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Optimization for the forming process parameters of thin-walled valve shell

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Abstract

Ball valves are widely used in industry, and the valve shell, a key component, is conventionally produced by casting and forging. A new technique, tube hydroforming, is introduced to overcome limitation of the conventional techniques. In order to obtain the optimal forming parameters of hydroforming, a new method combining genetic algorithm with finite element simulation is proposed in this paper. On the basis of plastic theory, the internal pressure and axial feed are expressed as a function of the stress ratios, respectively. Then, finite element method is used as a solver of the objective function, and genetic algorithm is employed to search the optimal stress ratios. Finally, the optimal internal pressure and axial feed are calculated by using their computation expressions. Verified experiments are carried out in the plant. The experiment results show that the proposed method can effectively obtain the optimal loading paths of tube hydroforming and remarkably improve quality of the ball valve shell.

Keywords: Tube hydroforming; Finite element method; Valve shell; Loading paths; Genetic algorithm

1. Introduction

Ball valves are used in detergent, pharmaceutical, chemical, rubber, pulp and paper plants, water treatment systems, textile mills and food processing plants. In general, ball valves offer many advantages when contrasted with other valve types. They provide superior ease of operation and can maintain and regulate high volume, high pressure and high temperature flow. Most ball valves offer rugged construction providing for a long service life, and a comparably low cost. Additionally, the design of the regulating element allows the valve to function without the complications of side loads, typical of butterfly or globe valves, and the valve design permits inspection and repair of seats and seals without removing the valves' body from the line, see Fig. 1.

The ball valve shell is the key component. Currently, on home and oversea the major methods for manufacturing the ball valve shell are casting and forging. As for casting, the method easily results in the high rejection ratio and wasting material due to the sand hole and blow hole; whilst the forging shell has a high quality, but the forging process is complicated, manufacturing cost is high and utilization ratio of materials is low. The all above disadvantages will have the unfavorable effects on the competition power of production. Thus, it has an extensive prospect and momentous economic value to deeply study on the newly manufacturing technology of the ball valve shell.

Tube hydroforming (THF) process utilizes mainly fluid pressure and tube material to produce various shaped parts [1,2] (see Fig. 2). This relatively new technology are widely applied in industry with respect of consolidation of parts, high strength-to-weight ratio, tight tolerance, better rigidity, less post-process operations, easy assembly [3–6]. Main applications of THF can be found in the automotive and the aircraft industries as well as in the manufacturing of components for sanitary use.

Here, the THF method is introduced into manufacturing the ball valve shell. First, the ball valve shell is obtained by THF, as Fig. 3(a). After rough machining, the median

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Nomenclature

C	the sufficient constant of the fitness
d_i	the instantaneous tube diameter at the middle of the tube
d_0	the initial tube diameter
L_0	the initial tube length
p_i	the internal pressure in the tube
$R_{p0.2}$	the yield strength of the tube
t_i	the instantaneous tube thickness at the middle of the tube
t_0	the initial tube thickness
α	the stress ratio
β	the strain ratio
σ_1	the principle stress of the circumferential direction
σ_2	the principle stress of the longitudinal direction
σ_t	the principle stress of the thickness direction
$\bar{\sigma}$	the equivalent stress
ρ_1	the instantaneous tube radius at the middle of the tube
ρ_2	the circular arc radius along the longitudinal direction

frequency welding is applied to weld the ball valve shell with the corresponding tube together, as Fig. 3(b). Finally, through the proper machining, the on-gauge shell is obtained. Comparing with the conventional manufacturing methods, the THF method has many advantages as shown in Table 1. In this paper, only the THF process is deeply discussed.

The THF process is influenced by many factors, such as tube geometric dimensions, mechanical properties and the THF processing parameters, i.e. the internal pressure versus the axial feed curve (the loading paths). The proper coordination of the internal pressure and axial feed is the key issue, as these process parameters have to be applied synchronously [7,8]. If the axial feed is too small and the internal pressure is very high, bursting may occur. If the axial feed is very large while the internal pressure is too low, the tube may buckle and wrinkle. Thus, it is a challenge how to obtain the optimal loading paths.

In the previous optimization, the internal pressure and axial feed were often regarded as the design variables respectively, which dissevered the relationship between the internal pressure and axial feed and could not make sure that materials in forming were under a feasible stress state. Furthermore, the design variable bounds were usually decided by experiments and estimates, which resulted in the long computational time or missed the optimal solutions [9,10]. In this work, the computation expressions are deduced by using the theoretical analysis. The stress ratios

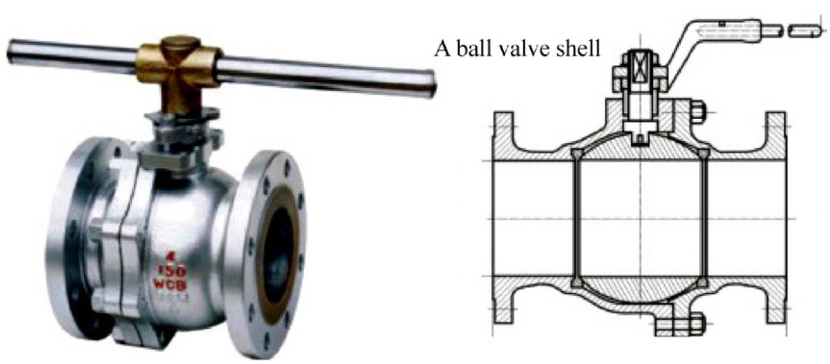

Fig. 1. A ball valve and profile.

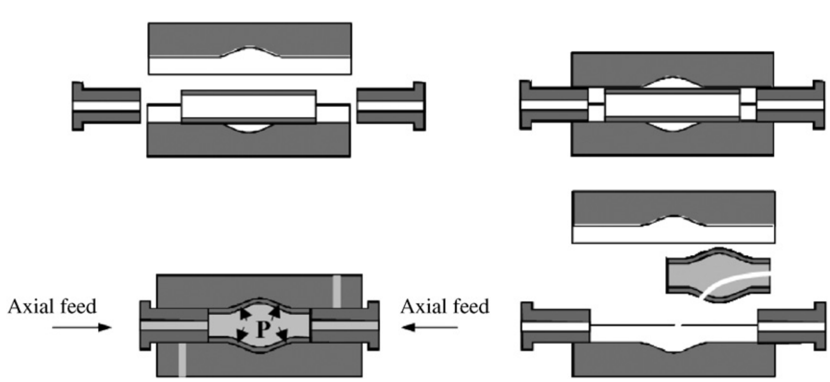

Fig. 2. The principle of tube hydroforming.