# A Study and Modal Analysis of Flow Forming Roller Based on Finite Element Analisys

Dr. G. Venkateshwarlu[1], Dr. J. Upendar[2], Dr. E. Madusudhan Raju[1]
[1]*Mechanical Engineering Department, University college of Engineering, Osmania University, Hyderabad 500007, India.*
[2]*Electrical Engineering Department, University college of Engineering, Osmania University, Hyderabad, 500007, India.*

**Abstract : Flow Forming is used mainly to produce thin walled high precision tubular components. Flow Forming is the only metal forming process that allows the flexibility to vary the wall thickness to produce thicker and thinner sections in any combination almost anywhere the rollers come in contact with the part. The flow forming process is mainly used for producing rocket motor casing shells and various other missile sections. In the present study the dynamic characteristics of the flow forming roller are theoretically calculated and studied by the finite element method. The finite element model of the flow forming roller is established by using ANSYS software. Through the analysis and calculation of the model, the first 6 natural frequencies and vibration shapes are computed, which provides a reference for the analysis and design of the flow forming roller.**

***Keywords: Flow forming, FEA,* Modal analysis *roller geometry***

## I. INTRODUCTION

The flow forming technique has emerged as the latest metal forming technique which can meet the challenging requirements of manufacturing high strength, precision, thin-walled thrust chambers with excellent surface finish and minimum material waste in an eco-friendly way, which parameters are playing a major role in flow forming process is important for getting down better results[1]. There are a large number of references available in the literature on the mechanism of flow forming and various flow forming machine parameters affecting the properties and dimensional accuracy of the flow formed components. However, there are very few papers available on the appropriate roller geometry selection in flow forming process. This problem reduces the tooling cost as well as selection of roller geometry to reduce the number of defects. The process parameters varied from material to material [2] but systematic analysis to be required before attempting experiments. This systematic analysis to be avoided confusion for selecting proper process parameters in flow forming process for obtaining better components. in the successful operation of the process, as the roller dia increases contact area between the roller and the work piece increases, the roller attack angle, roller corner radius, relief angle, and feed, are studied for eliminating defects.

It will be guidance for the practical production engineers engaged in this area. It can be reduced no of trials on flow forming experiments for obtaining optimum process parameters. This approach may be varied material to material. Previous literatures mainly studied the design, optimization and finite element analysis of the flow forming roller related functional components, but the modal analysis of the roller was not studied. However, the modal analysis of the roller plays an important role.

Through the modal analysis, the natural frequencies and vibration characteristics of the roller can be obtained. Theoretical basis for the study of vibration can be provided through the modal analysis, so as to improve the strength of roller, the heat dissipation condition and the failure safety. Therefore, in this paper, the structural modal analysis of a certain type of roller is carried out, and its structural size is optimized to provide reference for design and manufacture.

## II. PROCESS VARIABLES

There are numerous process variables that contribute to the successful production of a spun product. Some of the more significant process variables and their effects on conventional spinning, investigated by other researchers, are discussed below.

*2.1. Mandrel Speed*: Different speeds are to used for different materials depending on their hardness and formability. The upper speed limit is restricted by the power of the machine and its rigidity. The lower limit of speed is a process limitation and flow forming by plastic deformation will not take place below its limit. Higher speeds for ductile steels, medium speeds for harder steels and lower speeds for non ferrous are employed. Very high speeds will lead to heavy vibrations.

*2.2. Saddle Feed*: The feed is distance travelled by roller for a revolution of mandrel. The feed will affect the surface finish and diameter of final component.

*2.3. Roller Infeed*: The gap set between the roller and mandrel is called roller infeed. The exact infeed as to be determined by trial and error with a gap equal to final thickness. Roller infeed controls the final thickness. If the infeed is too high vibrations will occur.

*2.4. Roller Axial Stagger*: The Three rollers are axially staggered and take bite on the material one after another. If the stagger is too high, increased work hardening of material takes place and the control of inner diameter also becomes difficult. if the stagger is too small, high ovality will be developed in tubes.

