Material characteristics evaluation for DC04-welded tube hydroforming

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Abstract
Tube hydroforming (THF) technology is widely applied especially in the automotive and aircraft industries. Material characteristics of tubular workpieces should be evaluated in terms of bending and THF processes. A mathematical model, which combines the assumption of the elliptical contour of a bulged wall and the prediction equation of wall thickness, was designed to analyze the THF process and to obtain the strain–stress relationship of tubes. Material characteristics of a DC04-welded tube were obtained by using a self-designed THF test machine. Considering the effects of pre-work hardening, the material strain–stress relationships of the tube and original sheet blank were discussed. An approximate determination method was proposed to obtain the stress–strain curve of the tube by using the curve of the original sheet blank and the hardness of the tube and sheet blank. A suitable constitutive equation with pre-work hardening was applied to the DC04-welded tubes through simulation and experimental methods.

Keywords Material characteristics · Welded tube · Sheet blank · Finite element simulation

Nomenclature

- \( L \) Length of the bulging region
- \( R \) Initial radius of the tube
- \( t_0 \) Initial wall thickness
- \( t_b \) Thickness of point b
- \( h_i \) Bulging height
- \( R_a \) Radius of the elliptic contour in the x-axis
- \( R_b \) Radius of the elliptic contour in the y-axis
- \( R_r \) Radius of the die
- \( P_i \) Internal bulging pressure
- \( P_\varphi \) Meridian radius of curvature
- \( \sigma_{ST} \) Yield strength of the tube
- \( \sigma_{SB} \) Yield strength of the sheet blank
- \( \sigma_\varphi \) Stress in meridian direction
- \( \sigma_\theta \) Stress in circumferential direction
- \( \sigma_t \) Stress in normal direction
- \( \bar{\sigma} \) Equivalent stress
- \( \nu_\varphi \) Strains in meridian direction
- \( \nu_\theta \) Strains in circumferential direction
- \( T(x_i, y_i) \) Tangent point coordinates of the bulging region contour and mold contour
- \( \epsilon_i \) Strains in normal direction
- \( \bar{\epsilon} \) Equivalent strain
- \( \rho_\theta \) Circumferential radius of curvature
- \( H_T \) Vickers hardness of the tube
- \( H_B \) Vickers hardness of the sheet blank

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1 Introduction

The tube hydroforming (THF) process has been diffusely used in various manufacturing sectors, such as the automotive and aircraft industries [1, 2]. The technology is based on the plastic deformation of a welded tube using a pressurized fluid [3]. Compared with traditional stamping, THF has the following advantages: low cost, improved strength and stiffness, uniform wall thickness distribution, and few secondary operations [4, 5]. Material characteristics (flow stress, yield strength, and ductility) are of critical importance for reliable finite element (FE) simulations of THF [6]. It is now realized that the tube bulging test provides better data than the sheet tensile test for THF simulation [7]. However, the lack of availability of measurement hardware often overshadows the advantages of the tube bulging test. Therefore, looking into the relationship of material characteristics between the original sheet blank and tube, and proposing an approximate...
determination method to obtain the stress–strain curve of the tube is of critical importance in the industry.

