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Numerical Analysis of the Effect of Sinusoidal Pressure Path on Thinning of Tube in Hot Metal Free Bulging Process

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Abstract

Light-weight and high strength alloys such as Al-Mg alloys are used in order to reduce the weight of industrial components. However, these materials should be formed at elevated temperatures due to their poor formability at room temperature. Hot metal gas forming is one of the high-tech forming processes that is used to solve this problem. Recent investigation on tube hydroforming showed positive effects of oscillation of pressure paths in improving the formability of tubes. In this study, the effects of a sinusoidal pressure path on tube wall thinning of an Al6063 tube in HMGF process is investigated, and the results are compared with equal constant pressure by the finite element method. Moreover, the effect of stroke on thickness reduction of the tube is also investigated. The results show that the proposed sinusoidal pressure paths have an obvious improvement of thinning in hot metal gas bulging of tube and some defects such as necking and bursting are prevented by the oscillation of the inner pressure.

Keywords

Hot Gas Bulging, Sinusoidal Pressure, Finite Element Method, Formability

1. Introduction

Hydroforming is one of the metal forming processes which was introduced by Grey et al. in 1939. According to primary material and blank, this process is classified into three main categories including shell hydroforming, sheet hydroforming and tube hydroforming [1]. Tube hydroforming is a well-known method which is also known as hydraulic pressure forming and liquid bulge forming. Tube hydroforming system consists of various parts such as presses or clamping devices, pressure system, tooling and axial feeding system [2].

Most of produced parts by this process are used in aerospace and automotive industries. Significant advantages of tube hydroforming include lightening of metal parts, reduction of secondary operation, and lowering cost in complicated parts [3].

Koc and Altan forecasted process parameters on defects in tube hydroforming such as wrinkling, buckling, and bursting numerically [4]. Asnafi investigated the effect of parameters such as material and tube dimensions in tube hydroforming process. He studied the axial feeding and effect of this parameter on prevention of bursting and wrinkling [5].

Past studies have shown that pulsating pressure could partly optimize this procedure [6-8]. Mori et al. have studied pulsating pressure paths in tube hydroforming. The results showed that the formability is largely improved by oscillation of inner pressure [6]. Hama et al. have studied an automotive part which was simulated by pulsating hydroforming using finite element method [7]. Loh-Mousavi et al. have studied advantages of T-shape tube hydroforming by pulsating pressure using both numerical and experimental methods. The results proved that pulsating pressure have prevented tube bursting [8]. Lio et al. have investigated improvement of formability of Y-shape tube by pulsating hydroforming [9]. Ashrafi and khalili, using taguchi method, have studied the effect of pulsating pressure on T-shape tube hydroforming in 2015 [10].

Substituting metal parts with aluminum parts is common in order to reduce weight in automotive industry [11]. Aluminum- magnesium alloys have poor formability in room temperature. In order to resolve this limitation, hot and warm forming processes such as warm hydroforming and hot metal gas forming could be offered [12].

Kim et al. have studied free bulge forming of AA6061 tube at elevated temperature both numerically and experimentally [12]. He et al. have studied mechanical properties and formability of TA2 tube in hot metal gas forming and their results showed that tensile strength decreases while temperature is increasing [13]. Maeno et al. have studied how to improve bulging process for aluminum alloy tube by resistance heating [14].

In this paper, the effect of sinusoidal pressure path on hot gas free bulging is investigated by numerical method and the effects of this pressure path on geometry and thickness reduction are evaluated. In addition, the effect of axial feeding on variation of tube wall thickness has been studied.

2. FE Simulation

The free bulging process of an Al6063 tube was simulated by Abaqus 6.14. Solving method for this procedure was Dynamic, Temp-disp, Explicit. As shown in Figure 1, in order to reduce processing time, only the half of tube was modeled. The tube was meshed with 374 CAX4RT elements. The parameters used in this simulation are shown in Table 1.

