Investigation of Material Properties Effect on the Ovalization Phenomenon in the Tube Bending Produced by RDB

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ABSTRACT

Rotating draw twisting (RDB) is among the best-known techniques utilized for cylinder shaping. Twisting profiles are utilized in most mechanical fields, including car design, aeronautic design, plant building, fluid transport, heat exchangers and many other sectors. Ovalization affects the nature of cylinder bowing. It occurs in the cross segment of the cylinder in the wake of bowing when the cylinder has twisted without a mandrel, or with a change of mandrel structure. This paper examines the ovalization phenomenon in cylinder bowing with turning draw twisting procedure and utilizing distinctive material properties (types of material: 1.4301(2x40), 1.0036(2x40), 6060T7(2.5x40), 1.4301(4x40), 1.0038(4x40), 1.5415(7.1x51) and 1.7380(7.1x51)). The finite element method (FEM) and experimental tests are applied to compute the ovalization proportions. This investigation helps to distinguish the impact of the material properties.

Keywords Tube bending; Ovalization; Rotary Draw Bending (RDB); Material Properties

INTRODUCTION

The rotary draw bowing procedure has found an ever-increasing number of applications in car, flight, aviation and other high-innovation sectors. It has turned out to be one of the primary fields in the innovative work of cutting-edge plastic shaping innovation; according to Yang et al. [1]

In the rotary draw bowing procedure, the cylinder is placed into the twisting machine and clipped between the internal and the external cinch dies. By the revolution of both around the twisting pivot, the cylinder is framed by the span of the bowing. The weight die (slide piece) effectively takes up the outspread pressure, which is created amid the shaping procedure and supports the straight cylinder end. In the event that a mandrel and a wiper are connected furthermore (mandrel twisting), high work piece quality can be accomplished even with slender-walled cylinders and minimal bowing radii. [2, 3].
Figure 1 shows the rotational draw bowing setup.

![Figure 1](image.png)

**Figure 1.** The rotary draw bending process [3]

Ovalization is a noteworthy imperfection which significantly affects the nature of cylinder bowing. Amid the twisting tasks, the cross area of the cylinder is mutilated into an oval. By contrasting cylinders bowed and cross-sectional bending and without cross-sectional twisting, it can be seen that cross-sectional mutilation is affected by variable attributes which lead to the low quality of the cylinder.

In any case, ovalization in the cross segment of the cylinder can be diminished by changing the mandrel’s structure longitudinally along the cylinder hub. This additionally results in better support of the cylinder, and it prompts higher frictional powers on the inward side of the external curve of the cylinder. Grinding can be decreased by adequate greasing of the mandrel/ internal tube.

An ovalized cross-sectional shape is shown in Figure 2. Here, it can be perceived how the proportional thickness on the external and inward circular segment of the cylinder changes due to cylinder bowing. Also, the focal point of the cylinder will in general move towards the inward circular segment of the cylinder, due to the ovalization.
Ovalization has interested many researchers in recent years. Kale and Thorat [4] studied the pipe twisting procedure. Their focus in this work was on a novel pipe twisting system in terms of planning, advancement, manufacture and gear use, which delivered tube twists with little ovality and better quality. Yang et al. [5] and Yang et al. [6] considered the impact of rubbing on the ovalization of slim-walled tubes. The contact between mandrel, wiper, weight and the cylinder affected the segmental nature of slim-walled tube bowing. Results demonstrated that to improve the cross-sectional quality, the rubbing between mandrel, wiper die and cylinder ought to be diminished, while gratings between the weight die, twisting die and cylinder ought to be expanded, as per Yang et al. [5]. Yang et al. [6] introduced the impact of rubbing on bowing conduct from different perspectives, for example, wrinkling, divider thickness dissemination and cross-sectional contortion. This examination can be utilized to improve the nature of thin-walled tubes by changing the handling parameters.

In this examination, exploratory tests demonstrate the impact of material properties on the ovalization phenomenon and FE recreation of rotational draw twisting has been created to simulate the ovalization proportions and compare the outcomes with those from the experimental tests.

EXPERIMENTAL PROCEDURE

A. Rotary Draw Bending Processes

The bowing tests were conducted with a CNC bowing machine from the Tracto-Technik GmbH and CO.KG Company. This machine has been designed for use in rotating draw bowing and for freestyle twisting. It is shown in Figure 3 [7].

Figure 2. A cross section of the tube before and after bending
**B. Mechanical Properties**

The mechanical properties of the cylinder were obtained from the uniaxial elastic test. A rectangular example is utilized for these malleable tests. The trademark material qualities are yield quality $R_{p0.2}$, elasticity $R_m$ and uniform stretching $A_g$, which are altogether controlled by pliable tests. These qualities are obtained from the estimations of three tractable examples. The normal mechanical properties are shown in Table 1. An example of the stream bends for these tests are given in Figure 4.

![Figure 3. Rotary draw bending machine TT120UTS](image)

**Figure 3.** Rotary draw bending machine TT120UTS

![Figure 4. The flow curve for the tested materials [7](image)

**Figure 4.** The flow curve for the tested materials [7]
Table 1. Mechanical properties of the semi-finished products

| Short name | Material | Yield strength Rp0.2 (N/mm²) | Tensile strength Rm(N/mm²) | Uniform elongation Ag (%) |
|------------|----------|-----------------------------|---------------------------|--------------------------|
| SS40x2     | 1.4301   | 464.01                      | 706.95                    | 44.68                    |
| S40x2      | 1.0036   | 302.87                      | 417.32                    | 21.28                    |
| AL40x2.5   | 6060T7   | 109.42                      | 213.52                    | 20.07                    |
| SS40x4     | 1.4301   | 236.63                      | 583.73                    | 56.9                     |
| S40x4      | 1.0038   | 370.08                      | 450.42                    | 25.27                    |
| SMo51x7.1  | 16Mo3    | 404.83                      | 552.94                    | 15.72                    |
| SCr51x7.1  | 10CrMo9-10 | 342.53                  | 506.97                    | 13.36                    |

Figure 5. Deformation region and cross section deformation

MATHEMATICAL CALCULATION
The cross-sectional contortion of the cylinder in the curve part is a noteworthy deformity, and gives a low quality of twist. The cross-sectional distortional degree amidst the bowing edge is practically most extreme incentive to the twisting degrees of the cylinder cross segments. The disfigurement area of the cylinder bowing and cross-sectional bending of the cylinder are shown in Figure 5.

