2 : Die yielding and peak load (45^0 die)

S.No	Yield strength of billet (MPa)	Yield strength of die (MPa)	% yielding of die	Load (MN)
1	80	1200	99.5	15.8
2	100	1200	94.3	40.1
3	120	1200	95.6	40.4
4	80	1500	99.7	15.8
5	100	1500	93.7	15.1
6	120	1500	98.2	62.7
7	80	1800	99.71	15.9
8	100	1800	92.9	50.4
9	120	1800	93.3	52.5

TABLE 3 : Die yielding and peak load (60^0 die)

S.No	Yield strength of billet (MPa)	Yield strength of die (MPa)	% yielding of die	Load (MN)
1	80	1200	95.9	17.4
2	100	1200	94.3	99.7
3	120	1200	90.2	85.1
4	80	1500	89.6	50.3
5	100	1500	93.4	87.1
6	120	1500	93.9	94.0
7	80	1800	90.7	51.9
8	100	1800	89.2	63.0
9	120	1800	91.7	54.4

mum load requirement is in 45^0 die when billet and die strengths are 100 & 1500 MPa. Maximum load is in 60^0 die is when billet and die strengths are 100 & 1200 MPa. Based on this study die angle and material properties can be selected to result in minimum load requirement.

Die yielding

Yielding of the die for different die angles and billet and die strengths are given in TABLE 1,2 & 3. Die yielding for the three dies as functions of billet and die strengths are shown in Figure 7, 8 & 9.

From the Figures and tables it can be observed that maximum yielding is in 45^0 die when billet strengths is 80 MPa irrespective of die strengths. Minimum yielding is in 60^0 die when billet and die yield strengths are 80 MPa and 500 MPa respectively. Hence by selecting proper geometrical parameters die yielding can be controlled to some extent.

Billet strength plays an important role on die

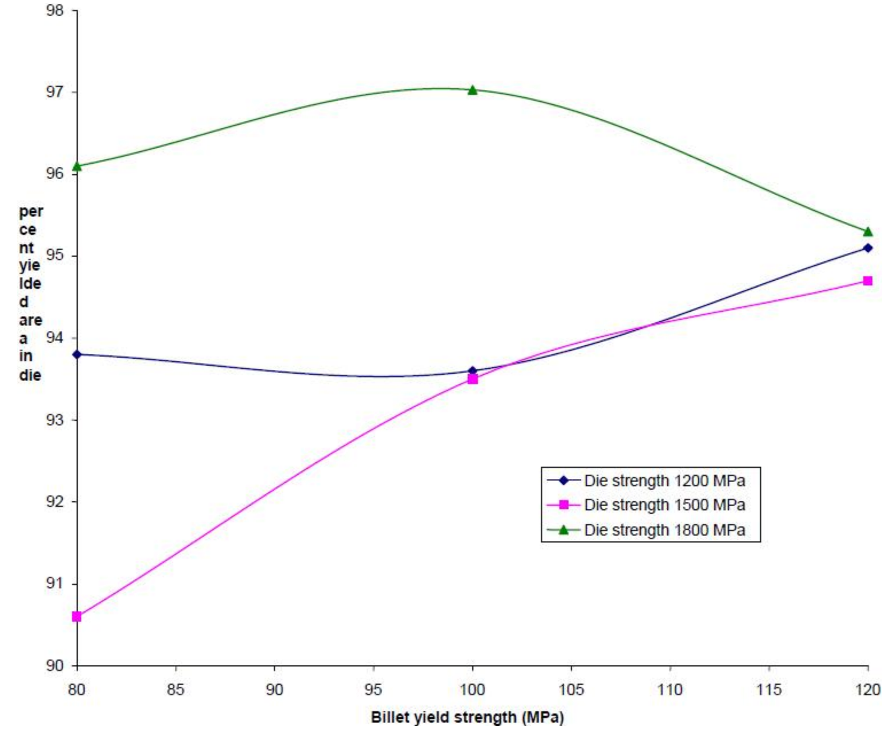

Figure 7 : Die yielding (30^0)

