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Analytical and experimental study on lateral extrusion of cross fittings with a lost core

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ABSTRACT

Purpose: The authors discuss deform mechanism of lateral extrusion process with a lost core for cross fittings. Outline of the is as follows: At first, cavity of pipe, or channel material, is filled up by liquid of low temperature melting material, for instances, low temperature melting alloy, ice (or water) and wax. Then low temperature melting material is solidified to be a soluble core of pipe. Authors call this soluble core the 'lost core [1-4].' The third, the material is compressed longitudinally as a composite billet, and extruded for lateral direction. After deformation, low temperature melting material is melted and removed. The authors think the process is suitable for production of cross-fittings because such the product has constant sections for lateral direction.
Design/methodology/approach: The authors have examined the process with experiments [1] and numerical analysis with ANSYS9.0.
Findings: The feature of the process is revealed. Extrusion defect is caused at the center of the cross on the inner wall of the pipe because of volume constancy when the branch diameter close to the initial pipe diameter. In such the case, contact between pipe and die surface is unstable and the branch part is not stretched enough, then it causes wrinkles. In such the case, it is better to provide more pressure against the head of branch projection.
Research limitations/implications: In future work, the effect of the relationship amongst mechanical properties of the pipe and lost core is to be examined. In addition, the authors will seek better material for the lost core that is cheaper, easier to remove, clean and safer for the man and environment.
Practical implications: Throughout the above research, authors conclude the suggested process is useful for making cross fittings, and the process can be useful on the other hollow products.
Originality/value: The above result helps design of the economical process for fittings. The process requires only simple equipments.
Keywords: Plastic forming; Forging; Extrusion; Hollow product

1. Introduction

Tube forming technology, especially making hollow products, has become more and more important today for producing light products. Most popular bulge processes employ a hydro-forming process [5-12]. However, the forming limit and the expensive dedicated forming machine for it is the barrier to take the process newly.

The authors have engaged in the study of forging of hollow parts with a lost core of low temperature melting materials [1-4] (Fig.1). At first, cavity of pipe, or channel material, is filled up by liquid of low temperature melting material, for instances, low temperature melting alloy, ice (or water) and wax. Then low temperature melting material is solidified to be a soluble core of pipe. Authors call this soluble core the 'lost core.' The third, the material is forged to form the shape of a product. Two basic forging patterns are thought for this step, lateral extrusion and upsetting. After deformation, low temperature melting material is melted and removed. The deformation of the material is not performed by the internal pressure of lost core like plain hydro-forming, but by extruded material flow mainly [2], so the process can obtain large bulged part easily.

In addition, authors have applied it on production of cross fittings [1], because such the part has constant sections for lateral direction and it is advantageous for extrusion process generally in contrast to hydro-forming [13-15]. In this paper, authors perform FE simulation of the process and discuss its form mechanism, defects and its solutions with based on the above analytical and experimental results.

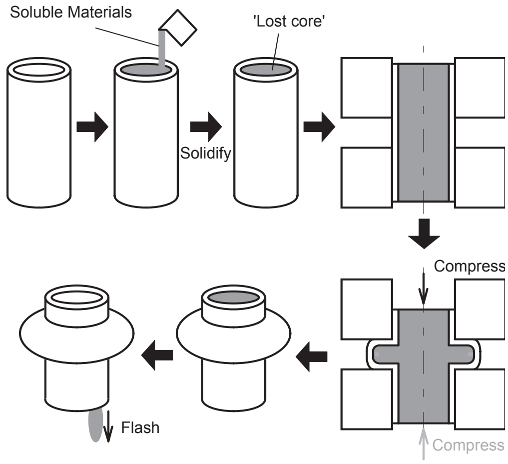

Fig. 1. Lateral extrusion with a lost core process and its typical applications [1]

2. Conditions of numerical analysis and experiments

2.1. Conditions of numerical analysis

ANSYS9.0 is employed for the deform analysis of the pipe and lost core. Figure 2 shows the model of the process and Table 1 and Fig 3 show the properties of the model material. The multilinear isotropic hardening rule is applied on the model. Coefficient of friction between the pipe and die surface is supposed to be 0.1.

