On the reduction of high starting load in cold drawing of circular tubes

G. Mathan[1], G.Manikandan[1]*, Abhishek Raj[1] Ashish P Rajgure [2]

[1] Research and Development, Tata Steel Limited, Jamshedpur 831001, India
[2] Tube Division, Tata Steel Limited, Jamshedpur 831001, India

***Corresponding author: Email: manikandan.g@tatasteel.com, Tel.: +91-657-2148964**

Abstract

High starting load during cold drawing process is an important factor affecting draw bench capacity utilization. Finite element simulation was used to optimize die parameters to reduce the high starting load. The shape of the pointed end was optimized to minimize high starting load. Experiments were conducted by modifying the dies of pointers and the resulting drawing force was measured. It was observed that the pointing operation creates out of roundness and due to that a high starting drawing force is required for drawing operation.

Keywords: cold drawn tubes, finite element simulation. Folding pointers

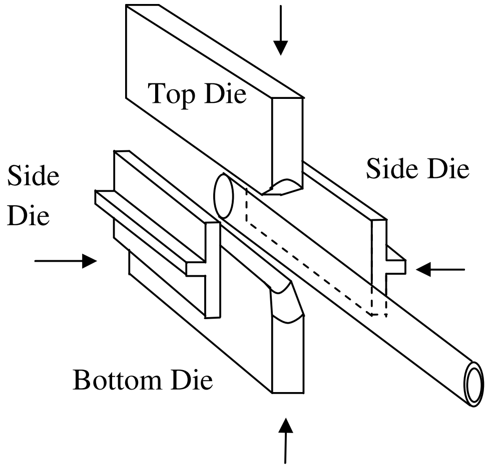
1. INTRODUCTION

Cold drawing process involves the drawing of tube through a converging die such that its external diameter is reduced. The operation gives a closer tolerance on outside diameter and improves surface finish. The drawing process is performed on draw benches. Pointing is a pre-forming operation in which one end of tube is reduced to a smaller diameter to enable it to pass through the draw die. After pointing, the tube will be inserted in draw die and Jaws grippes one end of tube to begin the draw operation. A plug is also inserted inside the tube during the process to govern final thickness of drawn tube. The process is as shown in Fig.1. Based on the capacity of the draw bench, more than one tube will be drawn simultaneously. Hence to improve productivity, the drawing load has to be minimized to an optimum level.

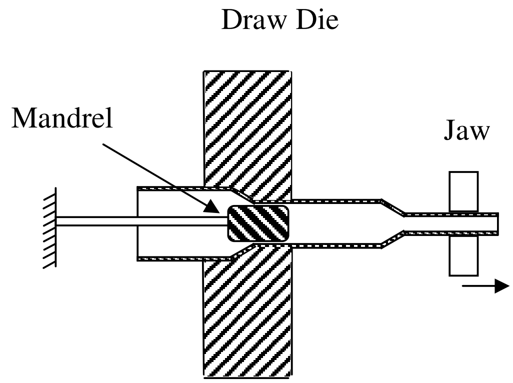
The important parameters affecting drawing load are mechanical properties, percentage of reduction, die semi angle, friction coefficient and peak load during start up. In analysing the drawing process, a number of studies have been undertaken. The application of slab method to the drawing process was first investigated by Hoffman and Sachs (1953). Pioneering work on tube sinking theory can be accredited to Hill (1950). Boer and Webster (1985) investigated the application of the upper bound solution and finite element method for round to square drawing. Collins (1969) obtained slip line field solution for axisymmetric tube drawing process. The use of slab method for analysing the drawing process has found widespread acceptance due to its simplicity and accuracy. The design of optimized cold drawing process also involves trial and error procedures based on designer experience.

Finite element analysis is a proven method to simulate and optimize various manufacturing process. The optimization of various tool and design parameters can be made using simulation tools. FEM solutions for tube drawing have been done by many authors. Validation of finite element modeling of tube sinking process has been done by Pietrzyk and Sadok (1990). Sawamipakdi et.al (1991) had been investigated the tube drawing process by finite element method. Karnezis and Faruzia (1998) used workability criterion to determine failure in cold drawing process. Rasty and Chapman (1991) investigated the effect of process variables on the tube drawing process and product integrity using the finite element package ABAQUS. This study concentrated on the effect of die and plug angles on the performance of the drawing operation.

