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A Study on Manufacturing of Head-Part of Pipes Using a Rotating Manufacturing Process

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Abstract**—**A large variety of pipe flange is required in marine and construction industry. Pipe flanges are usually welded or screwed to the pipe end and are connected with bolts. This approach is very simple and widely used for a long time; however, it results in high development cost and low productivity, and the productions made by this approach usually have safety problem at the welding area. In this research, a new approach of forming pipe flange based on cold forging and floating die concept is presented. This innovative approach increases the effectiveness of the material usage and save the time cost compared with conventional welding method.

To ensure the dimensional accuracy of the final product, the finite element analysis (FEA) was carried out to simulate the process of cold forging, and the orthogonal experiment methods were used to investigate the influence of four manufacturing factors (pin die angle, pipe flange angle, rpm, pin die distance from clamp jig) and predicted the best combination of them. The manufacturing factors were obtained by numerical and experimental studies and it shows that the approach is very useful and effective for the forming of pipe flange, and can be widely used later.

Keywords**—**Cold forging, FEA, finite element analysis, Forge-3D, rotating forming, tubes.

I. Introduction

VALVES and fittings are used for pipe connection in the hydraulic industry, and are widely used for fluid flow control in almost all industries, including the shipbuilding, petrochemical, power generation system, industrial plant, and semiconductor industries. Furthermore, there are wide varieties of valves. Low-priced universal large-demand valves are being produced in China and India while high-value-added valves such as control valves are produced in advanced countries like USA, Japan, and Germany, with an over 80% share in the global market. In particular, precise fittings and valves for instruments are applied to all areas associated with the development of national basic industries, including the semiconductor, shipbuilding, petrochemical, power generation, aviation, and military industries.

Recently, a domestic fitting manufacturer developed a method of addressing the leakage of fluids and the blocking of valves. The lock-type fittings in Fig. 1 (a) need four parts (excluding the pipe), and the ferrule in the middle (excluding the two nuts and the fitting bodies) require precise machining and mechanical properties [1]-[4]. The ferrule between the nut and the pipe are compressed and sealed by the torque applied to the nuts during assembly, but the prices of the fittings are on the rise due to the increased machining time and cost burden of the ferrule. For the flange-type fittings, which require flange forming, manual production has limitations.

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(a) Lock-type fittings (b) Other related types of fittings

Fig. 1 Fitting-related products

The present study was conducted to improve the efficiency of the materials through the pipe flange orbital-forming approach, based on the cold forging and die design of the fittings, thereby reducing the time cost relative to the conventional welding methods, and promoting their wide application.

II. Finite-Element Analysis Conditions of Orbital Forming

Stainless pipes have a symmetrical shape around the central axis. The pipe end is spread during the forming process.

As shown in Fig. 2, orbital forming is used to form the stainless pipe end with a smaller force.

The commercial finite-element analysis program FORGE 2009 was used for the analysis of orbital forming for stainless steel pipes. The analysis model is shown in Fig. 3, and the analysis conditions are listed in Table I.

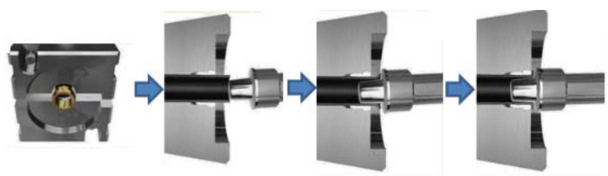


Fig. 2 Orbital-forming process

The pipe material is fixed onto the top lamp die, and the material is formed while the bottom pin die is rotating. There is a ring inside the clamp die. The most important factor in forming analysis is the forming of the pin die by stroke, as shown in Fig. 3, and the precise forming of the pipe exterior must be checked.

