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Influence of tube properties on quality of hydropiercing

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Abstract: The influence of tube properties on hydropiercing quality was investigated. The results show that the influence of different materials on collapse is dissimilar. The higher the yield strength of the material is, the larger the collapse after the hydraulic punch is. With reducing the internal pressure, the collapse of the size increases. At the same internal pressure, the collapse along the longitudinal direction changes relatively slow, and that along the vertical direction changes quickly. The influence of different materials on the quality of the fracture is different. The higher the yield strength of the material has, the better the quality of the fracture is. When the material is softer, the phenomenon on tear is more apparent.

Key words: hydropiercing; tube properties; collapse

1 Introduction

Parts manufactured using the hydroforming process are state of the art for a number of applications, in particular in car body structures such as engine cradles, axle frames, side members and exhaust parts [1]. Hydropiercing technology is a punching method by using the punch separating wall material under the tube liquid pressure support [2]. This technology combines with hydroforming technology, and can manufacture a variety of different shapes at the same time after hydroforming maintains a certain pressure [3−4].

To meet the demand for lightmass structure of automobile, hollow parts formed by tube hydroforming have been increasingly used today [5−7]. Many hollow parts need some holes in the final shape, which may be made by drilling or cutting the wall of the formed parts after hydroforming. When the tube with internal pressure is pierced with a punch which pushes the tube wall into the liquid, the tube is warped and the edge of the hole sinks in the process [8−9]. It is desirable to make the holes with high dimensional accuracy during or just after hydroforming on the same machine.

Piercing holes in the tube are carried out in the last calibration stage using high internal pressure. In many cases, piercing is performed from the outside of the tube. The indentation deflection is large because high pressure liquid is used instead of a rigid die in the inward piercing [10]. There is another method for piercing holes from the inside of the tube using high internal pressure instead of a rigid punch [11]. In the outward piercing, the indentation deflection is small because a rigid die is used but rollover is greater than that in the inward piercing [12]. Recently, the practical application of the outward piercing technique was realized [13]. An integrated automotive steering column with high accuracy that has several holes of various shapes was hydroformed using this technique [14].

This technology is characterized by such qualities as less procedures, higher productivity, higher positioning accuracy, and excellent fracture surface, so it becomes one of the key technologies to achieve the industrialization of hydroforming [15]. In this work, hydropiercing experiments were conducted with $10^{\#}$ steel, $20^{\#}$ steel and MS264 materials, and the influence of tube properties on the hydropiercing quality was investigated.

2 Principles of hydropiercing

The principles of hydropiercing are shown in Fig. 1. The cavity die is not used in the forming process.

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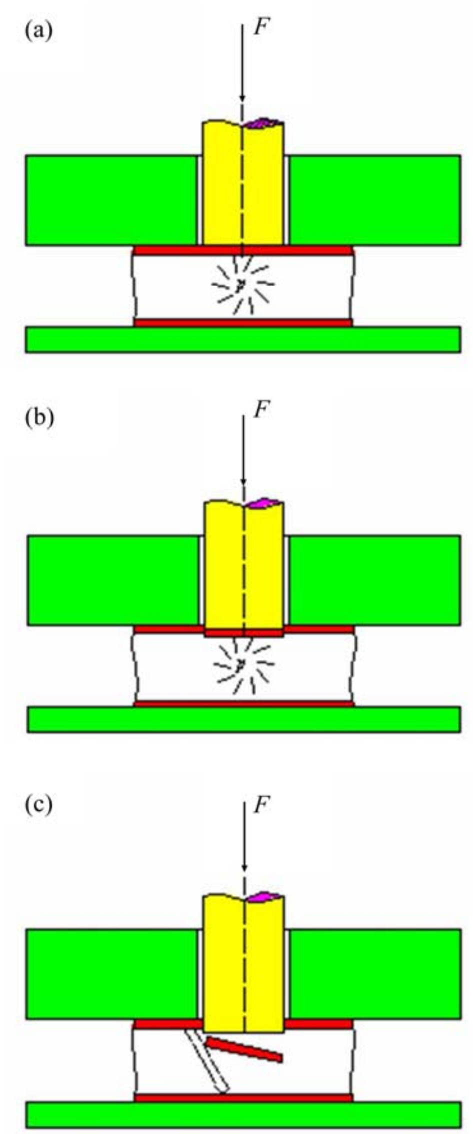

Fig. 1 Principles of hydropiercing: (a) Elastic deformation; (b) Plastic deformation; (c) Fracture separation

Hydropiercing has many similarities with the ordinary punching. Three stages of elastic deformation, plastic deformation and fracture separation were conducted for wall materials [16−17].

