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Procedia CIRP 55 (2016) 146 – 151

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5th CIRP Global Web Conference Research and Innovation for Future Production

Influence of Operating Variables during Flow Forming Process

Ravi J Bhatt[a,]*, Harit K Raval[b]

[a]Research Scholar, Department of Mechanical Engineering, S V National Institute of Technology (SVNIT), Surat-395007, Gujarat, India
[b]Professor, Department of Mechanical Engineering, S V National Institute of Technology (SVNIT), Surat-395007, Gujarat, India

* Corresponding author. Tel.: +91-9974411480; *E-mail address:*d13me007@med.svnit.ac.in

Abstract

Flow forming is gradually employed in production of high precision seamless components in the field of aerospace and defense. Rocket & missile casing, rocket motor case, cartridge case, rocket nose cones are few examples of flow forming process. The nature of process is non linear with complex deformation behavior. There are mainly two strategies used during the process viz. forward and backward/reverse. In forward method, the direction of roller feed and material deformation is same and in reverse method, the direction of roller feed and material deformation is opposite. Usually there are three force components encountered during the process i.e. axial, radial and circumferential. The understanding and knowledge of forces are crucial for tooling design for various geometrical and material conditions. The online force measurement during the process is quite difficult in commercial machines. Therefore, a simulation model is developed to estimate forces during the process. Taguchi L9 design has been used to develop the model because it is a well established design of experiment method to solve complex and time consuming problems. Three levels of three operating variables (rotational speed, axial feed and depth of forming) along with friction factor have been used during the study. The material utilized as Aluminum Alloy 6063 due to its light weight, excellent corrosion resistance, recyclable, cost effectiveness, ease of availability, durability etc. It has been observed that axial force is found to be highest followed by the radial and circumferential force. Also it has been discerned that axial feed and friction factor are the most prominent factors affecting axial and circumferential forces during the process. Further, radial force is influenced by friction factor only. The effect on von mises stress and equivalent plastic strain also studied and reported.

Peer-review under responsibility of the scientific committee of the 5th CIRP Global Web Conference Research and Innovation for Future Production

Keywords: Operating Variables; Friction; Flow Forming; Forces; Von-mises Stress; Plastic Strain; Taguchi; ABAQUS

1. Introduction

Flow forming is plastic deformation process which is specifically used to manufacture high precision seamless components for aerospace and defense industries. The application includes rocket motor case, cartridge case, missile casing etc. In this process, a deformable workpiece is placed over rigid mandrel and rollers are deforming it under contact area. Mainly two strategies adopted during process i.e. forward and backward/reverse. In forward method roller motion and deformation are in same direction (Fig. 1 (a)) and in reverse method; roller motion and deformation are in opposite direction (Fig. 1 (b)). It is important to have knowledge of behavior & pattern of deformation, forces encountered, stresses generated in order to design tooling (rollers and mandrel) for different material and geometric condition. Several work reported on flow forming. Zoghi et al. [1] had investigated on hot tube necking of 42CrMo (steel) using finite element analysis. Those results were validated experimentally. Earlier, Zoghi et al. [2] had studied that non uniform contact during process leads to the non uniform deformation. Rasoli et al [3] did experimental study on flow forming using ultrasonic vibrations. The modal analysis is done by giving mandrel and roller ultrasonic vibrations. Based on the study, they found that inner surface quality of the tube can be improved by lower frequency of vibrations. Srinivasulu et al. [4] had concluded that annealing improves the mechanical properties of flow formed components. They had

Peer-review under responsibility of the scientific committee of the 5th CIRP Global Web Conference Research and Innovation for Future Production
doi:10.1016/j.procir.2016.08.025

done experiments on single roller CNC machine for AA6082. Molladavoudi et al. [5] investigated that as the reduction of thickness increases; hardness, surface roughness and diametral growth increases while accuracy of geometry decreases.