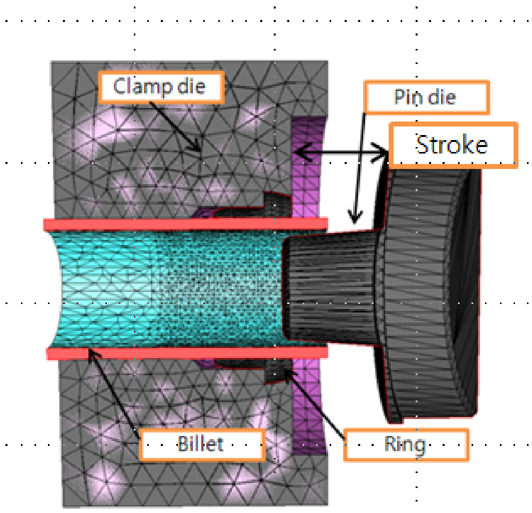


Fig. 3 Modeling of the pressorbital-forming process

The conditions for finite-element analysis include the clamp die velocity, clamp friction, mandrel friction, clearance, etc., as shown in Table I.

TABLE I
ANALYSIS CONDITIONS OF THE ORBITAL-FORMING PROCESSES

Condition	
Pin die rpm	4
Pin Die friction	0.3
Pin die angle	4.5
Clamp Friction	Bilateral sticking
Clamp die velocity	1mm/sec
Mandrel friction	Sliding
Billet-mandrel	1/100 * pipe thickness

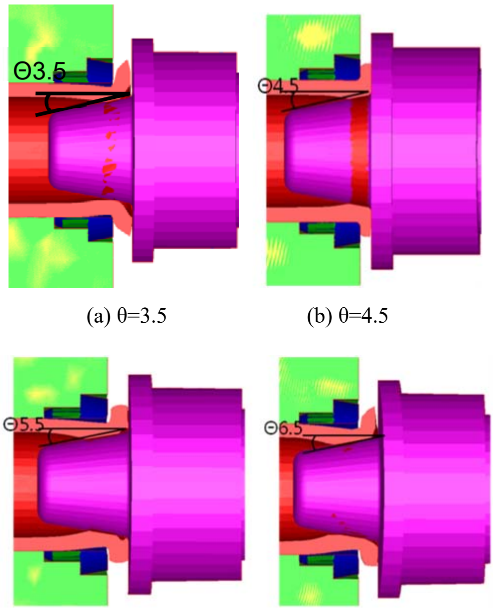
III. ANALYSIS RESULTS AND DISCUSSION

A. Analysis According to the Pindie Axial Angle

The fillet angle of the pin die jig has a great effect on the material forming and on the product-filling part shown in Fig. 4. In this study, the fillet angle was varied from 3.5 to 6.5 degrees, and the effects on product forming were identified. Fig. 4 shows the final shapes of the pin die according to the fillet angle. The results of Fig. 4 indicate that the greater the fillet angle is, the worse it becomes. The forming was closest to the flange shape at θ=4.5, which is the middle value [5]-[7].

B. Analysis According to the Stroke Distance

The pin die stroke has a great effect on the flange shape. A small stroke cannot satisfy the exterior shape of the pipe while a large stroke causes an assembly problem as the flange pipe thickness is insufficient due to overforming. Therefore, an accurate stroke in tune with the pipe thickness is required. Fig. 5 shows the analysis results at high and proper pin die strokes after fixing the fillet angle at 4.5 [8], [9].



(a) θ=3.5 (b) θ=4.5

(c) θ=3.5 (d) θ=4.5

Fig. 4 Deformation behavior according to the fillet angle size change

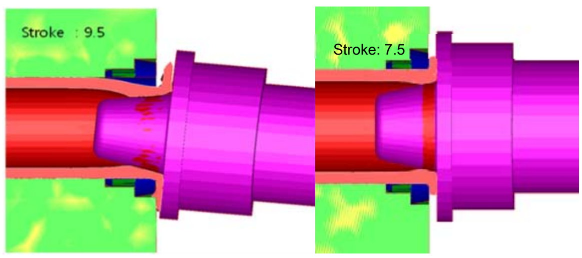


Fig. 5 Pipe deformation according to the pin die stroke deformation

The result shows that there was a 7.5 mm stroke. Fig. 6 shows the load variation according to the changing stroke. The greatest load occurs at the starting point of deformation. After a gradual decrease, the load increases again at the point of the second deformation, and it decreases again when the second deformation finishes.