The high starting load phenomenon is common in most of the forming processes, mainly due to frictional forces. The effect of friction and lubricant on the peak load in tube drawing process was investigated by Neves and Button (2005). Typical lubricants used in tube drawing are soap with or without conversion coatings and emulsions. The peaks are more intense in the tests with the most viscous lubricants (Renoform and Extrudoil). In many tests with the less viscous lubricant (SAE) the peaks are not well defined. The peak load during starting of extrusion process is also observed in the experimental data Beland et.al (2011). The affect of other parameters on peak load like out of roundness, plastic deformation during pointing have not investigated yet.



a) Pointing



b) Cold Drawing

Fig.1. Cold drawing process

2. FINITE ELEMENT SIMULATION

Pointing operation was simulated with the software Abaqus explicit. Three dimensional models were constructed as shown in Fig.2. Finite element simulation need inputs like die geometry, friction co-efficient, Tube mechanical properties and Mill operating parameters. The weld affected zone is modeled in the finite element model. Half of the pointing tool assembly only is modeled to make use of the symmetry and thus to reduce computation time. The pointing dies were considered as rigid surfaces. The tube is modeled with solid elements and with anisotropic Hill plasticity material model. The pointing simulation has been done to analyze the effect of pointing die radius (Fig.3) on deformed shape. The top and bottom pointing tool were given displacement boundary conditions to compress one end of tube and produced the crushed shape in the simulation.

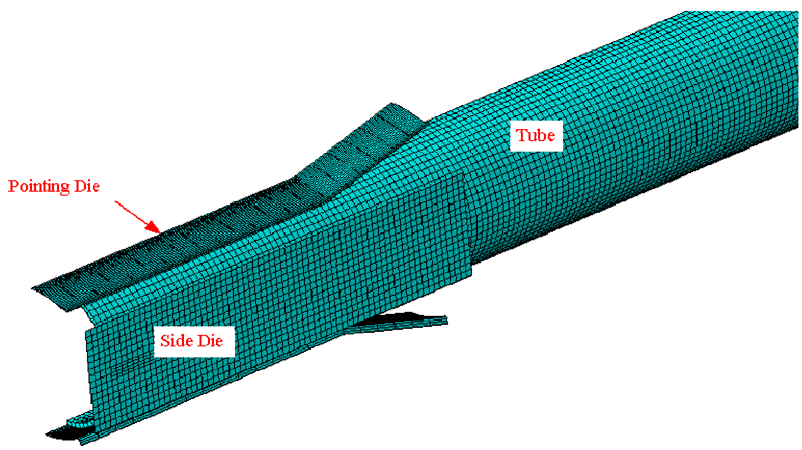


Fig.2 3D Finite Element model- Pointing

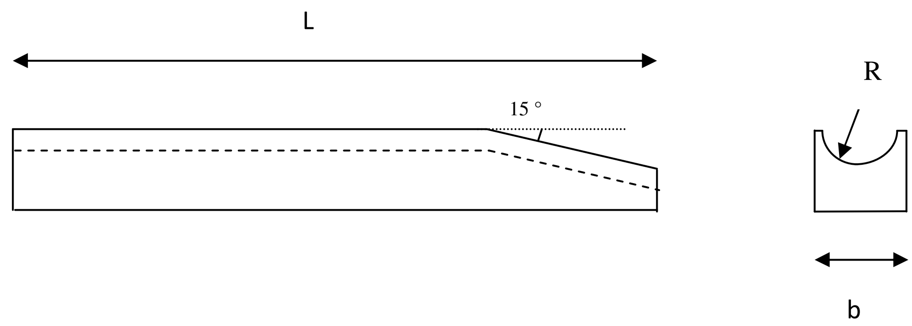


Fig.3.Pointer die

3. MATERIAL TESTING

The mechanical properties of tube are tested experimentally and are used in FEA. The specimens were prepared for the tensile test from different location of tube base metal and Heat Affected Zone (HAZ). The width and thickness of the specimens were 12.5 and 3.5 mm respectively. The gauge length used was 50.0 mm. The tests were performed on a state- of-art electromechanical universal testing machine. The mechanical properties for different samples were as shown in the Table 1.It is to be noted that the HAZ has similar mechanical properties compared to the base material. The chemical composition of the material is shown in table 2.

