FINITE ELEMENT SIMULATION OF SINK PASS ROUND TUBES USING ANSYS

M.P. Nagarkar\textsuperscript{a}, R.N. Zaware\textsuperscript{b} and S.G. Ghalme\textsuperscript{a}

\textsuperscript{a} SCSM College of Engineering, Ahmednagar (M.S.) - 414005 India
\textsuperscript{b} PDVVP College of Engineering, Ahmednagar (M.S.) - 414111 India

Modeling and simulation of metal forming processes are increasingly in demand from the industry as the resulting models are found to be valuable tools considering the optimization of the existing and development of new processes. By the application of modeling and simulation techniques, it is possible to reduce the number of time-consuming experiments such as prototyping. Seamless tubes of various sizes and shapes are manufactured by various processes like sinking, fixed plug, floating plug, moving mandrel, cold working and hot working.

The present work deals with the simulation of round tubes while passing through the sink pass, using ANSYS software. The simulation results are the displacement and von Mises stresses. The procedure can be used to improve the product quality and to study the effect of various parameters like die angle on the product quality.

KEY WORDS: Sink pass, Finite Element Analysis (FEA), Finite Element Method (FEM), Seamless tubes

INTRODUCTION

In most of the industries, cold working process is used for the production of various components. Cold working of metal and alloys is done below their recrystallization temperature. (1, 3, 4)

There are five tube drawing methods: sinking, rod drawing, floating plug drawing, tethered plug drawing, and fixed plug drawing. Choosing the right method or a combination of methods for a particular application requires understanding of the characteristics of each of them.

In the tube drawing, the die angle and bearing length are of essential importance for the finished tube’s appearance. The die angle influences the tubing’s surface finish—a gentle angle results in a smooth finish, whereas a steep angle results in a rough finish. The bearing length must be long enough to ensure the correct diameter and roundness, but not so long as to increase and mar the surface finish.

* Corresponding author: Mahesh P. Nagarkar, SCSM College of Engineering, Ahmednagar (M.S.)-414005, India, e-mail: maheshnagarkar@rediffmail.com
The die, most commonly used in tube drawing, is a sintered tungsten carbide insert encased in steel, with a cobalt content of approximately 10%. Higher cobalt content provides more shock resistance, whereas a lower content provides better wear resistance. The basic tube drawing processes are sinking, rod (mandrel) drawing, and several types of plug drawing. (1, 4, 5)

Kim et al. investigated the process parameters related to the tool configuration. They proposed a conventional straight type and terraced type of mandrels to obtain successfully formed shaft without any defect. For both types of mandrel, finite element (FE) analyses of drawing processes were carried out, using the ductile fracture criterion to predict a forming failure. The results are further used to design advanced mandrel shapes (6).

An analytical procedure based on the upper bound method for the investigation of formation features of the workpieces in dies for extrusion and/or drawing of fin-tubes and fin-bars has been developed by Kiuchi and Jima. Through a series of analyses, the effects of working conditions on shapes and dimensions of manufactured fin-tubes and fin-bars have been consistently clarified. The procedure offers a systematic approach to the design of dies and the pertaining processes (7).

In cold lubricated extrusion of round tubes, the material properties and surface quality of the extruded products are influenced by the die profile. Streamlined dies induce less redundant work and render desirable distribution of strength. Experiments have been carried employing A12024 as working material. The effects of the process parameters such as area reduction, die length, tubular shape ratio (thickness to outer diameter) and friction condition, etc. on the extrusion power are used to study the metal flow. The theoretical predictions concerning both the extrusion load and metal flow appeared to be in good agreement with the experimental results (8).

This paper discusses the modeling and simulation of the sink pass using ANSYS. Quarter models of the die and the tube are modeled. The model is meshed using Solid 93 3-D element. Then, it is solved by applying quarter symmetry and boundary conditions.

**Sinking**

In the tube sinking process, the tube is drawn through a die to reduce the outside and inside diameters. Sinking does not use an internal support, such as mandrel. Theoretically, the wall thickness does not change. However, it may increase or decrease, depending on the die angle and diameter-to-thickness ratio. Multiple sinking operations are generally used for commodity tubing for these applications such as low-cost lawn furniture (1, 2, 3, 9, 10).

In a sinking process, the typical die angle is 24°, with a relatively long bearing. Wall thickening is caused by a lower angle, whereas higher angles result in the wall thinning. Sinking uses a long bearing to achieve the correct size and optimal roundness, making this process suitable for a final sizing operation.
Figure 1. Sinking operation

Figure 2. Sinking operation – Die and tube showing various zones

FE Simulation using ANSYS

The finite element method is the numerical analysis technique for approximate solutions to the varieties of engineering problems. The finite method is originated as a method of stress analysis. The finite element procedure produces many simultaneous algebraic equations which are generated and solved by using computer. It transforms a physical system having an infinite number of unknown into a finite number of unknowns. ANSYS is a computer software for solving FEM and partial differential equations.