So far, the tube bulging test methods have been studied by many researchers. Sokolowski et al. [8] designed a tube bulging device to apply axial loads on the tube. Tube material properties were examined by using the hydraulic bulge testing method. Strano et al. [9] described the superiority of obtaining the strain–stress curve through a hydraulic bulging test and proposed an inverse energy approach to determine the flow stress of tubular materials. Velasco et al. [10] performed an in-depth study on an analytical model to obtain material characteristics with tube bulging tests but committed an error evaluation through differential analysis by using the analytical model. They found that thickness strongly influenced the stress evaluation. In the early stages of research, the contour of the bulging area was assumed circular before a novel assumption of the contour shape was presented. Hwang et al. [11] developed a mathematical model to determine the flow stress of isotropic tubular materials under a new assumption that the profile of the bulged region is an elliptical contour. They found the elliptical model to be more efficient than the circular model [12]. Ouirane et al. [13] presented a semi-analytical model and revealed the influence of the initial wall thickness $t_0$ on the accuracy of the hardening curve. Muammer et al. [14] described an on-line and continuous measurement of flow stress for tubular materials and obtained results that matched well with off-line measurements. Analytical models for thickness prediction were found to be consistent with experimental measurements. Yuan et al. [15] evaluated the formability of an aluminum alloy friction stir-welded tube by examining the relationship of microstructures with plastic deformation and the hydraulic bulging process through simulations. They found that the welded nugget unlikely dominated failure during the hydraulic bulge test, and the tube exhibited high formality. Khalfallah [16] proposed a simplified method to obtain the characteristics of welded tubes by considering the welding bead and heat-affected zone. This method was assessed by comparing simulation predictions with experimental measurements. Zribi et al. [17] also proposed an inverse approach strategy comprising an optimization algorithm combining the results of experimental free-bulging test and simulation to determine the constitutive parameters of tubular materials. They also observed that the predicted parameters were consistent with the experimental data. He et al. [18] established a practical technique to characterize the deformation behavior of tubular materials and demonstrated that the three key factors controlling the accuracy of equivalent stress–strain curve obtained by hydro-bulging tests are reasonable analytical models of stress and strain components, precise description of the profile in the bulging zone, and accurate data of pole thickness. Recently, Suttner et al. [19] presented a strain rate controlled hydraulic bulge test using the Digital Image Correlation (DIC), but the closed dies were not adapted for measures with DIC systems [7]. Khalfallah et al. [20] proposed a reverse identification approach, which minimized
the error between experimental data and FE simulation of the tube bulging. The Khalfallah’s approach is effectual, but it’s time cost is expensive.

Although great progress on tube bulging test methods has been made, there still lacks an applicable and simple approach to obtain the stress–strain curve of the tube. Tubes are produced by multiple roll bending and then welded, as shown in Fig. 1. Material characteristics of welded tube and sheet blank are different due to multiple roll bending. Therefore, the effects of plastic deformation in initial roll bending on the material characteristics of welded tubes should be considered. Meanwhile, the effects of the anisotropy coefficients of sheet blanks on THF should also be investigated.

In the present study, a mathematical analytical model was used, and the assumption of an elliptical bulge contour [12] and the prediction equation of wall thickness [14] were combined. The hydro-bulging tests on the DC04-welded tubes were conducted and the strain–stress curves of the tube were obtained by using a self-designed equipment TUBEHYDRO-1. The analytical model was verified by comparing the results from FE simulation and experimental data.

Fig. 3 Stress state of the highest point $b$

(a) Experimental set-up

(b) Flaring and sealing process

(c) Injection process

(d) Bulging process

Fig. 4 Diagram of the testing principle. (a) Experimental set-up. (b) Flaring and sealing process. (c) Injection process. (d) Bulging process
An approximate parameter determination was proposed to define the material characteristics of the tubes from the original sheet blanks.

### Table 1 Geometric parameters of the tube

| Material | Diameter of the tube (mm) | Thickness (mm) | Length of the bulging region (mm) |
|----------|---------------------------|----------------|----------------------------------|
| DC04     | 65                        | 1.7            | 130                              |

2 **Mathematical analysis model**

The model of the free-bulging process for thin tubes is shown in Fig. 2. The two ends of the tube are fixed by the die and hence retain the length of the free-bulge region $L$ in a constant value. The axial section profile of the free bulge region is assumed to be an elliptical curve.

The contour equations can be presented on the basis of the geometrical relationship and tangent point coordinates $T(x_i, y_i)$ [12]:

\[
\frac{x_i^2}{R_a^2} + \frac{y_i^2}{R_b^2} = 1
\]

(1)

\[
\left(x + \frac{L}{2}\right)^2 + \left(y - R_r\right)^2 = R_r^2
\]

(2)

The following equations can be obtained on the basis of the geometric constraints of the tangent point $T$:

\[
\frac{dy_i}{dx_i} = -\frac{R_b}{R_a^2} \left(1 - \frac{x_i^2}{R_a^2}\right) = \frac{x_i + L/2}{R_a + R_b - y_i}
\]

(3)

\[
R_a = \left(\frac{x_i^2 - x_0^2}{x_i + L/2} - r - y_i\right)^{1/2}
\]

(4)

\[
R_b = \left(\frac{y_i^2 - x_0^2}{x_i + L/2} - r - y_i\right)^{1/2}
\]

(5)

In addition, the radius of the elliptic contour in $y$-axis $R_b$ can be expressed as

\[
R_b = r + h_i
\]

(6)

The bulging height, $h_i$, can be obtained in real-time measurement during the bulging test; thus, $R_b$ can be easily obtained through Eq. (6). Once $R_b$ is known, the coordinates $T(x_i, y_i)$ can be obtained from Eqs. (1) to (5), and $R_a$ can be determined with Eq. (4).