Nomenclature

F_x	Radial force
F_y	Circumferential force
F_z	Axial Force
f	Axial Feed (mm/s)
s	Rotational speed (RPM)
d	Depth of forming (mm)
μ	Friction co-efficient

Abbreviation

DOF	Degree of Freedom
SS	Sum Square
MS	Mean Square

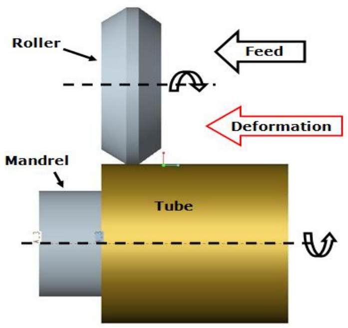

Fig. 1(a) Configuration of Forward flow forming

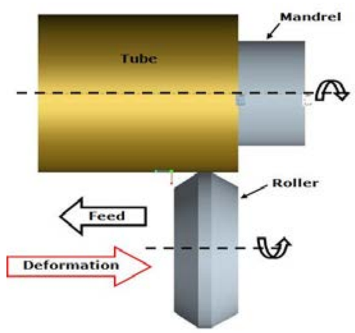

Fig. 1(b) Configuration of Backward/Reverse flow forming

Parsa et al. [6] developed correlation between feed with axial and angular velocities using FE simulations. Taguchi approach was employed by Davidson et al. [7] experimentally for AA6061 to determine significant factor which affecting the flow forming process. However, online measurements of forces are still difficult in commercial machines. Also, trial and error method normally adopted to work out optimal combination of parameters for different conditions. That increases lead time, indirect cost and waste. Hence, a simulation model is developed to estimate forces. Three operating parameters (rotational speed, axial feed, forming depth) and friction co-efficient are used during the study because these can be controlled manually by operator. The material is taken as AA6063 as it is widely used in aerospace and defense applications.

2. Analysis and Optimization

Flow forming is affected by many factors like operating parameters, material properties and roller geometrical configurations as shown in Fig. 2. Operating variables are easily controllable while material properties and roller geometrical parameters are difficult to deal with. Because, material properties may varies from batch-to-batch and lot-to-lot for same material. Furthermore, it is also difficult to vary roller configuration experimentally because several rollers consumes more material along with workpieces that increases material and inventory carrying cost. Therefore it is more convenient to use FE based tool to analyze such process by varying operating parameters to reduce raw material cost of workpiece and tooling.

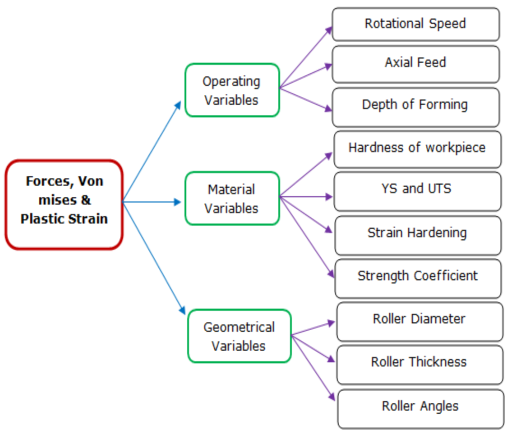

Fig. 2 Different factors affecting forces, von mises and plastic strain

In the present study, operating parameters are concentrated as those can be controlled for uniform quality of products. The operating parameters (rotational speed, axial feed and forming depth) selection is done based on the literature review and some preliminary experimentation. Moreover, friction factor is also considered to investigate its effect on forces. In practice, friction can be regulated by the different lubricating conditions. The backward/reverse strategy has been adopted because it doesn’t require any special fixture to grip workpiece during and after operation. Normally three forces are encountered during the process i.e. axial, radial and circumferential. Figure 3 (a) and 3 (b) shows the initial model with meshed blank and forces acting during process respectively. Here, AA6063 has been chosen as work material because it serves several advantages like light weight, excellent corrosion resistance, recyclable, high ductility, and various applications in aerospace and defense sectors. The mechanical properties of AA 6063 are [8]: density (ρ) = 2700 kg/m^3, YS (yield strength) = 48.3 MPa, elastic modulas = 68.9 GPa, poisson’s ratio = 0.33, US (ultimate strength) = 89.6