ANSYS can also be used to solve problems involving fluid flow, heat transfer, electromagnetic field, diffusion, and many other phenomena. In this paper, we have used it to predict the deformation and stress fields within solid bodies subjected to external forces. (4, 11)
FE Modeling of Die and Tube for Sink Pass

To construct the geometric model in ANSYS, 2-D model of die and tube is modeled using key points, lines and areas as shown in Fig. 3. The c/s is then revolved about the x axis to obtain the quarter model (see Fig. 4).

![Figure 3. 2-D Model of die and tube](image)

![Figure 4. Solid model of die and tube](image)

Meshing of Die and Tube for Sink Pass

Meshing is done by using 20-node solid95 since the material has nonlinear characteristics. Refer Fig. 6.

SOLID95 Element Description

SOLID95 element can tolerate irregular shapes without as much loss of accuracy. SOLID95 elements have compatible displacement shapes. It is well suited to model curved boundaries.
The element is defined by 20 nodes having three degrees of freedom per node: translations in the nodal x, y, and z directions. The element may have any spatial orientation. SOLID95 has plasticity, creep, stress stiffening, large deflection, and large strain capabilities. (11)

![Figure 5. SOLID95 - 3-D 20-node structural solid element.](image)

**Figure 5.** SOLID95 - 3-D 20-node structural solid element.

![Figure 6. Meshed model of die and tube](image)

**Figure 6.** Meshed model of die and tube

**FE Contact Pair**

The analysis of the sink pass is concerned with the contacts taking place between the inner surface of the die and outer surface of the tube. A contact pair is generated using the contact wizard (Fig. 7). Here, a frictionless contact (i.e. the coefficient of friction = 0) is modeled. Various lubricants can also be incorporated in the modeling by inputting various values of the coefficient of friction.

![Figure 7. Contact pair between the die and the tube](image)

**Figure 7.** Contact pair between the die and the tube
FE Boundary Conditions

In the simulation, the die is fixed while the tube is moved past the die along the X-direction. Boundary conditions are applied on the nodes. As the number of unknowns in the global force vector—there are more global displacement vector matrices than equations (see Fig. 8). After applying the boundary conditions the number of unknowns becomes equal to or less than the number of the equations.

![Figure 8. Boundary conditions die and tube](image)

RESULTS AND DISCUSSION

Analysis is carried out in the ANSYS 10 environment.

The material used for the tube in the sink pass is EN-31, with the modulus of elasticity of 210,000 N/mm2 and Poisson’s ratio 0.3. This is a non-linear type of contact analysis, contact between the die inner and the tube outer surfaces. Thus it is necessary to introduce the non-linear nature of the material in the analysis. Fig. 9 shows the non-linear behavior of the tube material as a stress-strain diagram. In the analysis, the part under study is the tube and not the die. Hence the die material is assumed to have a very high value of the modulus of elasticity of 2.1 x 109 N/mm2. Thus one can observe the stresses and displacement plots only for the tube.

The materials used is having the following mechanical properties:

Material for the die:  
\[ E_x = 2.1 \times 10^9 \text{ N/mm}^2 \]  
\[ \nu = 0.3 \]

Material for tube: EN-31  
\[ E_x = 210,000 \text{ N/mm}^2 \]  
\[ \nu = 0.3 \]
Nodal Solution

Figure 9. Non-linear material model for the tube

Figure 10. Displacement in the X-direction  Figure 11. Displacement in the Y-direction

Fig. 10 shows the displacement of the tube after completion of the sinking process. This is the total displacement of the tube. Figs. 11 and 12 represent the reduction of the diameter by 7.996 mm in the Y-direction and 8.129 mm in the Z-direction. Fig. 13 shows the von-Mises stress plot for the sinking process. The maximum value of the induced stress in the sinking process is 64.299 N/mm². This value is well below the material yield limit.
CONCLUSION

From Figs. 10, 11 and 12, it can be seen that the sink pass of round tubes is simulated successfully using ANSYS software. Fig. 11 shows the total displacement of the tube during the sink pass, while Figs. 11 and 12 show the reduction in the diameter during the sinking process. The von Mises stress plot (Fig. 13) shows that the induced stresses are well below the permissible stresses of the steel. Thus the sink pass operation is successfully carried out without material failure. Standard ANSYS has a lot of advanced non-linear features, solution methods, and convergence tools. It serves as a virtual prototyping tool for such processes. Simulation reduces the modification, redesign and re-analysis time, thus giving greater flexibility to the designers.

In future, the effect of the increase in the land and die angle can also be studied and optimum land and die angle can be obtained using ANSYS. Also, this model can help to simulate sinking process of various grades of steel and with various lubricants.
REFERENCES


11. ANSYS – Help.
рада уз помоћ покретног клина, обрада уз помоћ покретног вретена, хладно ваљање и топло ваљање.

Овај рад се односи на симулацију процеса обликовања округлих цеви техником пропуштања кроз отвор, уз примену ANSYS софтвера. Резултати симулације су померање и von Mises-ова напрезања. Поступак се може применити за повећање квалитета производа и за испитивање утицаја различитих параметара као што је угао алата за обликовање на квалитета производа.

Кључне речи: Обликовање пропуштањем кроз отвор, анализа коначних елемената (FEA), метода коначних елемената (FEM), бешавне цеви.

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