3 Experimental device of hydropiercing

In the hydropiercing process, the die was fixed in the press through module pad. First, the round tube was punched into square tube. High pressure fluid was put into the square tube and the blank further bulged. In this process, the punch closed the tube wall, kept the high pressure liquid in the tube and the punch began feed until punching was completed, finally the hole shape was obtained, as shown in Fig. 2.

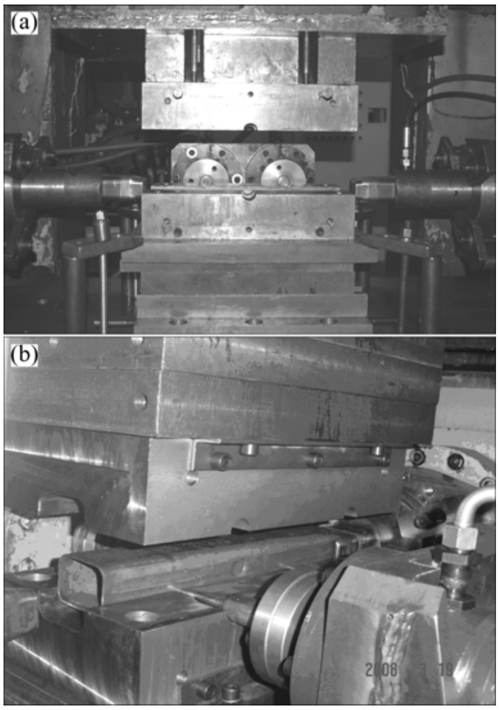

Fig. 2 Experimental device of hydropiercing: (a) Experimental die; (b) Pressing square tube

4 Results and analysis

In the following experiments, three different sheets, 10# steel, 20# steel and MS264, were examined. To compare the influence of tube properties on the hydropiercing quality, the tensile strength was measured by tensile experiments. The strengths for 10# steel, 20# steel and MS264 are 380, 470 and 580 MPa, respectively. Figure 3 shows the formed elliptic hole.

The collapse of punching was measured along the length and vertical directions in order to research the influence of different materials on collapse. Every 5 mm the partition was used to take a spot starting from the fracture, then intervals were labeled every 1 mm to label, finally the collapse of 0 point is obtained. Figure 4 shows the measured points of collapse.

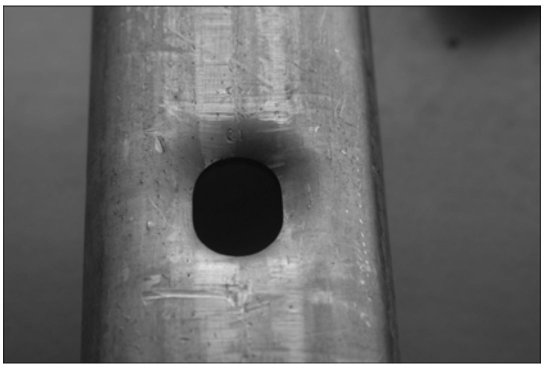

Fig. 3 Photo of formed elliptic hole

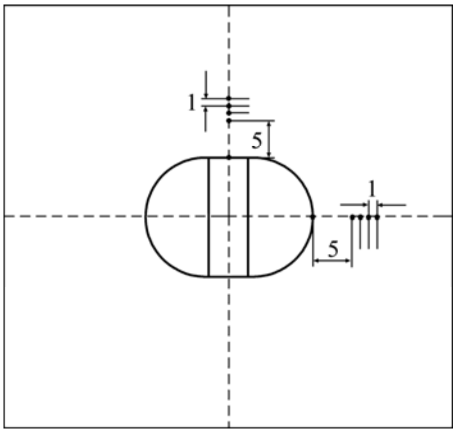

Fig. 4 Measured points of collapse (unit: mm)

