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COMPARISON OF EXPERIMENT AND FEM SIMULATION OF BULGING EFFECT

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Abstract: In this study experimental results on deformation of commercial aluminum are compared with those obtained through FEM modeling. Comparison is made using bulging at different specimen heights, different specimen size, axial deformation, lateral deformation and forging load . Also, calculated the coefficient of friction between the die and the work piece . The accuracy of results of FEM based simulation is different for different parameters studied in this work. Numerical values of such deviations may be used as a guideline while attempting to model forging process using FEM.
Keywords: FEM simulation ,bulging , coefficient of friction.

I. INTRODUCTION

One of the most important manufacturing processes is metal forming in which the desired size and shape are obtained through the plastic deformation of a material. Metal forming processes involve changing the shape of the work piece by forcing it to flow through a die. This requires immediate contact between the die (tool) and the work piece. In general, the work piece and the die move relative to each other under pressure or deforming force, which is normal to the die-work piece interface. As a result of this contact, tangential frictional forces are generated at the interface of the die/work piece to resist this relative movement. In order to analyze forming processes, the metal flow, the friction at the die-work piece interface and formability of material have to be described for a given process [1-3]. For quantitative expression of friction, friction coefficientμ) (and friction factor (m) are used. These values are used when tangential stress is defined, which is emerging due to friction on contact surfaces. There are three models of tangential stress formulation that arises due to the friction. [4-7]

a) $\tau k = \mu.\sigma n$ 1.1
b) $\tau k = \mu.k$ 1.2
c)) $\tau k = m.\tau max$ 1.3

Where , τk is tangential stress due to the friction on contact between die and workpiece, σn is normal contact stress, μ is friction coefficient , k is Flow stress, τmax - maximal shear stress of deformed material and m is Friction factor According to this model, tangential stress due to friction (τk) depends on friction factor (m) and shear stress of deformed material (τmax). In this case tangential stress (τk) is independent of normal stress (σn). This model of friction is suitable for processes where normal stress is higher than flow stress and where sticking of the material occurs. There is dependence between friction factor and friction coefficient: $m = \sqrt{3}\ \mu$
Since mmax= 1 it follows that μ max= !
√! =0.577
With an increase in m value, the resistance to metal flow at the interface increases, as it approaches the sticking friction condition (m=1). But the metal flow easily along the horizontal axis (A-B in Fig) of the sample. So the higher the m value, the more will be the bulging effect & at m=0 the bulging will be nil (for the same deformation).with an increase in the m value , the ratio of diameter of bulge (D_B) to diameter of the initial billet (D_o),say D_B/D_o, will increase either linearly or nonlinearly as shown in fig **.**

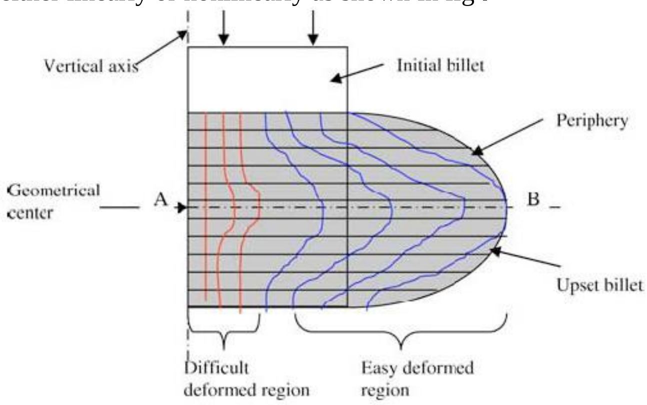

Figure 1.1: Schematic representation of “easy and difficult deformed regions” in upset sample (not to scale) [8].