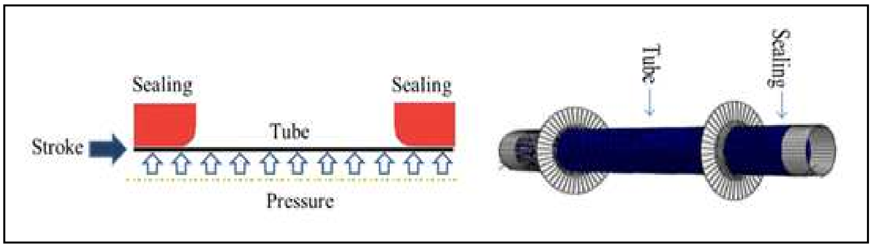

Figure1. Finite element model used for simulation

Table1. Parameters and conditions used in finite element simulation

Parameters	Value
Outer diameter	25 mm
Thickness	1.5 mm
Length	130 mm
Poisson's ratio	0.33
Coefficient of friction	0.1
Radiation Emissivity	0.33
Specific Heat	900 J/Kg°-C
Conductivity	209 W/M-K
Film Condition	2000 W/M^2-K

The sinusoidal pressure path which is used in simulation is illustrated in Figure 2. The average aforementioned pressure path was oscillated from the average pressure of 0.65MPa with an amplitude of 0.15 MPa and with a 1Hz frequency in 20 seconds. Then the constant peak pressure path equaled to the maximum value of sinusoidal pressure was simulated and the results were compared.

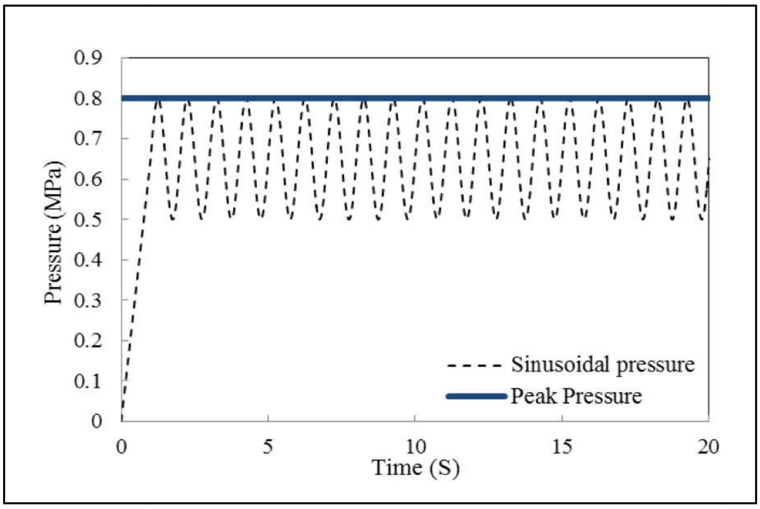

Figure2. Pressure path used in finite element simulation

As shown in Figure 3, tensile strength and elongation curve of Al6063 tube at elevated temperature was utilized in Dynamic-Explicit finite element model [14]. The temperature distribution graph along the length of the tube is shown in Figure 4. According to this figure, the temperature is non-uniformed on the surface of the tube and increases around center of the tube. The temperature of sealing components has been assumed to be constant.

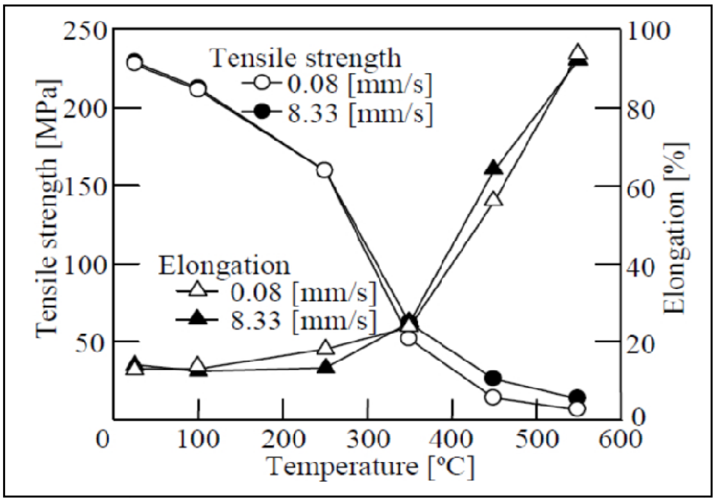

Figure3. Variations in tensile strength and elongation with heating temperature obtained from tensile test of A6063-T5 tube [14]

