PARAMETRIC ANALYSIS OF INDUSTRIAL COLD DRAWING PROCESS

Praveen Kumar Loharkar

SVKM's NMIMS MPSTME Shirpur Campus Dhule 425405 India,ploharkar@gmail.com

Abstract— Seamless tube cold drawing is one of the most important bulk deformation processes as the products manufactured through this process are utilized in various engineering sectors like automobile manufacturing, mining industry, pipelines, boiler manufacturing etc. Therefore, it becomes quite significant to establish optimum values of parameters associated with the process and use the existing computational facilities to develop a simulation environment for the cold drawing process itself. This paper is an effort to demonstrate the use of finite element method to analyse cold drawing process and to determine the effect of the process by variation of the parameters like die entry angle and cross-section reduction on the industrial cold drawn seamless tube.

Keywords — Seamless tube, Cold drawing, bulk deformation process, finite element method, die entry angle, cross section reduction.

INTRODUCTION

Cold drawn seamless tubes of alloy steels have wide area of applications. They are used in automobile industry, mining industry, boiler manufacturing etc. Cold drawing process adds value to the product as it not only improves the surface finish and geometrical tolerances but it also enhances the mechanical properties.

Cold drawing process have been analyzed earlier through different analytical methods like slab method, upper bound method or slip line theory [1]. With the development in computational capabilities, Finite element analysis has started playing a major role in enabling industries towards new product development. Ironically, still there are many industries which still have not utilized the full potential of these advancements and therefore are lagging behind at the development and innovation index.

An attempt is made to carry out parametric study of the cold drawing process using finite element analysis by considering industrial data.

COLD DRAWING PROCESS

Cold drawing is essentially a bulk deformation process, that is, it involves plastic deformation to achieve the desired shape and size [2]. It can be classified under two categories. In the first category of the process, wire or rod is given the shape and the cross-sectional dimensions of the drawing die. While in the latter case, the outside is formed by the drawing die and the inner side is formed by a plug or a rod using the combination of tensile and compressive forces. This work is concerned with the tube drawing process.

FINITE ELEMENT ANALYSIS

The finite element analysis is carried out on an axisymmetric model of seamless tube in the ABAQUS Software. The dimension of the hollow tube on which the drawing simulation was carried is 110x9.50. The Final tube size was determined for different cross-section reductions, viz. 0.2, 0.3, 0.4 by keeping the inner diameter constant at 91 mm.

The finite element analysis was performed by choosing the drawing conditions based on full factorial design of experiments (D.O.E.). In this design, two factors, namely, die entry angle (20^o, 24^o, 30^o) and cross section reduction (20%,30%,40%) with three levels are used. As far as friction condition is concerned, the value of coefficient of friction was kept as 0.05 which resembles the actual drawing friction scenario [3].The drawing speed is kept constant at 400 mm/s.

1. Assigning Material Property

The material chosen for the analysis is STR 525, which is an alloy steel, used specially for making hydraulic cylinders. The composition of the alloy steel is close to ST 52 which is a standard alloy steel. For checking the actual composition of the material, an instrument called X-Met was used. Young's modulus and density values were chosen from standard data available for the alloy steel.

2. Mesh Generation and Other Computation Parameters

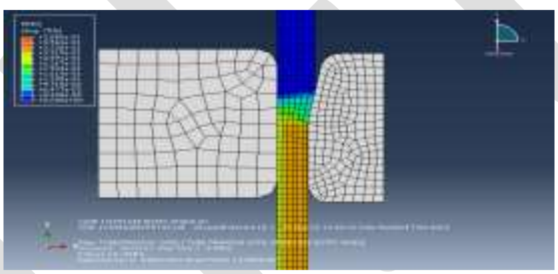
The finite elements used for meshing tube are 4 noded-2D axisymmetric elements with reduced integration points (CAX4R).Deformation was initiated with the provision of down-ward motion of the hollow. Adaptive remeshing facility given by the software has been used to repair the meshes during deformation. Adaptive remeshing is an excellent feature that makes the analysis more realistic thereby increasing the reliability of the solution obtained. Mass scaling was done with a factor of 1600 to speed up the analysis. Two steps were used for the simulation. The first step, initial, which is a default step, was used to define the boundary conditions, while the next step, tube drawing, was used to establish the contact between hollow (tube at inlet), tools and to initiate material deformation.

