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A STUDY ON INFLUENCE OF FLOW FORMING PARAMETERS IN MANUFACTURE OF Cu TUBES

*Lakshmana Rao M[1] Rao T V L N[2] Gopala Krishna A[3]

[1]Department of Mechanical Engineering, B.V.R.I.T, Narsapur, Medak (Dt.) A.P, India
[2]Sundaram Clay Ltd, Chennai, India
[3]Dept of Mechanical Engineering, University College of Engineering, JNTU, Kakinada – 533 003, A.P, India

ABSTRACT

Flow forming process is an advanced echo-friendly chip less metal forming process which is used to manufacture a large variety of thin walled axi-symmetric shapes from plates or preforms.This process has several advantages like improved mechanical properties and surface quality for a finished part. Components produced through this process are widely used in aerospace and missile applications. In the present work, the experiments were carried out on a single roller CNC Flow forming Machine. This present paper deals with the manufacturing methodology and experimental findings during the course of development and production of these tubes. The effect of roller attack angle on surface finish and ovality are studied.

Keywords: *Flow Forming, Surface Finish, Ovality, Cu Tubes*

1. Introduction

Copper tubes up to certain minimum thickness are generally manufactured by flow forming process. Good dimensional accuracy and surface finish are achieved by this process. A lot of work on both theoretical analysis and experimental findings of this process was reported by many authors. Wu et al. [1] carried out finite element analysis of three-dimensional metal flow in cold and hot forming processes. Wong et al. [2] studied the effects of roller geometry and feed rate on forming load and material flow when flow forming a simple solid cylindrical component with uniform diameter. An experimental investigation on flow forming of AA6061 alloy using Taguchi approach was carried out by Davidson et al. [3] in which the effect of speed of mandrel, depth of cut, and feed on percentage elongation was studied. Some researchers [4-7] conducted experimental and theoretical analysis in flow forming of tubes to evaluate power and load requirements as well as the effects of process variables such as feed rate, approach angle and percentage reduction on surface finish and forming load. The influences of flow-forming parameters and the state of the microstructure on the quality and mechanical properties of a D6ac steel were studied by Jahazi and Ebrahimi [5]. The effects of feed rate, shape of the contact line, roller angle and percentage reduction on the elimination of spinning defects such as a wave-like surface, microcracks and bore were studied. Also, the influence of the preheat temperature, the holding time and the cooling rate on the microstructure and mechanical properties of the material was investigated.

In their previous work [8], the authors compared the experimental and simulation approaches for flow forming of Al (2219) tubes. DEFORM-2D was used for analysis. The authors modeled the flow forming problem as both plane-strain and axi-symmetric models. It can be noted that the literature on the achievable dimensional accuracy and surface finish in flow forming process is sparse. The actual difficulty lies in establishing the final optimum parameters to flow form the tubes with required dimensional accuracy and surface finish. The experiences from experimental work carried out during development and production of 5mm thickness copper tubes by this process are presented in this paper.

2. Flow Forming

Flow forming is an advanced echo-friendly chipless metal forming process for producing axi-symmetric components from plates or preforms. The cylindrical blanks, called preforms are stretched over a rotating mandrel by means of one or more rollers, arranged equidistant to each other. The preforms are stretched to the required lengths in one or several passes. Usually, all the materials which are ductile enough to be cold formed by any process can be flow formed. However the maximum percentage thickness reduction that a material undergoes without intermediate annealing between passes is different for different materials.

The components produced by flow forming finds applications in motor casing, warhead casings,

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**Corresponding Author - E- mail: lakshmanrao5@yahoo.com*

nozzles, cartridge cases, critical items of jet engines, exhaust pipes for motorcycles, automobile components and household appliances. Flow forming can be combined with deep drawing to economically form otherwise difficult components in near to net finished condition. Flow forming offers several advantages over conventional methods of tube forming like extrusion and drawing. By flow forming one can achieve excellent specific strength, good surface finish, close dimensional accuracy, minimum material waste, and low tooling cost.

3. Experimental Details

The flow forming rollers were made of die steel and heat treated to a hardness of 60/62 HRC and ground. The diameter of roller was kept larger than the diameter of mandrel. The initial thickness of the preform was determined depending on the maximum percentage of thickness reduction that a material undergoes without any annealing in between passes. This type of data is available for all the common materials in standard hand books.

Table 1: Experimental Conditions

Mandrel speed (rpm)	300
Roller geometry (Entry angle/ Corner radius/ Exit angle)	(15/8/5)
Roller feed	3.4mm for each pass
Roller diameter	260mm
Preform inner diameter	80mm
Preform outer diameter	105mm
Preform length	100mm
Preform final length	560mm
Number of passes	10

Copper generally can undergo maximum of 70% to 80% thickness reduction without any intermediate annealing. In the present work, the available 25mm thickness cold drawn tubes were taken as preforms and tubes of 5mm thickness were considered as the end products. The tubes were processed in 10 passes. Reverse flow forming was used to manufacture the tubes.

Flow forming experiments were carried out on a single roller CNC machine. The initial parameters were set based on the past experience of flow forming of aluminum components. Experiments were conducted by changing the parameters until the tube was formed with required tolerances on inner diameter and thickness. The initial conditions at which the experiments were performed are given in Table 1.