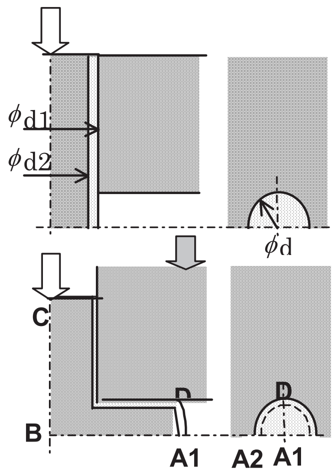

Fig. 2. Model of the process for FE analysis (ϕd1=16mm, ϕd2=13mm, ϕd3={12, 14, 16}mm)

Table 1.
Mechanical properties of model materials

	Tube	Lost core
Model material	Aluminum alloy	Low temperature melting alloy
Yong's modulus	7.30E+10 Pa	1.36E+10 Pa
Poisson's ratio	0.33	0.44

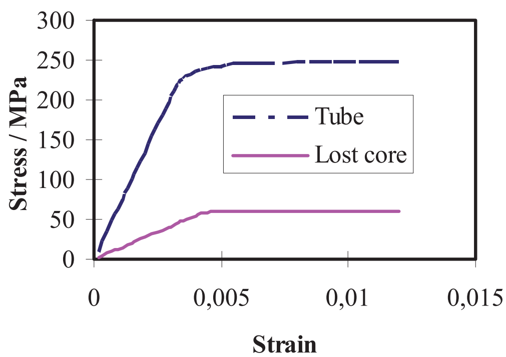

Fig. 3. Stress-strain curve of model materials with the multilinear hardening rule

2.2. Conditions of experiment

The A6063S aluminium alloy extruded pipe is used for the experiment. The pipe is annealed at 415°C79 for 1.5 hours. The thickness is 1.5mm. The author marked at each 2mm for axial direction to track the change of the thickness. Table 2 shows the chemical composition of the low tempareture melting alloy for the lost core. Its melting point is 58°C. Therefore, the core can be removed form the pipe by washing with the hot water. We uses two die sets having different branch diameter; i.e. 10 mm and 16mm. The die set is parted in the two pieces horizontally. In the experiment, the die parts are clamped 196 KN.

Table 2.
Chemical composition of the lost core (wt %)

Bi	Pb	Sn	In
49	18	12	21

3. Results and discussions

3.1. Distribution of the wall thickness

Figure 4 and 5 show examples of the distribution of the thickness of the wall compiled form the deform simulation.

Left and right shear bands kiss each other when the branch diameter is equal to or larger than the initial pipe diameter. Then, necking is occurred on the inner surface of the pipe at the center of the cross because of volume constancy. At last, the necking grows up to extrusion defects (Fig.6). On the other hand, thickness at the center increases when the branch diameter is smaller than the initial pipe diameter.

Extrusion velocity of the core is slower when the branch diameter is larger. The reduction of minimum thickness part of the branch exceeds 1.0 when the branch diameter is larger than initial pipe diameter. In this condition, the process does not stretch the branch enough to avoid wrinkles.

3.2. Distribution of contact pressure distibution between the pipe and die

Figure 7 shows an example of the distribution of contact pressure between the pipe and die. At the beginning of the process, we observe a high-pressure line along to the rim of the shear band. However, the line does not stable when the branch diameter is equal to or larger than the initial pipe diameter, because volume of the pipe is taken to the branch part to reduce the pressure at the center of the cross. This is one of causes of wrinkles.

3.3. Solution for wrinkles

Based on the above, to prevent the pipe from wrinkles when the branch diameter is equal to or larger than the initial pipe diameter, we have to gain internal pressure to keep pipe-die contact stable and stretch the branch part by accelerating the velocity of the extrusion of the core material or slowing down the extrusion of pipe material. One of solutions is to provide counter punch against the head of branch projection (Fig.8).

4. Conclusion

In this paper, authors discuss about the deform mechanism of the lateral extrusion process with a lost core for cross fittings. The authors have examined the process for cross-fittings of A6063 aluminum alloy pipe with a lost core of low temperature melting alloy[1]. In addition, the authors perform deformation analysis with ANSYS9.0 for products having different branch diameter.

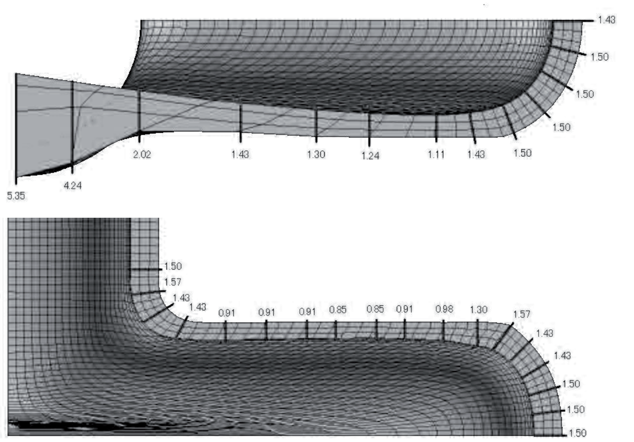

Fig. 4. Distribution of wall thickness (mm) ; D3=12mm, punch stroke: 12 mm.