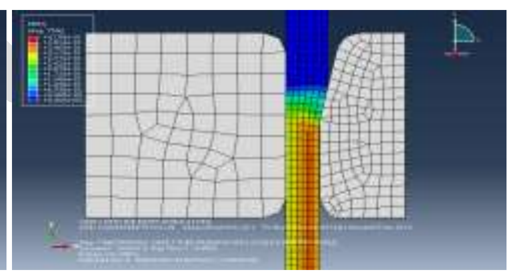
SIMULATION RESULTS AND ANALYSIS

Model was validated by comparing the strains developed in actual drawing practice to the strains developed in the finite element model after drawing simulation. Then simulation was carried out for other combination of parameters and results were obtained as discussed below.

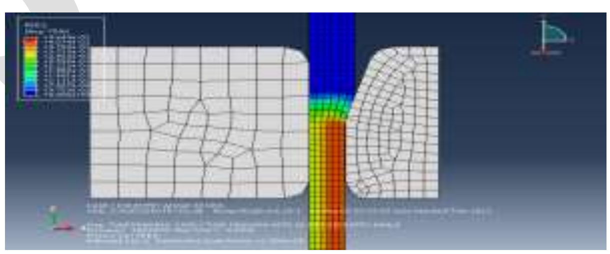
1. Die Entry Angle and Equivalent Plastic Strain Distribution

On observing the diagrams (Fig.4.1 a, Fig. 4.1 b, Fig. 4.1 c) of the equivalent plastic strain (P.E.E.Q) for different die angles, that is 20^0, 24^0, 30^0, it was found that the strain values increase in accordance to the angle values (although there is not much difference). P.E.E.Q in case of die entry angle 20^0 is around 0.3238 in the steady state condition at step time 0.45. But the same value for die entry angles 24^0 and 30^0 is 0.3812 and 0.4074 respectively.





(a) P.E.E.Q. for r=0.2, 2α=20^0, **(b) P.E.E.Q. for r=0.2, 2α=24^0**



(c) P.E.E.Q. for r=0.2, 2α=30^0

Fig. 4.1 Effect of Die Entry Angle on Equivalent Plastic Strain

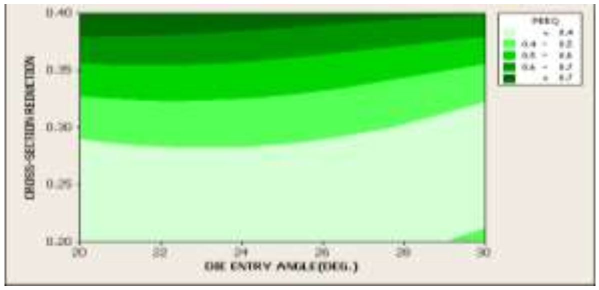
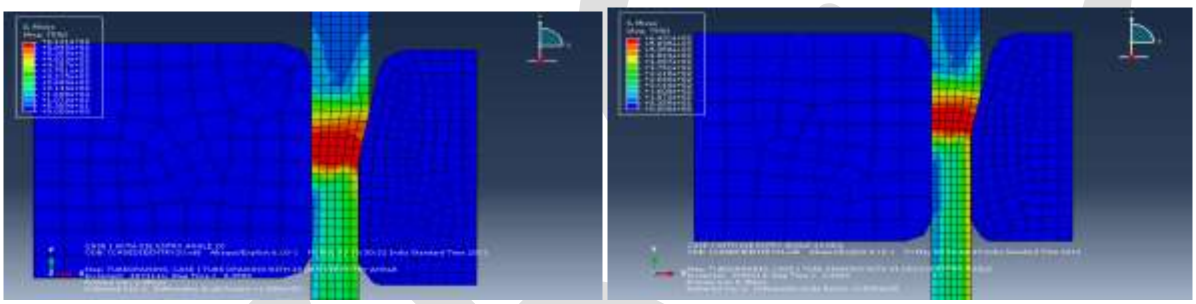


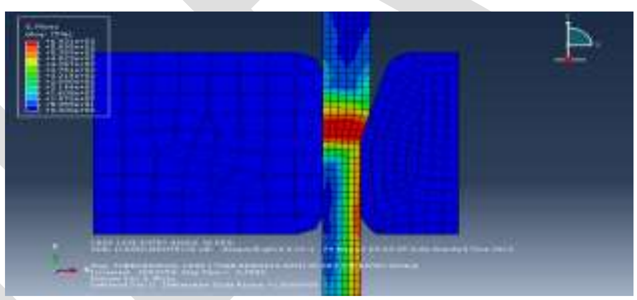
Fig. 4.2 Effect of Die Entry Angle and Cross-section reduction on Equivalent Plastic Strain