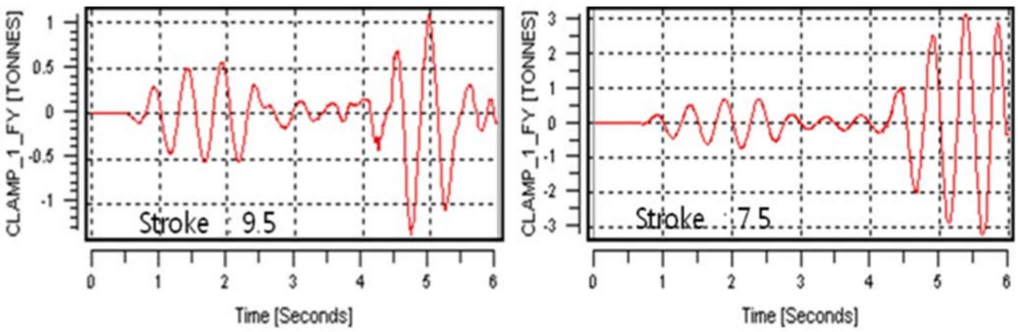


Fig. 6 Load variation according to the pin die stroke deformation

C. Effect on the Stroke of the Increase in Pipe External Diameter and Thickness

There are various kinds of stainless steel pipes, and it is important to identify the effects of the pipe thickness and stroke on the moldability of products [10]. The stroke changes according to the changing diameter at the same thickness was 5.37 mm for the 1T of Ø6, 5.42 mm for the 1T of Ø8, 3.58 mm for the 1.5T of Ø10, 4.76 mm for the 1.5T of Ø12, 5.13 mm for the 2T of Ø16, and 5.16 mm for the 2T of Ø20. Thus, the stroke increased together with the external diameter at the same thickness. This shows that as the external diameter increases, the deformation distance of the shape increases, which increases the stroke. Table II shows the stroke variations by changing diameter and thickness.

TABLE II
DEFORMATION BEHAVIOR ACCORDING TO THE INCREASE IN PIPE THICKNESS AND STROKE

Diameter	Thickness	Stroke (mm)	Condition	
6	1	5.37	Pin die rpm	4
8	1	5.42	Pin Die friction	0.3
10	1.5	3.58	Pin die angle	4.5
12	1.5	4.76	Clamp Friction	Bilateral sticking
14	2	6.74	Clamp die velocity	1mm/sec
15	1	4.76	Mandrel friction	Sliding
16	2	5.13	Billet-mandrel	1/100 * pipe thickness
18	1.5	6.02		
20	2	5.16		
22	1.5	7.27	Clearance	
25	2.5	6.27		
28	2	7.70		

D. Load Variations According to the Changing Pipe External Diameter

To check the effect of the load changes according to the velocity with the pin die revolutions fixed at 4 revolutions per 1 mm, the variations of the pipe deformation load were observed while the pin die jig velocity was increased from 0.5 to 1.75 mm/s in 0.25 mm/s units under the pipe-forming conditions of 10 mm for the external diameter and 1.5T for the thickness.

Table III shows the load variations according to the velocity changes. The difference in the maximum loads between the lowest and highest loads was 4.7 ton.

Table IV shows the load variations according to the changing external diameter and thickness. The load increased as the external diameter and thickness increased, and the thickness of the pipe had a greater effect on the load than on the external diameter.

E. Product Forming According to the Load Conditions

Fig. 7 shows photographs of deformed pipe products due to insufficient stroke during forming, and pictures of the products and sections caused by excessive stroke.

Fig. 8 shows the pilot product made by stroke and mold shape, according to the analysis results.