4. Experimental Findings

i. In the initial stage undue vibrations were observed. However, they were subdued in the successive stages by lowering the mandrel speed and the feed rate to 112 rpm and 1.4 mm/pass respectively. The preform and the final flow formed copper tube are shown in Fig.1.
ii. The chosen parameters of feed rate 112rpm and feed 1.4mm/pass were found to yield good surface finish also.
iii. Around 50% increase in tensile strength and 100% increase in hardness of the material was found after flow forming with the above set of parameters.
iv. The effect of attacking angle on the surface finish and the ovality are also studied. It is observed that when attack angle is increased, surface quality is improved. However, increase in attack angle also increased the ovality of the tubes.

Table 2 lists the obtained values and Figs. 2 and 3 depict the variation of surface finish inside and outside of the tube with respect to the variation in the attack angle. The effect of attack angle on ovality of the tube is portrayed in Fig. 4.

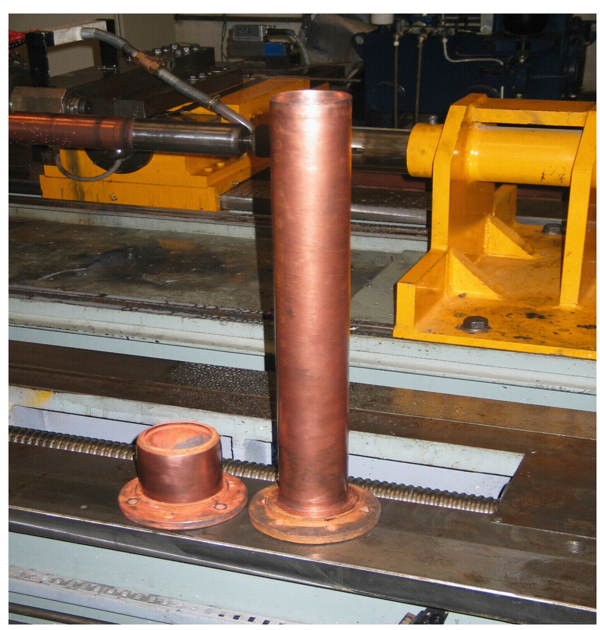

Fig. 1 Flow Formed Copper Tube and its Pre-form

Table 2: Effect of Attack Angle on Surface Finish and Ovality

Sl no	Attack angle or Approach angle	Surface finish Inside (µm)	Surface finish outside (µm)	Ovality (mm)
1	15^0	0.48	5.4	0.36
2	16^0	0.45	5.2	0.38
3	17^0	0.43	4.9	0.42
4	18^0	0.41	4.7	0.45
5	19^0	0.34	4.4	0.51
6	20^0	0.31	4.1	0.53

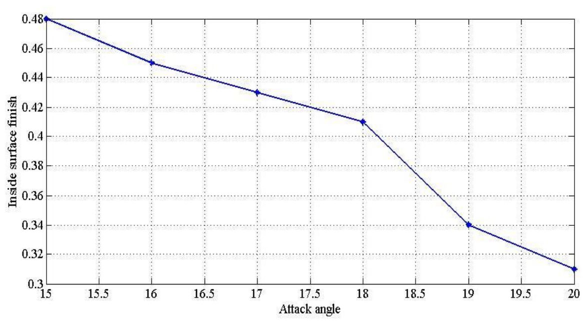

Fig. 2 Variation of Inside Surface Finish with Attack Angle

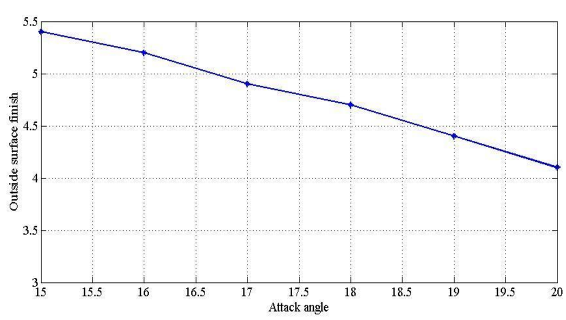

Fig. 3 Variation of Outside Surface Finish with Attack Angle

5. Conclusions

A flow forming process is used to manufacture thin walled copper tubes with good dimensional accuracy and surface finish. The parameters like mandrel speed, roller infeed, and roller geometry play an important role in this process.

An experimental investigation is made in this work to study the effect of the said parameters on surface finish and ovality of the finished tubes. It is observed that good surface quality is possible with large attack angle but, on the contrary, ovality has become excessive with large attack angle.

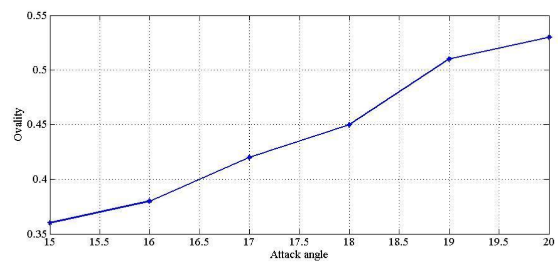

Fig. 4 Variation of Ovality with Attack Angle

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