2. Die Entry Angle and von-Mises Stress Distribution

As can be seen in the Fig.4.3, when the initial contact is established, stresses are induced in other regions of hollow that are still not in the deformation zone. Although the maximum stress at deformation doesn't vary but it can be clearly seen that in the drawing region, increase in the die entry angle results in an increase in the von-Mises stress (compare Fig. 4.3 a, Fig. 4.3 b, Fig. 4.3 c). The effect of variation of die entry angle and cross-section reduction on von Mises stress is shown in Fig. 4.4. As is seen in the contour diagram, increase in values of both the parameters lead to increase in von-Mises stress.



(a) von- Mises Stress Distribution for r=0.2, 2α=20^0, (b) von- Mises Stress Distribution for r=0.2, 2α=24^0



(c) von- Mises Stress Distribution for r=0.2, 2α=30^0

Fig. 4.3 Effect of Die Entry Angle on von-Mises Stresses

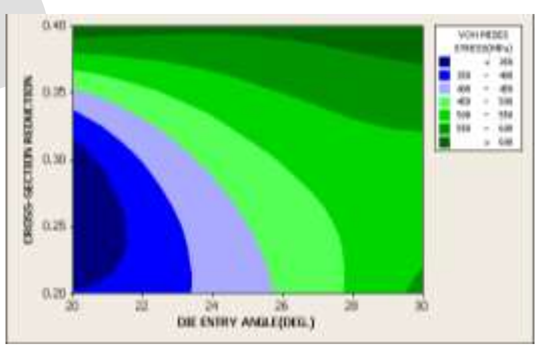


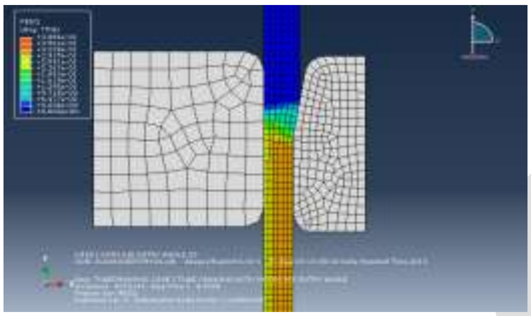
Fig. 4.4 Von-mises stress v/s Cross-section Reduction and Die Entry Angle

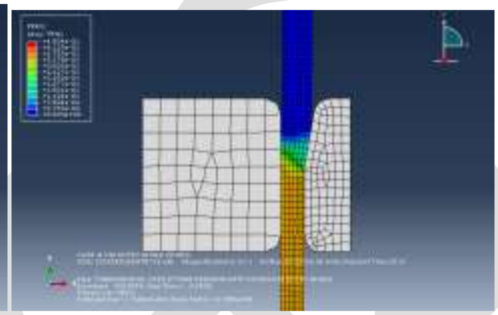
3. Cross-Section Reduction and Equivalent Plastic Strain Distribution

The cross-section reduction, naturally affects the strain component in any metal forming process significantly. When we see the diagrams (Fig. 4.5 a, Fig. 4.5 b, Fig. 4.5 c) for equivalent plastic strain with varying cross-section reduction it is evident that as the reduction in cross-section is increased the strain is also increased. For cross-section reduction 0.2, under steady state conditions at step time 0.45, P.E.E.Q. is 0.3238 which rises to 0.3753 and 0.5285 for cross section reductions 0.3 and 0.4 respectively.

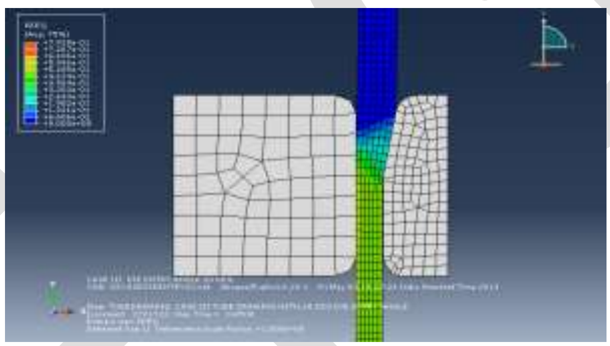
4. Cross-Section Reduction and von-Mises Stress Distribution

Diagrams show that von-Mises stress increases with the increase in the area reduction (compare Fig. 4.6 a, Fig. 4.6 b, Fig. 4.6 c).This is primarily due to the increase in reaction forces as load required to carry out high reduction is greater which induces higher stresses in the material.