During the tube bulging process, the stress state of the highest point $b$ is shown in Fig. 3.

The circumferential and meridian radii of curvature $\rho_\theta$ and $\rho_\varphi$ at point $b$ can be obtained, respectively:

\[
\rho_\theta = R_b
\]

(7)

\[
\rho_\varphi = \frac{R_a^2}{R_b}
\]

(8)

From the force equilibrium at point $b$, we can obtain

\[
\frac{\sigma_\varphi}{\rho_\varphi} + \frac{\sigma_\theta}{\rho_\theta} = \frac{\sigma_{t_b}}{t_b}
\]

(9)

---

**Fig. 5** Bulging test equipment TUBEHYDRO-1. (a) Bulging test equipment. (b) Inner experimental set-up
In addition, at point \( b \), the stress along the normal direction is

\[
\sigma_\theta = \frac{P_i (\rho_\theta - t_b)}{2t_b (\rho_\theta - t_b/2)} \quad (10)
\]

\[
\sigma_\varphi = \frac{P_i (\rho_\varphi - t_b)}{2t_b (\rho_\varphi - t_b/2)} (2\rho_\varphi - \rho_\theta - t_b) \quad (11)
\]

In addition, at point \( b \), the stress along the normal direction is

\[
\sigma_t = P_i \quad (12)
\]

Therefore, the equivalent stress can be expressed as follows:

\[
\bar{\sigma} = \frac{1}{\sqrt{2}} \sqrt{(\sigma_\varphi - \sigma_\theta)^2 + (\sigma_\varphi - \sigma_t)^2 + (\sigma_t - \sigma_\theta)^2} \quad (13)
\]

The strains can be determined on the basis of the assumption of volume invariance:

\[
\varepsilon_\theta + \varepsilon_\varphi + \varepsilon_t = 0 \quad (14)
\]

where the strains in circumferential and normal directions, \( \varepsilon_\theta \) and \( \varepsilon_t \), respectively, can be obtained as [14]:

\[
\varepsilon_\theta = \ln \left( \frac{R_b - t_b/2}{r - t_0/2} \right) \quad (15)
\]

\[
\varepsilon_t = \ln \left( \frac{t_b}{t_0} \right) = -\frac{1}{3} \ln \left( \frac{3/2 - \rho_\theta/2\rho_\varphi}{3/2 - \rho_\theta/\rho_\varphi} \right) \quad (16)
\]

The relationship of the thickness of point \( b \) \( t_b \) and the initial wall thickness \( t_0 \) can be expressed as follows:

\[
t_b = e^a t_0 \quad (17)
\]

where the non-dimensional \( a \) parameter is defined as

\[
a = -\frac{1}{3} \ln \left( \frac{3/2 - \rho_\theta/2\rho_\varphi}{3/2 - \rho_\theta/\rho_\varphi} \right) \quad (18)
\]

Once the strains in circumferential and normal directions are calculated, the equivalent strain can be determined as:

\[
\bar{\varepsilon} = \frac{2}{3} \sqrt{\varepsilon_\theta^2 + \varepsilon_\varphi^2 + \varepsilon_t^2} \quad (19)
\]

### 3 Test method and experimental set-up

The experimental set-up included the main mechanical body, a high-pressure liquid system, and a hydraulic system that provided the sealing force. As shown in Fig. 4a, the main mechanical structure for the bulging test consisted of dies, left and right movable plates, upper and lower baffle plates, left and right punches, and a shutoff valve. The highest pressure that the set-up could sustain was 230 MPa, and the highest sealing force was 600 kN. The laser displacement sensor was used to measure the bulging height of point \( b \). As shown in Fig. 4a–d, the specific testing process was as follows:

(a) The dies were first placed into the two left and right movable plates before placing the tube in the die cavity.