*2.5. Roller Geometry*: Diameter, entry angle, tip radius and exit angle of a roller or important factors in flow forming operation. The diameter of the roller is really equal to the diameter of mandrel. The entry angle and tip radius determine the sharpness of a roller. The rollers should be sharper high strength steels and less sharp for aluminum and other soft materials. The exit angle does not have any effect on the process or work piece and it is kept only for clearance. [8-9]

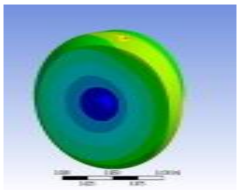
*2.6. Feed Ratio*: Feed ratio is defined as the ratio of the roller feed rate to the spindle speed. As long as the feed ratio remains constant, the roller feed and the spindle speed can be changed without any significant effect on the quality of the product. In contrast, too low a feed ratio will cause excessive material flow in an outward direction, which unnecessarily reduces work-ability and unduly thins the wall [3]. Wang et al. [4] explained that an increase of spindle speed would lead to two effects. One is an increased magnitude of spinning force due to the high deformation rate; the other is that the deformation energy required per revolution is likely to decrease because the feed rate is inversely proportional to the spindle speed (mm/rev).

*2.7. Roller Path*: The roller path is particularly important in affecting the quality of a spun part. Different roller paths such as linear, concave, convex, involute and quadratic relative to the work piece have an influence on the deformation of the blank. The tendency to buckle and cause wrinkles as well as cracking can be avoided by introducing the correct roller path. A concave roller path is the most widely used one in conventional spinning. The thinning rate in designing a roller path for the first-pass should be taken into account as it plays a decisive role in the final wall thickness [5].

Liu et al. [6] established an elasto-plastic FEM model to analyze the stress and strain distribution of the first-pass of conventional spinning with different roller paths, namely linear, in volute and quadratic, to convert the shape of the blank to that of the mandrel. They reported that both the radial and the tangential stress and strain are the smallest for the involute curve. They concluded that a comparison of the distribution of stresses and strains under the three different paths could provide a theoretical basis for selecting a suitable roller path in conventional spinning[7].

*2.8. Roller Design*: The design of the roller needs to be considered carefully as it can affect the component shape, wall thickness and dimensional accuracy. Although roller diameter has little effect on the final product quality, too small a roller nose radius will lead to higher stress and ultimately lead to poor thickness uniformity. Fig 3 gives details of roller and roller assembly. Various roller profiles have been developed to illustrate some of the considerations applied; some examples are given in Fig 2. As a general rule the softer the material, the smaller will be the angle α as this will tend to rise more than with the harder material. The exit angle located at the rear of the roller sometimes called the relief angle (β) is partially responsible for the surface quality of the flow formed part. Corner radius (r) is sharp for harder materials but trails to be required for finding suitable roller geometry before conducting experiments. This discussion may be helpful for designing a new roller.

Roller geometry consists of
α = Roller entry/Attack angle
β = Roller relief angle/exit angle,
Dr = Roller diameter.
r= Roller working Corner radius.



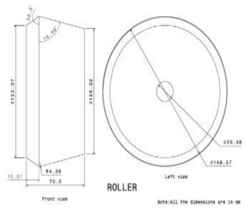



Fig.1.Finite 3D model of Roller Fig. 2. Schematic diagram of Roller geometry

*2.9. SPINNING RATIO*: Spinning ratio is defined as the ratio of blank diameter to mandrel diameter. The higher the spinning ratio, the more difficult is the spinning process. If the spinning ratio is too large, the remaining material cross section is no longer able to transmit the very high radial tensile stresses generated in the wall. This will lead to circumferential splitting along the transition from the flange to the wall. On the other hand, the spinning ratio is at its upper limit when the wrinkling in the flange becomes so large that subsequent passes of the tool cannot remove them