Figure 5 shows that the change of the collapse size has an obvious regularity. When the internal pressure with punching reduces, the change trend along the vertical and longitudinal directions on the collapse always increases because the internal pressure reduced in punching process is equal to the blank-holder force reduced in stamp. In addition, at the same pressure, the vertical collapse and longitudinal collapse are not identical, the length direction changes slowly and the vertical direction changes fast. This shows that the development of the length on the collapse has certain restriction. The influence of three different materials on the collapse is also different, and the higher the tensile strength of the materials is, the greater the collapse is.

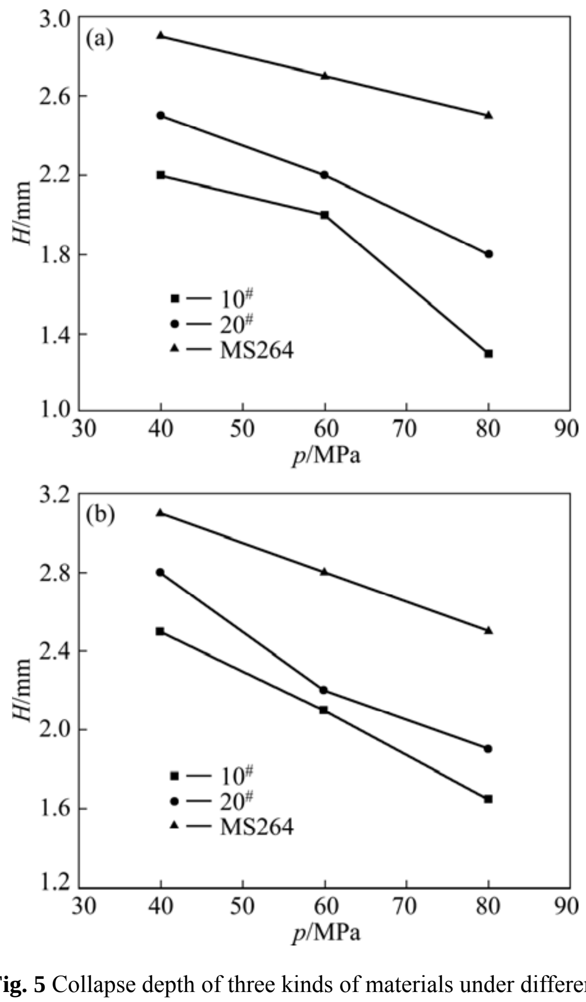

Fig. 5 Collapse depth of three kinds of materials under different pressures: (a) Vertical direction; (b) Longitudinal direction

5 Microstructural analysis

The fracture of hydropiercing also makes collapse, light belt and tear belt. Due to the influence of the fracture surface quality on parts, the light belt on fracture must increase and reduce the collapse, at the same time the ratio of various belts on section is changeable.

The microstructural analysis of the fracture was conducted for MS264, 10# steel and 20# steel in order to investigate the influence of different materials on the quality of the fracture. Figure 6 shows the micrographs of fracture burr of three kinds of materials at 80 MPa. It can be seen that the quality of the fracture of MS264 and 20# steel is better than that of 10# steel at the same pressure.

Figure 7 shows the fracture micrograph between the light belt and the tear belt of three kinds of materials at 80 MPa. It can be seen that MS264 and 20# steel are very smooth, and 10# steel is quite rough.

Figure 8 shows the fracture burr photos of the three kinds of materials at 80 MPa. It can be seen that the burr of MS264 is less, and the burr of 10# steel is bigger. Meanwhile, the tear is also severe for 10# steel. So the fracture quality of different materials is not the same. For "hard" material, the quality of fracture is better. As the material is soft, the tear phenomenon is more obvious. Therefore, the properties of materials also have certain effect on the fracture quality.

Figure 9 shows the microstructures by scanning. It shows that the lengths of the light belt of the straight segment and round segment are different. The light straight segment is shorter and the round segment is a little longer.