Along these lines, the cross-sectional twisting can be controlled by changing the proportions of the vertical extent and the flat size of cross area, which rely upon the ovalization proportion. The accompanying condition communicates the cross-sectional twisting proportion (ovalization proportion):

\[
\text{Ovalization ratio} = \frac{\text{Horizontal axis} - \text{Vertical axis}}{\text{tube diameter}} \cdot 100 \quad (1)
\]
FINITE ELEMENT SIMULATION

Software PAM-TUBE

We performed limited component reenactments of rotating draw twisting in the program PAM-
TUBE, to predict the ovalization proportion of the cylinder bowing at the half bowing point with
various bowing edges. Figure 6 illustrates the limited component model of the rotational draw
twisting procedures.

![Illustration of the FE-Model of a RDB-process using the simulation](image)

RESULTS AND DISCUSSION

FE reproductions and trial tests were completed to anticipate the cross-sectional contortion in the
bowing procedure. Table 2 shows the diverse bowing element, divider factor and material properties
used in the FE reenactments and test tests. Table 2 additionally shows the twisting parameters of the
turning draw bowing procedure.

Figure 7 gives the ovalization proportions in a cross area of the cylinder for SS40x2, S40x2, SS40x4,
and S40x4, estimated with various twisting plots for a similar bowing element and distinctive divider
thickness factors. It appears that the most extreme estimation of ovalization proportion increments
with the expansion of the bowing point. Also, the divider thickness factor affects the ovalization
proportions. Hence, the ovalization proportion is expanded with the reduction of the divider
thickness factor. Generally speaking, these outcomes demonstrate that the material properties have
influenced the ovalization proportions of the cylinder, which is due to the strain-stress behavior of
the cylinder.
### Table 2. Bending parameters, materials, and dimensions of the tube

| Material/ Bending parameters | SS40x2 | S40x2 | S | AL40x2 | SS40x4 | S40x4 | 71 | SM651x | SC51x7 |
|-----------------------------|--------|-------|---|--------|--------|-------|----|--------|--------|
| B (Bending factor) (-)      | 1.87   | 1.87  | 1.87 | 1.87   | 1.87   | 0.705 | 0.705 |
| W (Wall factor) (-)         | 20     | 20    | 16  | 10     | 10     | 7.18  | 7.18 |
| R (Bending radius) (mm)     | 75     | 75    | 75  | 75     | 75     | 36    | 36 |
| Lc (Length of the clamp die) (mm) | 80     | 80    | 80  | 80     | 80     | 120   | 120 |
| Lw (Length of wiper die) (mm) | 80     | 80    | 80  | 80     | 80     | -     | - |
| Lp (Length of the pressure die) (mm) | 200   | 200   | 200 | 200    | 200    | 450   | 450 |
| Fp (Pressure force) (KN)    | 45     | 45    | 30  | 55     | 55     | 180   | 180 |
| Fe (Clamp force) (KN)       | 70     | 70    | 30  | 90     | 90     | 300   | 300 |
| Fpm (Pressure die movement) (KN) | 5      | 5     | 5   | 5      | 5      | 15    | 15 |
| μc (between the tube and clamp dies) | 0.27   | 0.27  | 0.4 | 0.27   | 0.27   | 0.5   | 0.5 |
| (μb, μP, μW, and μM)        | 0.1    | 0.1   | 0.15| 0.1    | 0.1    | 0.1   | 0.1 |
Figure 7. Comparison of the ovalization ratio obtained using the FE simulations and the experimental tests for SS40x2 and S40x2 with different bending angles (in the middle of the bending angle)

Figure 8 demonstrates the ovalization proportions in the cylinder twisting for AL40x2 with various bowing points. Generally, the ovalization proportion increases with the expansion of the twisting point. Also, the FE reproduction results show great concurrence with exploratory test outcomes.

Figure 8. Comparison of the ovalization ratio obtained using the FE simulation and the experimental test for AL40x2 with different bending angles (in the middle of the bending angle)
In any case, the cross-sectional twisting qualities increase with lessening of the divider thickness factor. Figure 9 shows the ovalization proportion with various twisting plots for SCr51x7.1 and SMo51x7.1. It is seen that the estimations of the ovalization proportion increase with the expansion of the twisting edge. For this situation, the ovalization proportion estimates are higher than in past outcomes. That is due to mandrel type, material properties, and the thick-walled tube used in this part.

**Figure 9.** Comparison of the ovalization ratio obtained using the FE simulations and the experimental tests for SCr51x7.1 and SMo51x7.1 with different bending angles (in the middle of the bending angle)

**CONCLUSIONS**

The material properties have an effect on the ovalization phenomenon in cylinder twisting. We created an FE reenactment of the rotating draw twisting procedure in PAM-Tube. The experimental tests and the FE-simulation results are compared in this work and outcomes demonstrate that the material properties influence the ovalization proportions of the cylinder. In addition, the most extreme estimation of ovalization proportion increases with the expansion of the bowing edge just as the divider thickness factor affects the ovalization proportions.

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