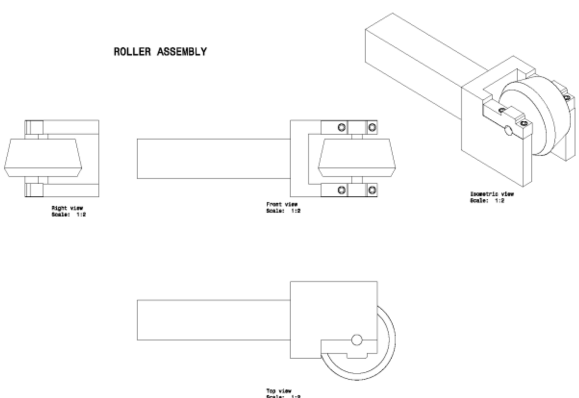



Fig. 3. Schematic diagram of Roller assembly

## III. MODAL ANALYSIS OF FLOW FORMING ROLLER

Model Establishment and Simplification of flow forming roller. In the modeling process, in order to avoid errors and improve the meshing and calculation speed of finite element calculation. The nonlinear taper cone structure in entity structure such as bradawl and tapper surface are simplified into a line. Avoid generating gaps when generating meshes, leading to the failure to build finite element models; The relatively complex geometry of the solid model is treated as a simple geometric shape. Geometric features, such as holes and grooves, which have little effect on the analysis results and calculation accuracy, are neglected. Mesh Generation.

Mesh generation is an important step in the pre-processing of finite element method, and it is time-consuming. The correct and reasonable meshing is the key to numerical simulation of finite element method. The quality of the mesh will directly determine the speed, accuracy and accuracy of the final analysis. This step plays a global role in the validity and reliability of the finite element analysis. When the brake drum is meshed, the 3D entity Solid 187 tetrahedron element is selected, and each unit has 10 nodes. The brake drum is meshed by the free meshing method. The flow forming roller is divided into 30954 nodes and 19651 units

## IV. CALCULATION RESULTS AND ANALYSIS OF ROLLER

The modal analysis of the flow forming roller is carried out, and the 1~6 order natural frequencies and modes of the free modal analysis are reviled. The calculated results of natural frequencies are shown in Table 1. Figure 4 shows the 1, 2, 3, 4, 5, 6 order vibration modes of the flow forming roller.

Table 1 Element analysis value of natural Frequencies (Hz) of Roller

| Mode Shapes | Frequency(Hz) |
|---|---|
| 1 | 1292.9 |
| 2 | 5007.4 |
| 3 | 5028 |
| 4 | 5573 |
| 5 | 5618.8 |
| 6 | 5963.5 |

According to the calculation results, the main vibration mode of the first, second order roller is that the roller edge has two deformations along the radial direction the deformation of the roller edge of the third, eighth order main vibration mode is basically equal; The roller edge of the second, third order main vibration mode has the biggest deformation along the radial direction. The main vibration mode of the second, third order is almost similar, and the deformation at the edge is the same, which is easy to cause the wear degree of the friction liner to be greatly different. The vibration displacement at the edge of the roller of the sixth, sixth order main vibration mode is larger, which is easy to produce vibration and noise and accelerate the wear of the friction lining.