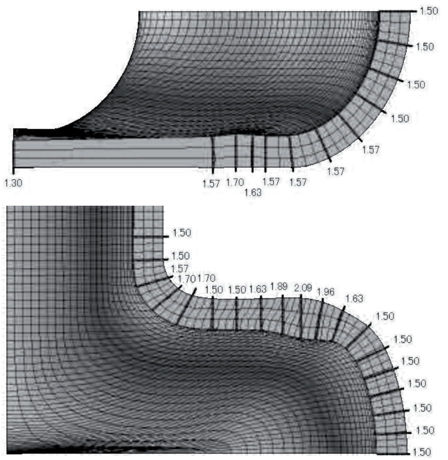

Fig. 5. Dstribution of wall thickness (mm); D3=16mm, punch stroke: 12 mm.

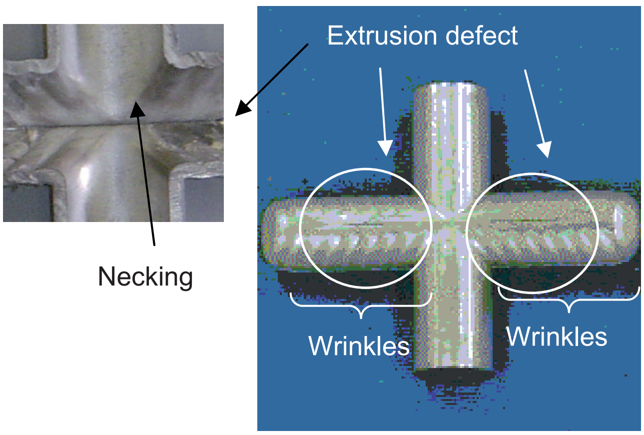

Fig. 6. Necking, extrusion defect and wrinkles

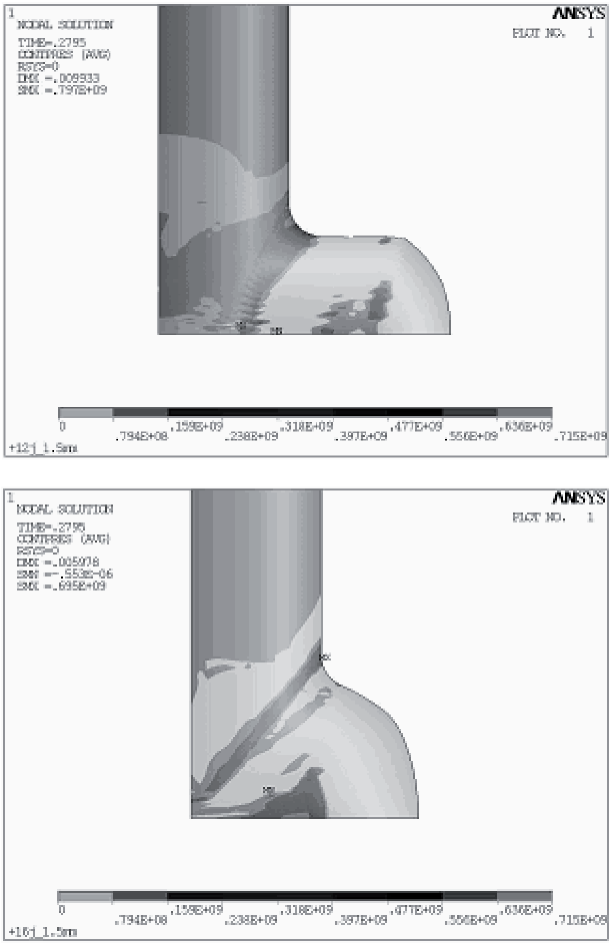

Fig. 7. Distribution of contact pressure between the pipe and die; punch stroke=5.6mm.

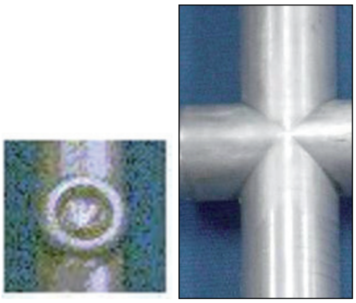

Fig. 8. Effect of fixed counter punch against the head of branch projection to avoid wrinkles[1]

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