4. RESULTS AND ANALYSIS

The finite element simulation has been done for pointing operation by using three dimensional finite element models (Fig.2) to analyze the effect of out of roundness. Friction between tungsten carbide die and tube was estimated as 0.1 previously, assumed to be Coulomb friction and are used in the present analysis. Displacement boundary conditions were applied to the top and bottom dies. Fig. 4 shows the deformed shape of tube after pointing operation. A small hump (earring) is created at the neck region of pointed tube. The height of the hump is depends on diameter and thickness of the tube and as well as pointing die radius. This particular zone is severely plastically deformed and in the subsequent drawing operation extra work has to be done to pass this hump through the drawing die.

The effect of pointing die radius on the out of roundness is analyzed. Fig.5 shows the results from pointing simulation in terms of out of roundness of tube for different R/r ratio, where R= Die radius and r = Tube radius. The out of roundness is reducing with increasing R/r ratio. The optimum value of the R/r ratio is found to be at 0.75. For higher R/r ratio, even though the out of roundness is low, the jaw slippage occurred during drawing operation. The upper limit on the R/r ratio depends also on the percentage of reduction because for higher R/r ratio the tube could not be inserted inside the drawing die.

5. EXPERIMENTAL OBSERVATION

The drawing force is measured from a load cell attached to the drawing bench. Table 3 shows a comparison of measured drawing force for various sizes of tubes. It was observed that for higher tube sizes the peak load is more pronounced. The out of roundness is very small and negligible for smaller diameter tubes. The yield stress for higher tube sizes are also high compared with smaller tube sizes. It shows that the deformed shape and plastic deformation affects the peak load significantly. Hence the deformed shape during pointing is depends on behavior of material (yield stress, strain hardening co-efficient etc).

The drawing force is very high at beginning of drawing operation and reduced to a constant value. Because of high starting force relatively for a small time, the capacity of the drawing bench is limited to certain sizes and lead to loss of production. Earlier the peak in drawing force is considered to happen because of friction. Lubricants with high viscosity need a high pressure to establish a steady state lubrication regime with a continuous lubricant film. Therefore drawing load (lubricant pressure) increases up to the peak, the film is formed, a hydrodynamic lubrication is established and the pressure drops to a steady value. From the measured data (Table 3) it was found that for a same size of tubes with same lubricant for two different deformed shapes the peaks are also different.

From table 3 and from pointing simulation, it is confirmed that the out of roundness significantly contributes to high starting load. To minimize the out of roundness, the pointing radius of pointing tool is modified as per the dimensions of table 4 according to pointing simulation results. The lubricants used are soap solution with zinc phosphate coating. Table 5 shows measured peak load and constant load during the process.

Table 1. Mechanical properties

Specimen Label	YS in MPa	UTS in MPa	Total Elongation in %	Strain hardening coefficient(n)
Heat Affected Zone (HAZ)	328	447	35	0.215
base metal	320	444	30	0.228

Table 2 Chemical composition of Steel in Wt %

	C[%]	Mn[%]	S[%]	P[%]	Si[%]	Al[%]	Ti[%]	Nb[%]	N[ppm]
IF Steel	0.12	0.85	0.015	0.05	0.015	0.060	0.1	0.015	80