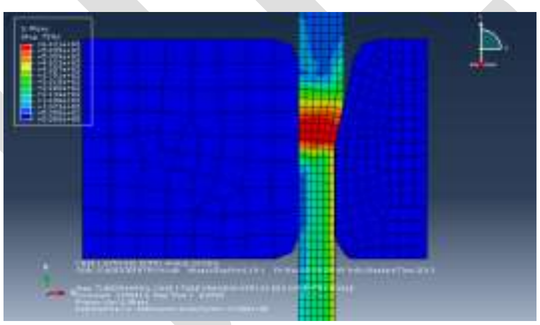


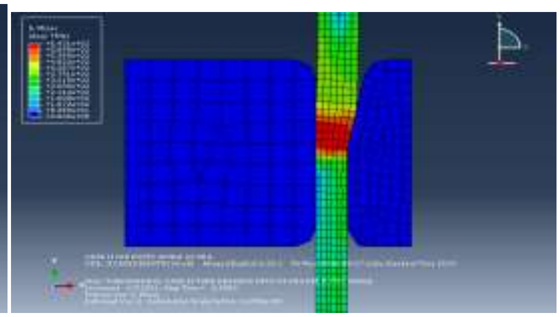
(a) P.E.E.Q. for r=0.2, 2α=20^0, **(b) P.E.E.Q. for r=0.3, 2α=20^0**



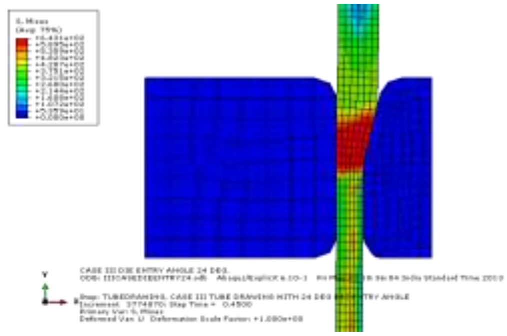
(c) P.E.E.Q. for r=0.4, 2α=20^0

Fig. 4.5 Effect of Cross-section Reduction on Equivalent Plastic Strain





(a) von-Mises Stress Distribution for r=0.2, 2α=24^0, (b) von-Mises Stress Distribution for r=0.3, 2α=24^0



(c) von-Mises Stress Distribution for r=0.4, 2α=24^0

Fig. 4.6 Effect of Cross-section Reduction on von-Mises stress

CONCLUSION

The Finite element analysis of seamless tube cold drawing process is done using industrial data. Based on the results obtained through this effort following conclusions were drawn. Stress distribution patterns were observed in the parts of tube even before coming in contact with the die, it suggests that elastic deformation of the tube material starts well before it enters into the deformation zone.

- It was observed that cross-section reduction has significant effect on equivalent plastic strain, von-Mises stresses and axial stresses. They all increase with the increase in the cross-section reduction value. Cross-section reduction upto 0.3 maintains the flow stresses at lower side and hence most preferred zone of metal working.
- Die entry angle is a crucial parameter in the drawing process. It was found that beyond 24 degrees, the value of flow stresses follow the rising pattern with the increase in the die entry angle. Consequently, the load on drawing mechanism increases.
- It is also found that maximum equivalent plastic strain existed in subsurface region for smaller values of cross-section reduction and die entry angle. The plastic deformation is much more uniform at higher die entry angles and higher cross-section reduction.

REFERENCES:

[1] Kumar, Praveen, and Geeta Agnihotri. "Cold Drawing Process–A Review." metal forming 3.3 (2013).
[2] Groover, M. P. Fundamentals of Modern Manufacturing. John Wiley & Sons (2010).
[3] Neves, F. O, S. T. Button, C. Caminaga and F. C. Gentile Numerical and Experimental Analysis of Tube Drawing with Fixed Plug. J. of the Braz. Soc. of Mech. Sci. & Eng., Vol. XXVII, No. 4/426-431(2005)..