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**Fig. 6** True strain–stress curve of the sheet blank for rolling direction

**Fig. 7** Sections of the tube

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**Table 2** Lankford coefficients of the sheet blank

| Material       | \( r_0 \) | \( r_{45} \) | \( r_{90} \) | \( \tau \) |
|----------------|----------|-------------|-------------|----------|
| DC04 (sheet)   | 2.51     | 1.89        | 2.94        | 2.45     |

---

\[ a = -\frac{1}{3} \ln \left( \frac{3/2 - \rho_\theta/2\rho_\varphi}{3/2 - \rho_\theta/\rho_\varphi} \right) \]
(b) The length of the bulging region was determined by the geometric dimensions of the baffle plates. The flaring and sealing of the tube were exerted by the cone-shaped punches. (c) The high-pressure liquid was injected into the tube via the channel of the right punch.

(d) As soon as the shutoff valve was closed, the high-pressure liquid was injected into the tube to implement the bulging test. During the bulging test, the bulged height was measured in real time by a laser displacement sensor. The bulged

| Test objects | Tube A | Tube B | Tube C | Tube D | Tube E | Sheet blank |
|--------------|--------|--------|--------|--------|--------|-------------|
| HV (kgf/mm²) | 115.3  | 107.4  | 103.8  | 105.4  | 99.5   | 83.3        |

![Bulging height-pressure curves](image1)

(a) Bulging height-pressure curves

![Enlarged view of Zone A](image2)

(b) Enlarged view of Zone A

![Enlarged view of Zone B](image3)

(c) Enlarged view of Zone B

**Fig. 8** Bulging height–pressure curves. (a) Bulging height–pressure curves. (b) Enlarged view of zone A. (c) Enlarged view of zone B
The pressure inside the tube was acquired by the pressure transducer. The dies in the active plates were easily replaceable to meet the requirements of different tube diameters.

In the present study, DC04-welded tubes were tested. The geometric parameters of the tubes are shown in Table 1. The bulge test equipment is shown in Fig. 5. It was able to test tubes of different sizes.

4 Material property test

4.1 Tensile tests of the original sheet blank

The tensile tests of the sheet blanks were conducted by the INSTRON 5982 material test machine. The sheet blank was the raw material for the DC04-welded tube. The test samples were cut from the sheet blank according to the Chinese national standard GB/T 228–2008, as shown in Fig. 6.

The true strain–stress curve of the sheet blank for rolling direction was obtained by a tensile test, as shown in Fig. 6. The least-square method was used to fit the strain–stress curve. The objective function was $\sigma = K\varepsilon^n\sigma$, and the fitting results calculated the strength coefficient of $K = 564.4$ MPa and the hardening exponent of $n = 0.29$.

According to the angles $0^\circ$, $45^\circ$, and $90^\circ$ from the rolling direction of the sheet blank, three types of tensile test samples were prepared. The Lankford coefficients at the engineering strain of 15% were obtained by the uniaxial tensile test at room temperature, as shown in Table 2.

Fig. 10 Tubes after bulging tests under different hydro-bulging pressures
4.2 Hardness tests of the tubes and sheet blanks

The DC04-welded tubes were made from the sheet blanks through bending and welding processes. The hardness tests were conducted to identify whether the material characteristics of tubes were affected by the forming process. From the forming process, the deformation of the tube was symmetrically distributed, as shown in Fig. 7. Each section of the tube, from A to H, was symmetric along the vertical symmetric axis. Besides, section A (0°) was the weld joint. Thus, only sections A to E are discussed.

With the digital micro-hardness tester, the Vickers hardness of the five sections of the tube from A to E was measured five times along the thickness direction. The Vickers hardness of the sheet blank was also measured. The average hardness values are shown in Table 3. Obviously, the average Vickers hardness of section A was the highest, whereas the average Vickers hardness of section E was the lowest. The average Vickers hardness of the sheet blank was lower than all the five sections of the tube because of non-uniform plastic deformation occurring in the tube during the roll bending process.

4.3 Bulging tests of the tube

Bulging tests of the DC04-welded tubes were performed with the bulging test equipment TUBEHYDRO-1. The bulging height–pressure curves of the five sections A–E were obtained. The pressure in different zones on the tube from A to E was acquired by the pressure transducer, as described in Sect. 2. The data of the five sections were compared after filtering, as shown in Fig. 8. From Fig. 8b, which is an enlarged view of zone A from Fig. 8a, it can be seen that the deformation behaviors of these sections are obviously different from each other in the elastic deformation stage. In the later stage of plastic deformation, as shown in Fig. 8c, it can be seen that the deformation behaviors are almost identical.