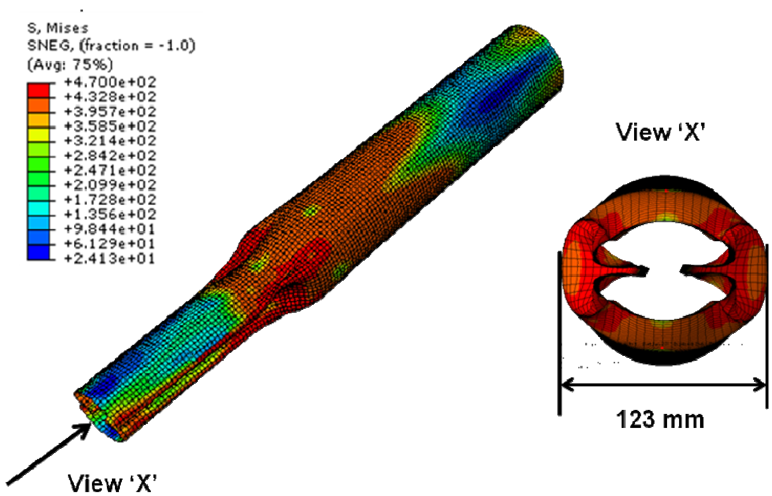


Fig. 4 Deformed shape of after pointing operation of tube (114.3 Outer diameter)

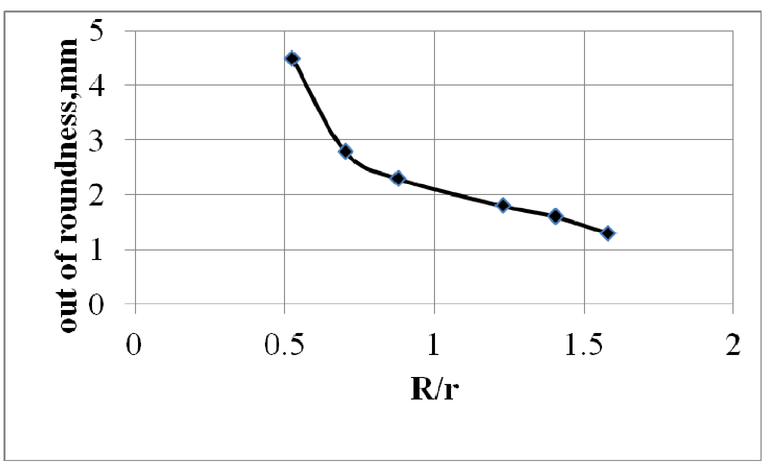


Fig.5.Influence of pointing die radius on out of roundness

Table 3 maximum load and constant load for tube sizes

Sl.No	Tube outer diameter	Thk,mm	Reduction,%	YS,MPa	UTS,MPa	Strain hardening co-efficient	Max load (kN)	Normal load(kN)
1	41.28	3.9	31.3	230	350	0.23	166	161
2	44.50	4.1	27.7	230	350	0.23	170	115
2	63.50	5.5	19.9	230	350	0.23	180	171
5	101.6	3.4	21.8	320	440	0.22	335	230
6	114.3	3.4	22.8	320	440	0.22	450	230

Table 4 Modified Die dimensions

Sl.No	Description	Pointing Radius(R),mm	Pointing width(b),mm	Pointing length(L),mm
1	Die 1	27	48	200
2	Die 2	40	64	200

Table 5 . Drawing force with modified die, Drawing speed 15 m/sec

Sl.No	Experimental		
	Peak Load,KN	Normal Load,KN	Out of Roundness,mm
Die 1	460	230	123
Die 2	390	250	118.5

6. CONCLUSIONS

The peak load occurring during start up of cold drawing process contributed to major production hurtle in tube drawing process. The reason for the peak load is believed to be by friction. It was demonstrated that the peak load is also depending on other parameters as well. The out of roundness of the tube is a important parameter for high initial starting load. From the pointing simulation and from experiments, the following conclusions were made,

i. The pointing operation creates out of roundness in tube cross section. By modifying the pointing tool the out of roundness can be optimized and the peak load can be minimized.
ii. The Effect of die semi angle on normal running load is 20 to 50 kN for a range from 10 to 15 Degree for a tube of 114.3 mm outer diameter and 3.4 mm thickness subjected to a reduction of 22.8 %. For the same size, The Effect of friction on normal running load is 20 to 80 kN for a range of 0.06 to 0.1.

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