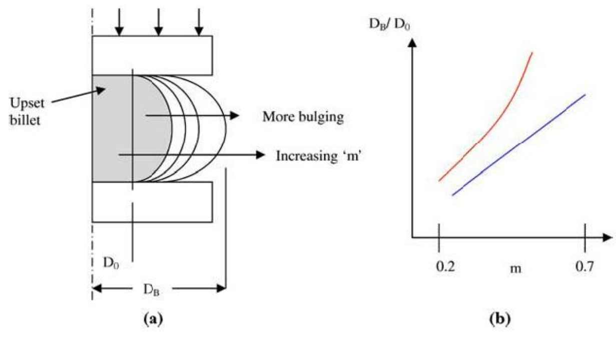

Figure 1.2: Schematic representation of influence of the m value on the bulging of the upset (not to scale): (a) influence of m on the bulging of the upset sample, (b) effect of m on the D_B/D_o ratio. [8].

FEM (Finite Element Method) has been adopted by many researchers for optimization of die design and die design process. This tool has been used to perform analysis of the die design parameters, and to get the accurate results without damaging any physical structure. The physical structure can easily be modeled in CAD package and then can be transferred to FEA package where the various analyses can be done. To optimize the product, one can easily change the geometry in CAD model to get the optimize geometry. Similarly the material properties also can be changed. The researchers have used these tools effectively for the simulation purpose. In this study FEM simulation is carried out on the deformation of solid cylindrical model under axial loading up to 30% of height with different coefficient of friction and compared with experiment bulging results of 30% deformed sample to determined the coefficient of friction between the die and work piece.

II. MATERIAL & METHOD

Commercial aluminum is used as sample material. Tensile test is carried out under deformation mode to determine the tensile strength and strength coefficient .The experiment setup for tensile test is shown in Figure 2.1

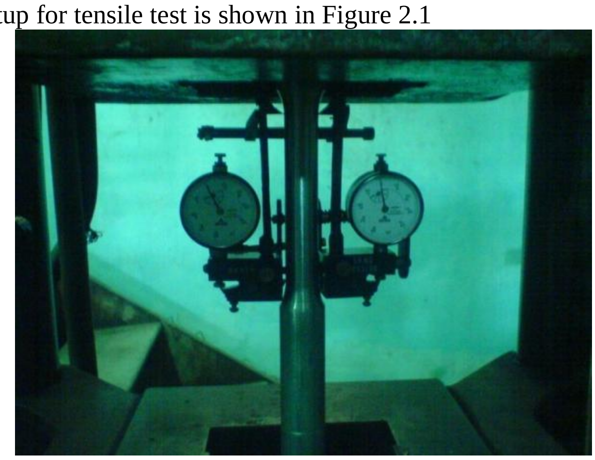

Figure 2.1: Experiment setup for tensile test

The samples cylindrical specimen is used i.e. Sample A , Sample B and Sample C with same aspect ratio.For each sample size three number of specimen is used and marked on each sample at 25 %, 50 % &75 % of height using height gauge. Later each samples are deformed at 30 % of height in universal testing machine. Forging load is recorded at each percentage of deformation.

2.1 FEM simulation method

Finite element analyses of the compression test are carried out in order to study the deformation behaviour with respect to friction. The finite element model is axisymmetric since the middle surface of the billet is a plane of symmetry. Element type CAX4R is used: this is a 4-node quadrilateral with a single integration point and "hourglass control" to control spurious mechanisms caused by the fully reduced integration. The element is chosen here because it is relatively inexpensive for problems involving nonlinear constitutive behavior since the material calculations are only done at one point in each element. In addition, in the Abaqus/Standard simulations element types CGAX4R, CGAX4T, CAX4P, and CAX4I are also used to model the billet; in the Abaqus/Explicit simulations element type CAX6M is also used to model the billet. . Specimen is modelled as deformable and platen as rigid bodies. FE simulations are carried out using Abaqus/CAE/Standard.The contact between the top and lateral exterior surfaces of the billet and the rigid die is modeled with the CONTACT PAIR option. The billet surface is defined by means of the SURFACE option. The mechanical interaction between the contact surfaces is assumed to be penalty frictional contact. The surface-to-surface formulation is introduced.

III. RESULT AND DISCUSSION

Yield strength and Ultimate strength of commercial aluminum is 112..1 N/mm^2 and 174.89 N/mm^2 is observed in tensile test .Then, Strength of coefficient (K) and Strain hardening exponent is 362.7N/mm^2 and 0.14 is calculated through linear log-log curve.