This phenomenon can be explained as follows. During the bulging process, the tube undergoes uniform deformation under bulging pressure. The material characteristics of the five sections are initially different. As hydro-bulging occurs, the deformation behaviors of these sections gradually...
become identical to each other. These sections eventually converge as the inner pressure further increases.

The SEM images of the tube bulging fracture are presented in Fig. 9. The fracture position was close to the inner surface. The fracture morphology, as shown in Fig. 9a, clearly revealed the thinning of the said thickness before fracture. The bulging fracture of the DC04-welded tube is a typical ductile fracture, as shown in Fig. 9b, and the dimples are clearly visible.

### 4.4 Wall thicknesses at different bulging pressures

The tubes under different hydro-bulging pressure are shown in Fig. 10. The bulging heights and the wall thicknesses at the highest point were measured, as shown in Table 4. The comparison of wall thicknesses at the highest point between the calculated results in Eq. (17) and experimental results is shown in Fig. 11. The maximum error between the calculation and experiment was 0.86%, which demonstrated that the mathematical analysis model can precisely predict the wall thickness of the highest point at different bulging pressures.

### 4.5 Tube material characteristics analysis and discussion

The bulging height–pressure curve of section E was obtained by the bulge test, as shown in Fig. 12a. According to the analytical model and Eqs. (7)–(19), the equivalent strain–stress curve was determined, as shown in Fig. 12b. The curves represent the deformation behaviors during THF. Two kinds of constitutive models, namely, the Ludwik constitutive model and the Swift constitutive model, were used to more accurately describe the tube material behaviors. These two constitutive models are illustrated in Table 5. Both models were utilized to fit the stress–strain curve (Fig. 13). The relatively simple Ludwik constitutive model is generally used to describe the material characteristics of tubes without pre-strain hardening, whereas the Swift constitutive model contains a pre-strain parameter and is more suitable for revealing the material characteristics for tubes with roll bending.

### 6 Result assessment by FE simulations

FE simulations were conducted to evaluate the whole procedure of tube material characteristics. The stress–strain curve obtained from the free-bulge test was used for simulation. The material parameters used in FE simulations were evaluated. The strategy of result assessment by FE simulations is shown in Fig. 14.

![Fig. 13 Strain–stress fitting curves. (a) Ludwik fitting curve. (b) Swift fitting curve](image-url)
6.1 FE model

The commercial software LS-DYNA was used to simulate the hydro-bulging process. The material model was Barlat’s three-parameter plasticity model. The material parameters of the Ludwik and Swift models of the simulation are listed in Table 5. The Young’s modulus was 207,000 MPa, with a Poisson’s ratio of 0.28. The FE geometric model was meshed with shell element, as shown in Fig. 15. The tube was modeled by the size of its neutral layer and contained 1440 quadrilateral elements. The models of the punch and die contained 1368 quadrilateral elements and 232 triangle elements, respectively. The motion state of the die was defined as stationary, and the punch was movable along the axial direction. The hydro-bulging process included two steps. First, the tube was flared and sealed by the punches. Subsequently, the hydro-bulging process was conducted. The simulation process is shown in Table 6.

6.2 Results and discussion

Comparisons of the pressure–height curves between the simulation and the hydro-bulging test are shown in Fig. 16. A good agreement was achieved, and this finding implies the reliability of the constitutive models obtained by the hydro-bulging method. The predicted pressure–height curve based on the Ludwik model was lower than that of the test when the bulging height was less than 1.5 mm because the pre-strain effect was disregarded in the Ludwik model. The Swift model resulted in more efficient predictions than the Ludwik model to simulate the whole hydro-bulging process.

6.3 Effects of anisotropy coefficient

It was found that the material characteristics of the tube during the bulge test can be precisely described by the stress–strain curve fitted by the Swift constitutive model and the anisotropy coefficients measured from the tensile tests of sheet blanks. The effect of the anisotropy
coefficients on the tube bulging was discussed through FE simulations. The average anisotropy coefficients were set as \( r = 1, 1.4, 1.6, 1.8 \). The predicted bulging height–pressure curves are shown in Fig. 17.