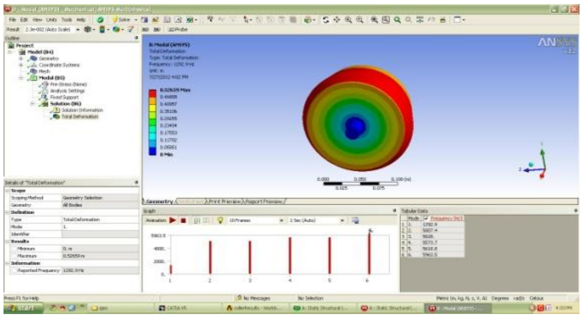


Fig.a First Mode Shape of Roller

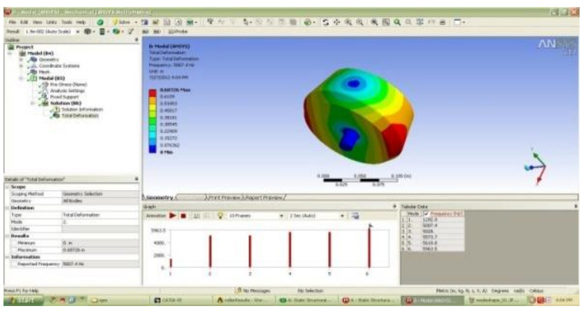


Fig.b Second Mode Shape of Roller

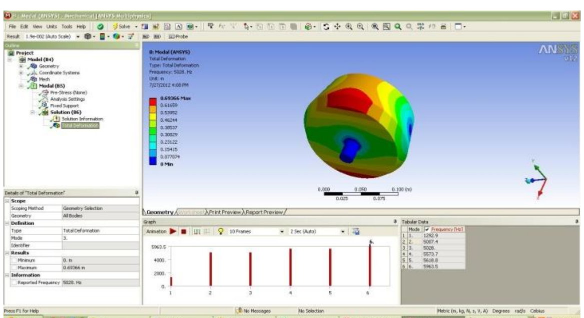


Fig.c. Third Mode Shape of Roller

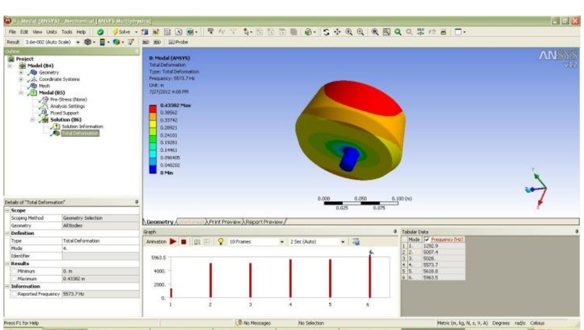


Fig.d. Fourth Mode Shape of Roller

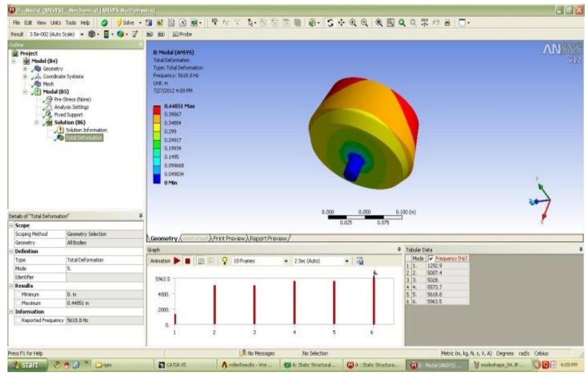


Fig.e. Fifth Mode Shape of Roller

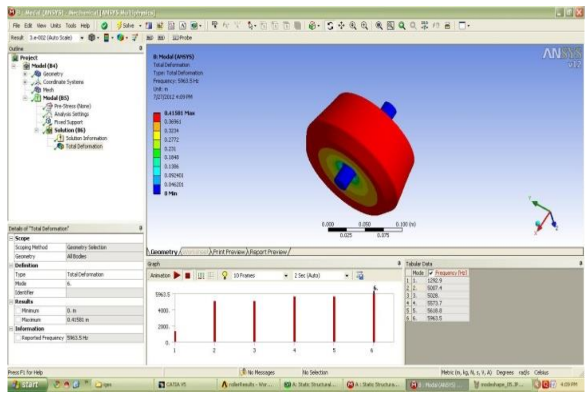


Fig.f. Sixth Mode Shape of Roller

Figure 4. Finite Modal diagram of natural frequency of Roller

## V. CONCLUSION

Selection of a roller is major problem in flow forming industries. This analysis is helpful for designing a new roller in flow forming process. According to the structure and mechanical performance requirements of flow forming roller, the flow forming roller is analyzed and calculated on the basis of finite element method.

The natural frequencies and vibration modes of the flow forming roller are obtained, and the modal analysis of the calculated results is carried out. The third order natural frequency of the brake drum is 5028Hz, while the 1000~5000Hz is the main research area.

The natural frequency is related to the quality and strength of the parts. The strength is higher, the quality is lighter, and the natural frequency is greater. Through the analysis of the natural frequency of the flow forming roller, and the influence of the structural change on the natural frequency, it is beneficial to the design of the flow forming roller.

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