After the deformation of sample A up to 30 % of height in universal testing machine the value of diameter at 25% , 50% and 75% are measured as shown in Table 3.1. similarly , the diameter of sample B and Sample C are measured after deformation at different percentage of height i.e. 30 %.

Table 3.1 After bulging the diameter of sample at different percentage of height .

Height	Sample No.	Intial Diameter (mm)	After Deformation						
			Diameter (mm)						
			1	2	3	4	Average	Diameter	Radius
0 %(TOP)	sample 1	32	36.48	36.48	36.52	36.54	36.505	36.517	18.258
	sample 2	32	36.54	36.52	36.58	36.58	36.555		
	sample 3	32	36.48	36.46	36.54	36.48	36.49		
25%	sample 1	32	38.22	38.28	38.24	38.26	38.25	38.285	19.143
	sample 2	32	38.44	38.36	38.3	38.38	38.37		
	sample 3	32	38.28	38.24	38.22	38.2	38.235		
50%(middle)	sample 1	32	39.18	39.14	39.18	39.2	39.175	39.200	19.600
	sample 2	32	39.18	39.22	39.2	39.2	39.2		
	sample 3	32	39.22	39.16	39.28	39.24	39.225		
75%	sample 1	32	38.28	38.32	38.24	38.28	38.28	38.247	19.123
	sample 2	32	38.26	38.32	38.3	38.26	38.285		
	sample 3	32	38.16	38.18	38.16	38.2	38.175		
100(base)	sample 1	32	36.48	36.48	36.52	36.48	36.49	36.468	18.234
	sample 2	32	36.44	36.48	36.44	36.48	36.46		
	sample 3	32	36.54	36.42	36.42	36.44	36.49		

FEM simulation of uppset forging for cyliderical billet at 30% percent deformation with different coefficent of friction are shown infigure. 3.1

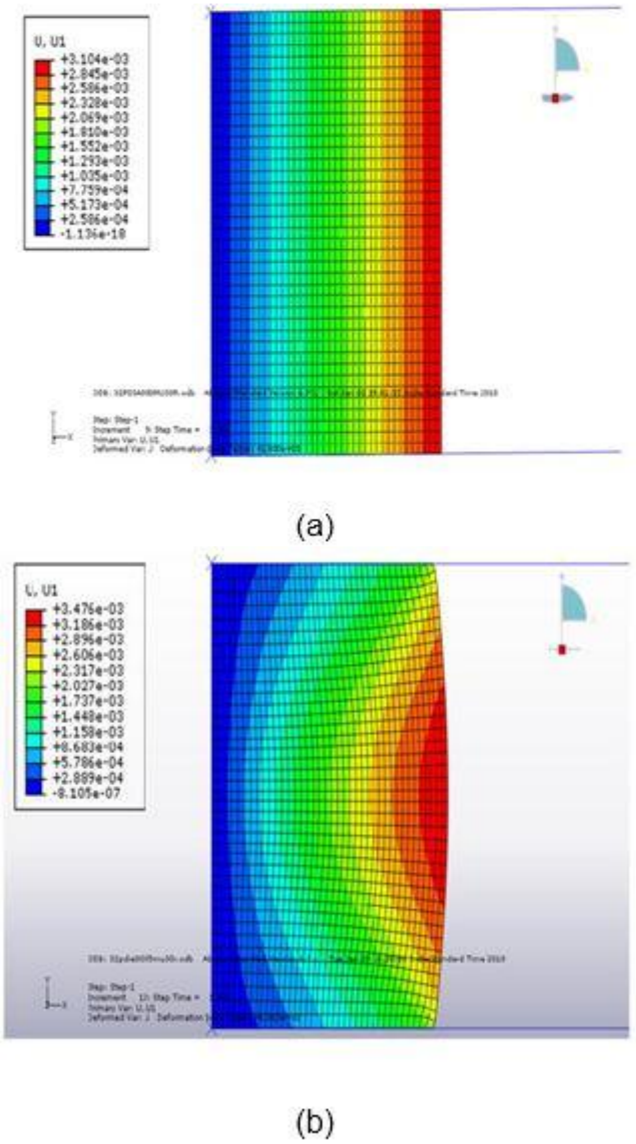

Figure 3.1 FEM simulation of Upset forging with differnt coefficent of friction between die and material .a) At zero coefficent of fiction and (b) At 0.85 coefficent of friction