The anisotropy coefficients were found to have significant effects on the bulging pressure–height curves of tubes in the tube hydro-bulging, which is consistent with the view of reference [21]. Lower pressure is needed at the same deformation of tubes with lower average anisotropy coefficients. To obtain more accurate simulation results during the hydro-bulging or tube bending process, the anisotropy coefficients should be considered in the tube material constitutive model.

### 7 Approximate determination method for the tube constitutive model

A comparison was conducted between the stress–strain curve of the sheet blank after translation and the stress–strain curve obtained by the hydro-bulge test, as shown in Fig. 18. The tube and the sheet blank were found to have similar hardening characteristics during large plastic deformation. The yield strength of the tube was higher than that of the sheet blank; this difference is attributed to the work hardening in the roll bending process.

Therefore, an approximate determination method to determine the material characteristics of tubes from the sheet blank is desirable.

| Maximum height \( h_i \) (mm) | Flaring \((h = 0)\) | \( h = 1.03 \) | \( h = 3.30 \) | \( h = 5.17 \) |
|-----------------------------|-----------------|-----------------|-----------------|-----------------|
| \( P_i \) for Ludwik model (MPa) | \( P = 0 \) | \( P = 15.6 \) | \( P = 18.8 \) | \( P = 19.8 \) |
| \( P_i \) for Swift model (MPa) | \( P = 0 \) | \( P = 16.8 \) | \( P = 18.8 \) | \( P = 19.9 \) |
blanks was proposed by analyzing differences in the material Vickers hardness between sheet blanks and tubes. The yield strength of the material was found to have a quantitative relationship with its Vickers hardness. Therefore, the yield strength of the tube can be obtained from the yield strength of the sheet blank and the Vickers hardness of the tube and the sheet blank; the yield strength is expressed as

$$\frac{H_T}{H_B} = \frac{\sigma_{yT}}{\sigma_{yB}}$$  \hspace{1cm} (20)$$

The calculated average Vickers hardness of the tube and sheet blank were 106.3 kgf/mm² and 83.3 kgf/mm², respectively. The yield strength of the sheet blank was 165 MPa; thus, the yield strength of the tube was calculated to be 210.6 MPa.

The approximate stress–strain curve of the welded tube was obtained by intercepting the stress–strain curve of the sheet blank from the point \(Y\) of yield stress 210.6 MPa, as shown in Fig. 19a. The stress–strain curve obtained by this approximate determination method was found to be clearly similar to that obtained from the hydro-bulging test, as shown in Fig. 19b.

The FE simulation was conducted with the stress–strain curve obtained from the approximate determination method to obtain the bulging pressure–height curve of the tube. The comparison between the bulging pressure–height curve from the abovementioned method and the curve from the bulging
test was made, as shown in Fig. 20. The simulation using the approximate determination method could obviously reproduce the real behavior of the tube. Therefore, the material behavior of the 65 mm diameter DC04-welded tube can be represented by the stress–strain curve of the sheet blank. The initial yield point can be determined by the yield strength of sheet blank and Vickers hardness of the tube and sheet blank. An approximate stress–strain curve can be obtained with this approximate determination method. This curve can describe the material characteristics of the welded tube after working hardening.

8 Conclusion

The material behaviors of the tube and the hydro-bulging method were theoretically and experimentally studied. The relationship of material characteristics between the original sheet blank and tube was investigated. The main findings are summarized as follows:

(1) A mathematical analysis model was used to determine the material characteristics of the tube. This model considered the assumption of elliptical contours and the predictive equation of wall thickness. The effectiveness of the model was verified through FE simulation.

(2) It was found that the stress–strain curve of the DC04-welded tube can be obtained by using the analytical model and the tube hydro-bulging test. The anisotropy coefficients significantly affect the formability of tubes in THF. High inner pressure is essential for tubes with large anisotropy coefficients.

(3) During bulging, the tube likely undergoes uniform deformation because of the influence of bulging pressure. The Swift constitutive model was found to be more suitable for describing the material characteristics of the DC04-welded tube attributed to the influence of pre-strain, especially when the bulging pressure is less than 17.5 MPa.

(4) An approximate determination method was proposed to provide a simple approach and to obtain the approximate stress–strain curve. Thus, this method can be used to describe the material characteristics of the welded tube after work hardening.

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Declarations

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Consent to participate Informed consent was obtained from all individual participants included in the study.

Consent to publish The publisher has the permission of the authors to publish the given article.

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