Then the front part formed by the extrusion material is smoother. The behind part was formed by the above material squeezing the under material, and then the light belt was formed under the parts.

6 Conclusions

1) The influence of different materials on the collapse is different. The higher the tensile strength of the material is, the greater the collapse is.

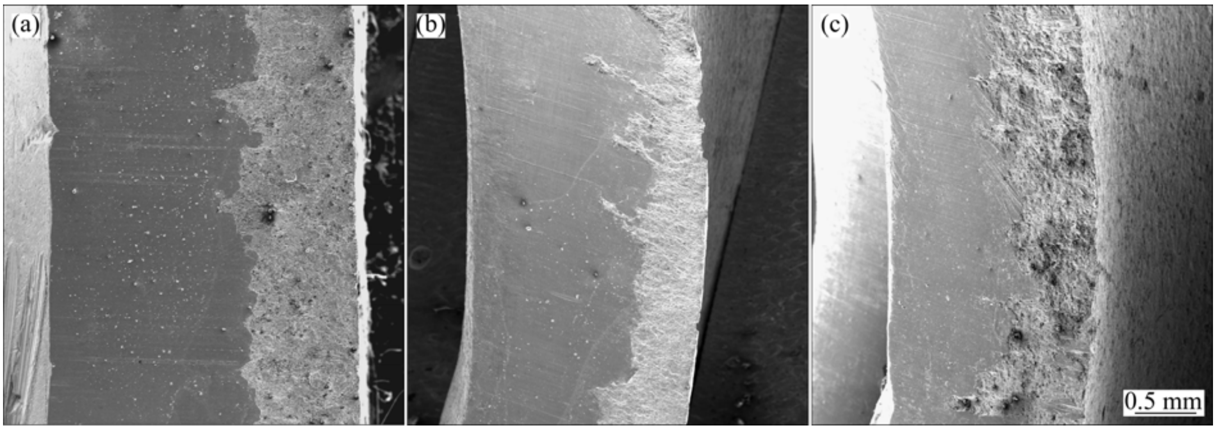

Fig. 6 Micrographs of fracture burr of three kinds of materials at 80 MPa: (a) MS264; (b) 20# steel; (c) 10# steel

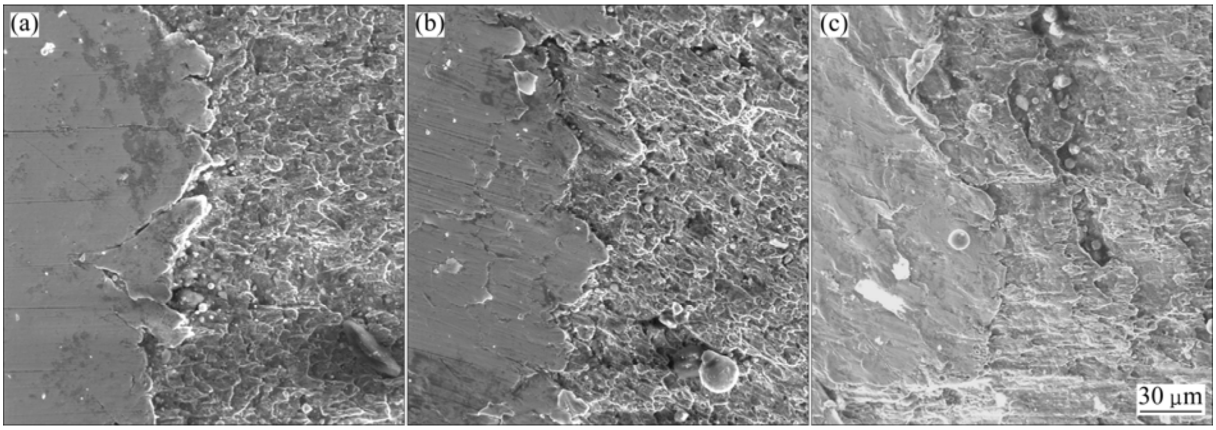

Fig. 7 Micrographs of fracture of three kinds of materials at 80 MPa: (a) MS264; (b) 20# steel; (c) 10# steel