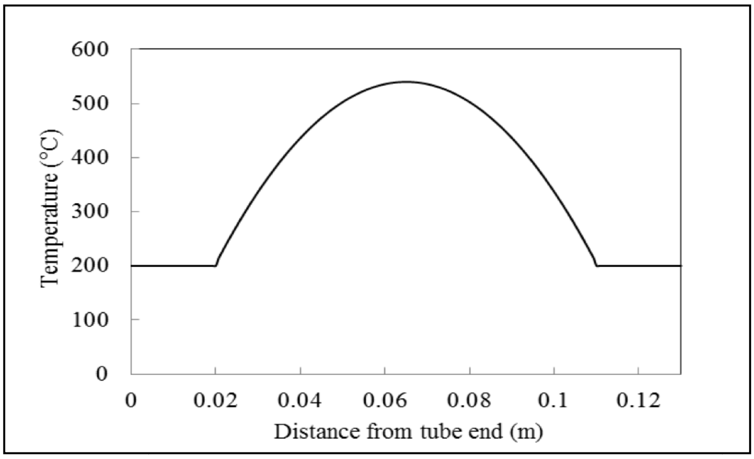

Figure4. Distribution of temperature on surface of tube [15]

3. Results and discussion

3.1. Numerical study on the effect of sinusoidal pressure on tube geometries

The comparative results of simulated tubes with and without sinusoidal oscillations are shown in Figure 5. The comparison indicates that sinusoidal oscillations leads to a flat shape geometry but utilizing the peak pressure creates a convex shape bulging.

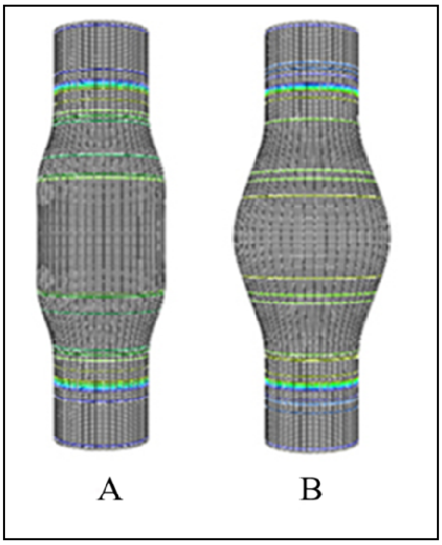

Figure5. Formed tubes in simulation for two pressure paths, A) Sinusoidal pressure, B) Peak constant pressure

3.2. Effect of sinusoidal pressure on thinning

As shown in Figure 6, results of both sinusoidal oscillations and non-pulsating pressure with axial feeding of 10 mm are compared. Inferred results show that thickness reduction in peak constant pressure had a significant decrease, but using oscillating pressure gradually decreases thickness reduction. This result indicates that local thinning and bursting occur faster when utilizing peak pressure, but substituting peak pressure with pulsating and hammering oscillations slows down this phenomenon. When axial feeding accompanies sinusoidal oscillations, it causes material flow during forming so thickness reduction of the tube is decreased.

The longitudinal wall thickness reduction is illustrated in Figure 7. The results show that using oscillating pressure improves the thickness obviously and makes it uniform.

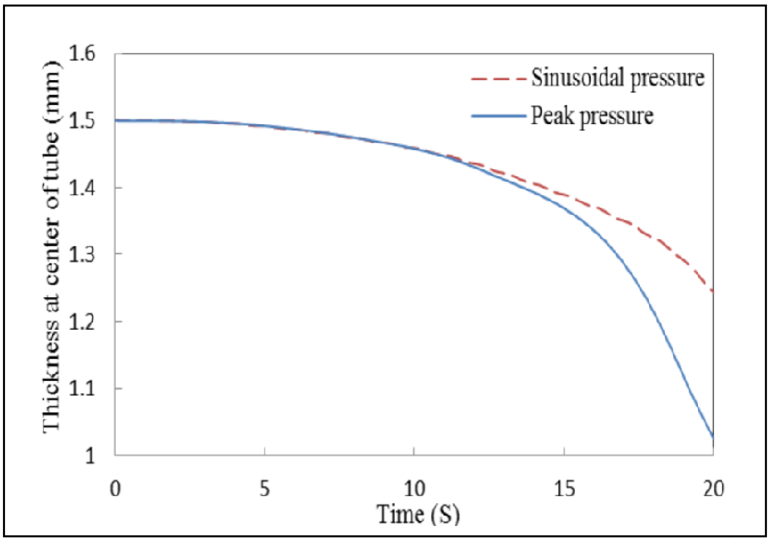

Figure6. Distribution of wall thickness at center of tube obtained from simulation