Through FEM simulation the bulging is recorded at different percentage of height with varying the coefficient of friction i.e 0.05,0.085 ,0.1,0.2 and 0.3 are shown in table 3.2.

Table 3.2: Bulging percentage at 30 % deformation of sample A
0

Coeff. Of friction	Initial radius R	R_m	T = R_m-R	Bulging percentage at diff. % of height				
				0%	25%	50%	75%	100%
0.05	16	19.334	3.334	0.00%	15.36%	20.80%	14.22%	0.00%
0.085	16	19.476	3.476	0.00%	27.07%	35.76%	25.27%	0.00%
0.1	16	19.527	3.527	0.00%	31.84%	41.70%	29.80%	0.00%
0.2	16	19.764	3.764	0.00%	45.12%	60.35%	41.99%	0.00%
0.3	16	19.838	3.838	0.00%	55.45%	72.38%	51.97%	0.00%

The experimental results of deformed sample A, B and C up to 30% of height are compared with the FEM simulation of 30% deformed of same size of samples (A, B and C) with different coefficient of friction between the die and work piece are shown in the Figure 3.2. The comparison reveals that the bulging percentage of sample A , B and C are matched with FEM simulation of 0.085 coefficient of friction.

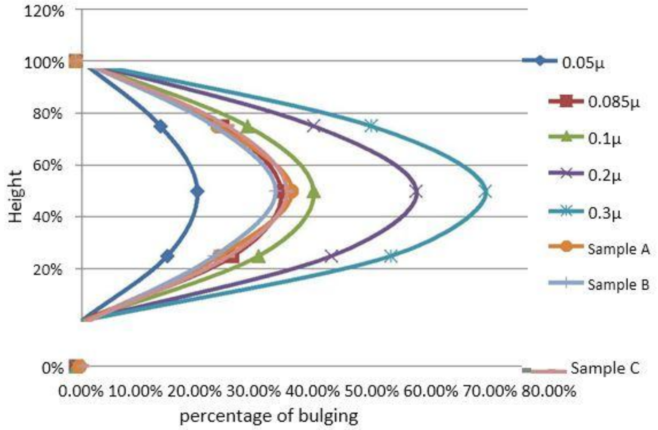

Figure 3.2 Comparison of experiment results with FEM simulation result at 30 % deformation

Variation in experiment results of deformed samples (A, B and C) up to 30% of height and FEM simulation of deformed sample with coefficient of friction 0.085 are shown in table 3.3

Table 3.3: Variation in bulging percentage of experiment results with FEM simulation at 30 % deformation

Height	μ=0.085	Percentage of Bulging			Percentage of Variation		
		Sample A	Sample B	Sample C	Sample A	Sample B	Sample C
0.00%	0.00%	0.67%	1.42%	1.10%	0.67%	1.42%	1.10%
25.00%	27.07%	24.70%	23.84%	26.36%	-2.37%	-3.23%	-0.72%
50.00%	35.76%	37.71%	34.75%	36.81%	1.95%	-1.01%	1.05%
75.00%	25.27%	24.47%	23.81%	26.17%	-0.80%	-1.46%	0.90%
100.0%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

IV. CONCLUSIONS

For the same aspect ratio and coefficient of friction, the percentages of bulging at particular deformation are in good agreement for samples of different size. This has been verified through both experimental results and FEM modeling. The difference between experimental results and results obtained through FEM, as shown in figure 3.2. Therefore, we may conclude that co-efficient of friction between die and billet can be determined through FEM, within the error limits given in Tables 3.3.

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