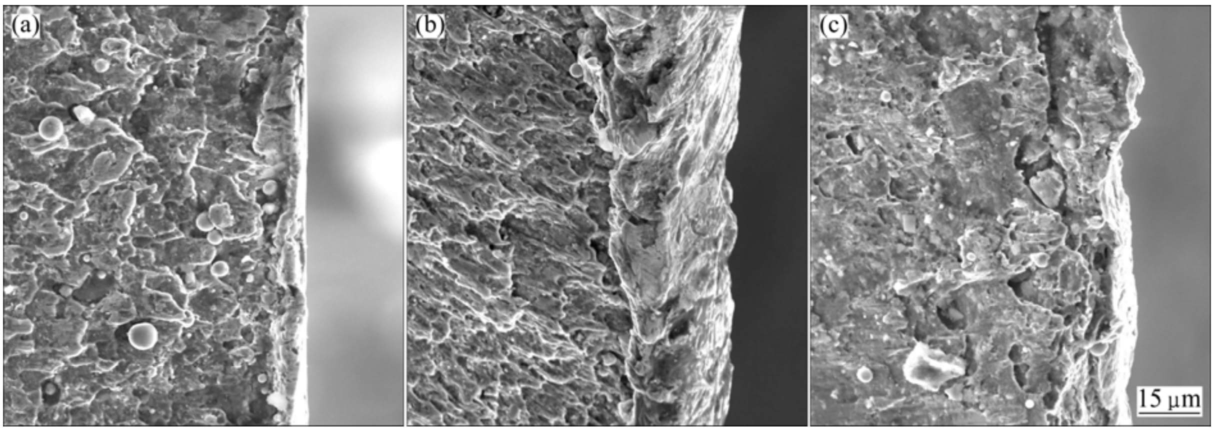

Fig. 8 Fracture burr photos of three kinds of materials at 80 MPa: (a) MS264; (b) 20# steel; (c) 10# steel

2) The change of collapse size has an obvious regularity with the internal pressure. As the internal pressure reduces, the change trend of the collapse along vertical and longitudinal directions always increases. At the same pressure, vertical collapse and longitudinal collapse are not identical, the length direction changes slowly and the vertical direction changes fast.

3) The influence of different materials on the quality of the fracture is different. The higher the yield strength of the material is, the better the quality of the fracture is. As the material is softer, the phenomenon on tear is apparent.

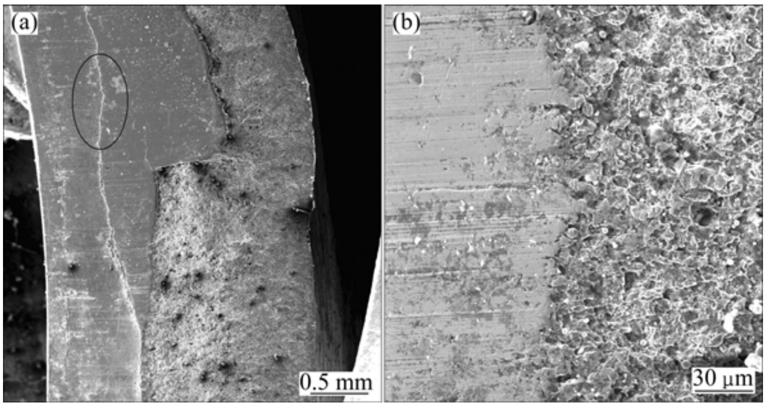

Fig. 9 Scanning macrograph (a) and scanning micrograph (b) of secondary shear parts

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管材性能对液压冲孔质量的影响

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摘 要：通过对 3 种不同材料的管材液压冲孔的实验研究，分析管材材料性能对液压冲孔质量的影响。研究表明：不同材料对塌陷形成的影响不同，材料的屈服强度越高，液压冲孔后的塌陷越大。塌陷尺寸随着内压的降低而增大，在同一内压下，沿管长方向塌陷变化较慢，沿垂直管长方向塌陷变化快。不同材料对断口质量的影响不同，材料屈服强度越高，断面质量越好，材料较软时，撕裂现象更明显。

关键词：液压冲孔；管材性能；塌陷

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