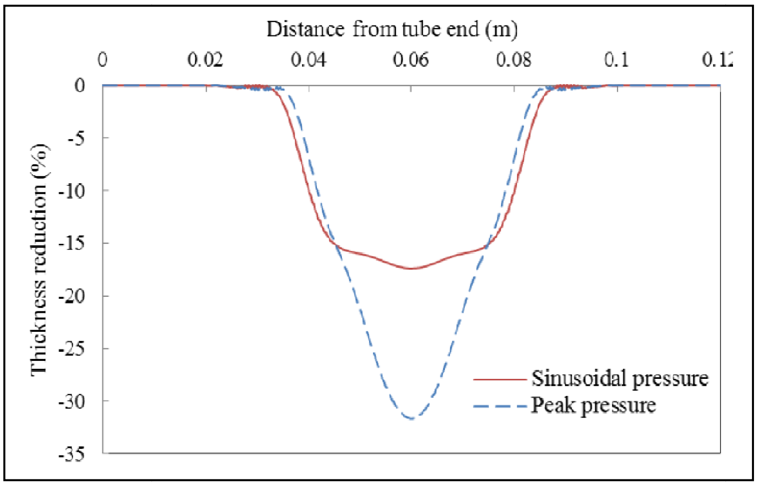

Figure7. Thickness reduction of the formed tubes obtained numerically

3.3. Effect of axial feeding (stroke) on thickness reduction

The results of two different values of axial feedings, obtained from the finite element simulation are shown in Figure 8. Results show that the more axial feed value, the better formability and thickness of the tube. This result is due to more material supply in deformation area, so it prevents defects such as bursting.

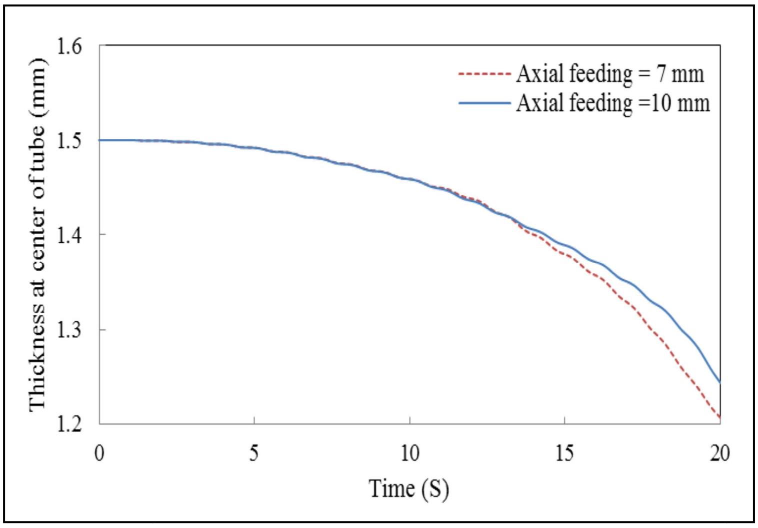

Figure8. Effect of axial feeding on the variation of wall thickness obtained numerically

4. Conclusion

In this paper, the effect of a sinusoidal pressure path on hot metal gas forming process was investigated. The simulation results showed that the deformed tube by sinusoidal pressure has a flat shape geometry. The proposed sinusoidal pressure path caused a uniform flat deformation with regular thickness reduction;where as non-pulsating pressure formed a round shape bulging.

For non-pulsating pressure path, the thickness decreases quickly and finally the tube gets burst. Furthermore, appropriate axial feed facilitates material flow in bulge zone during pressure oscillations and improves formability of the tube in HMGF process.

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