TABLE III
LOAD DEFORMATION ACCORDING TO THE INCREASE IN VELOCITY

Velocity	Load	Condition	
0.5	2.5	Pin die rpm	4
0.75	2.8	Pin Die friction	0.3
1	3.5	Pin die angle	4.5
1.25	3.6	Clamp Friction	Bilateral sticking
1.5	5.8	Clamp die velocity	1mm/sec
		Mandrel friction	Sliding
1.75	7.2	Billet-mandrel Clearance	1/100 * pipe thickness

TABLE IV
DEFORMATION BEHAVIOR ACCORDING TO THE INCREASE IN PIPE THICKNESS AND LOAD

Diameter	Thickness	Load (ton)	Condition	
6	1	1.23	Pin die rpm	4
8	1	1.15	Pin Die friction	0.3
10	1.5	1.02	Pin die angle	4.5
12	1.5	0.98	Clamp Friction	Bilateral sticking
14	2	1.81	Clamp die velocity	1mm/sec
15	1	1.78	Mandrel friction	Sliding
16	2	2.24	Billet-mandrel	1/100 * pipe thickness
18	1.5	1.52		
20	2	8.17		
22	1.5	7.28	Clearance	
25	2.5	13.81		
28	2	9.28		

(a) Photograph of folded products

(b) Photograph of incomplete and unfilled products

Fig. 7 Photograph of folded and unfilled products

Fig. 8 Photograph of the pilot product

IV. Conclusion

In this study, the orbital forming of stainless steel pipes was investigated, and the effects of the pin die fillet angle, stroke, and pipe thickness, including their effects on the velocity, were examined. The optimal forming conditions for the most frequently used stainless steel pipes, and their loads by external diameter, were presented. The conclusions of this study can be summarized:

(1) In the orbital-forming process of stainless steel pipes, the pin die fillet angle must be maintained at θ=4.5, and the stroke must be set properly.

(2) The stroke of the pin die is closely associated with the shape of flange products. An insufficient stroke of the pin die will fail to form the fillet round of flange whereas an excessive stroke will lead to low product thickness, which is not appropriate for fittings.

(3) After the selection of the forming conditions according to the diameter and thickness variations, pipes with precise exterior shapes can be formed using the orbital-forming process.

Acknowledgment

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References

[1] Ohashi, T.and Hayashi, K., "Lateral Extrusion of A6063 Aluminum Alloy Pipes", *Journal of Materials Processing Technology*, Vol.138, pp.560-563, 2003.

[2] Y. H. Bae, D. H. Kim, "The FEM Analysis in Seamless Pipe Expansion Process*", Proceeding of the KSMPE Autumn Conference 2014,* p.51.

[3] Atta urRehman Shah, Muhammad Abid, Abdul Wasy, J. I. Song, "Performance of a Gasketed Bolted pipe Flanged Joint under Bolt up, Internal Pressure and Harmonic Bending Loading", *Proceedings of the KSMPE Conference* 2012 p.145.

[4] H. Takahashi, M, Uchiyama "Loose flange-type flared pipe joint", Elsevier Science Puib. Co., p.12.

[5] Hsing-Sung Chen, Pi-Tang Tseng, Shun-Fa Hwang, "Failure analysis of bolts on an end flange of a steam pipe", *Engineering failure analysis* v.13 no4. pp 656-668.

[6] Woong Kim, Choon-Man Lee, " A Study on the Manufacture Process Parameters of Stainless/Carbon Composite Material Pipes Fitting", *Journal of the Korean Society of Manufacturing Process Engineers*, Vol.2008, pp.144-149.

[7] Akkus, N., Manabe, K., Kawahara, M.and Nishimura H., "A Finite-element Model for the Superplastic Bulging Deformation of Ti-alloy pipe", *Journal of Materials Processing Technology*, Vol.68, pp.215-220, 1997.

[8] Yuan, S.J., Xu, Z., Wang, Z.R.and Hai, W., "The Integrally Hydro-forming Process of Pipe Elbows", *International Journal of Pressure Vessels and Piping*, Vol.75, pp.7-9, 1998.

[9] Gursoz, E.L., Choi, Y.and Prinz, F.B., "Boolean Set Operations on Non-manifold Boundary Representation Objects", *Computer-Aided Design*, Vol.23, No.1, pp. 33-39, 1991.

[10] Kang, J. H., Lee, K.O., and Kang, S.S., "Spur gear forging tool manufacturing method considering elastic deformation due to shrink fitting", *Journal of Materials Processing Technology*, Vol. 187-188, No. 12, 2007, pp.14-18.