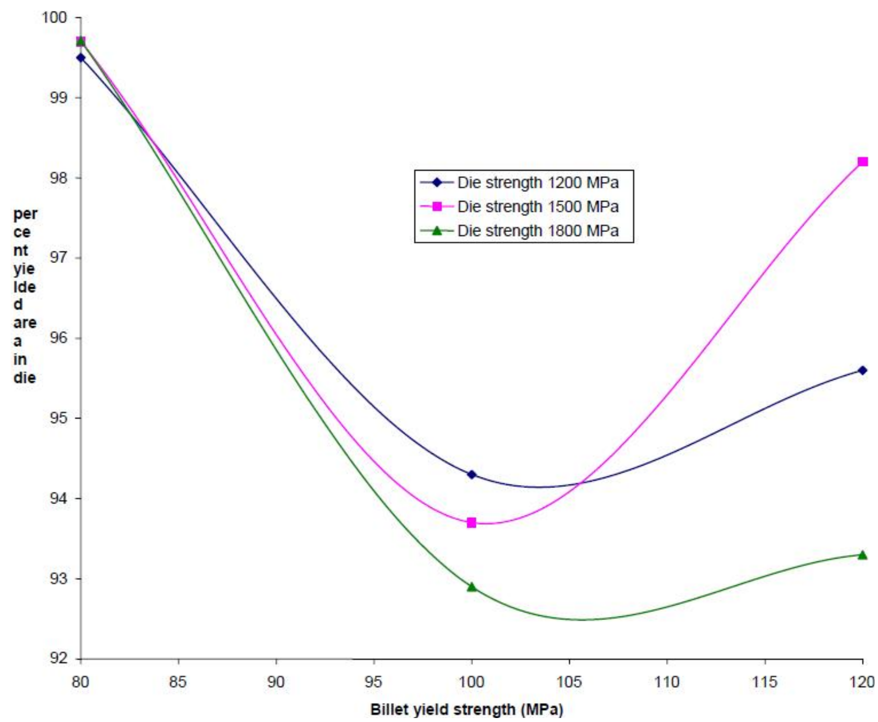

Figure 8 : Die yielding (45^0)

yielding. In 30^0 die, lower billet strength when die strengths are also lower side results in lower yielding. Yielding increases with increasing billet strength. In 45^0, die yielding is minimum when billet strength is around 100MPa irrespective of die strengths. It increases at lower and higher billet strength beyond 100 MPa. In 60^0, die yielding is maximum at low die and billet strength. At higher die strength, yielding increases with increase in billet strengths.

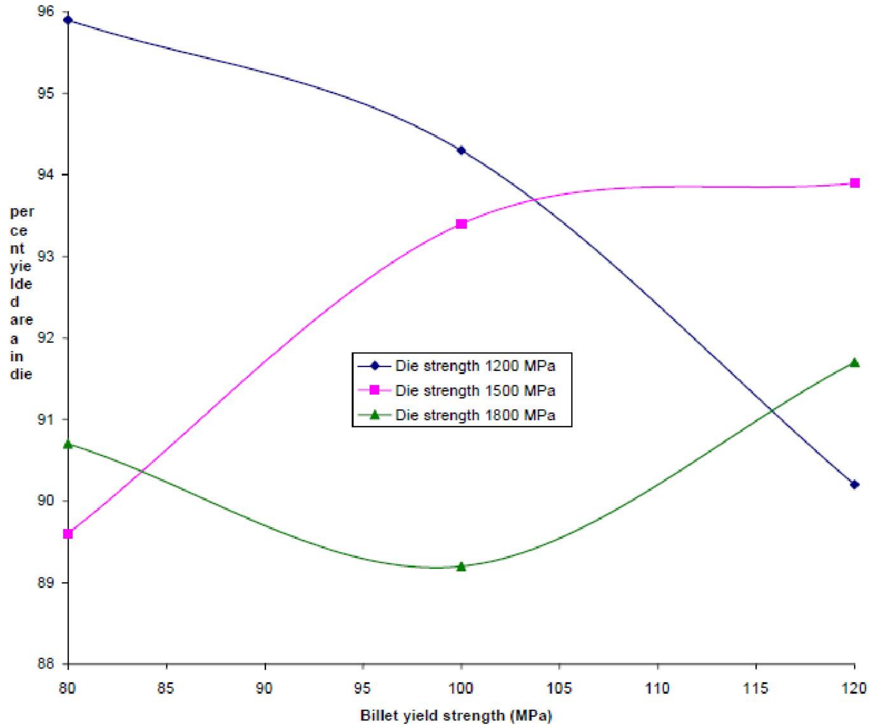

Figure 9 : Die yielding (60^0)

CONCLUSION

In this study effects of geometrical and material parameters on the rod extrusion process are studied. Die angle, die strength and billet strength are considered as study parameters. It is found that by suitable selection of these parameters, die yielding and load requirement can be optimized, which will eventually help in optimum utilization of energy and resources.

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