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Forming Technology for 3D Closed Section Parts from Sheet Metal

Masahiko Sato [a,]*, Tohru Yoshida [a]

Yukihisa Kuriyama [b], Katsuyuki Suzuki [b], Akihiro Tokugawa [b]

[a]*Nippon Steel & Sumitomo Metal Corporation*
[b]*The University of Tokyo*

Abstract

Most conventional closed section parts are made of tubular blanks including welded tubes; however, it is difficult to fabricate complex shapes with large variations of circumferential length because of restrictions in the circumferential direction. Another approach is to fabricate closed section parts directly from sheet blanks. Direct forming from sheets has less restriction in the circumferential direction than tube forming. Therefore, direct forming is expected to enable fabrication of more complex shaped closed section parts with larger variation of circumferential length. However, only a few fundamental researches were conducted. In this paper, fundamental studies on direct sheet forming were carried out for better understanding of deformation and to provide information regarding the design and forming condition. The horn tube, which consists of circular and truncated conical tubes, is a rather simple shape but it is a typical shape of a closed section. It is selected for this study. Through this study, even in two-stroke forming from sheets to final shape, it is revealed that it can be broken down into several deformation modes.

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Keywords: closed-section ; sheet metal ; deformation models

1. Introduction

In recent years, there have been strong demands for weight reduction and crashworthiness in automobiles in order to cope with environmental issues and safety regulations. To meet these demands, closed section parts have been applied in practical use for weight reduction and improving crashworthiness because of their high rigidity and high strength with light weight. Most closed section parts are made of tubular blanks including welded tubes (Fig. 1a).

* Corresponding author. Tel.: +81-70-3514-8031; fax: +81-439-80-2743.
E-mail address: sato.xc5.masahiko@jp.nssmc.com

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The tube hydroforming process is widely used for automotive parts [1][2]. However, it is difficult to fabricate complex shapes with large variation of circumferential length from welded tubes because of restriction in the circumferencial direction. Conical tube blanks and multi-action dies are utilized for tube hydroforming to overcome these difficulties [3][4]. Another approach is to fabricate closed section parts directly from sheet blanks (Fig. 1b). Direct forming from sheets has less restriction in the circumferential direction than tube forming. Therefore, direct forming is expected to enable to the fabrication of more complex shaped closed section parts with larger variation of circumferential length [5]. Furthermore, less circumferential restriction results in less thickness reduction [6]. Fig. 2 shows a comparison of thickness reduction between bending of tubes and direct forming of sheets. The maximum thickness reduction of direct sheet forming is relatively smaller than that of tube forming. Forming technologies have been studied to form straight and circular tubes directly from sheets by experiments and FEA [7]. Tubular products made via direct sheet forming are already adopted for use in actual automobiles; however, only a few fundamental researches were conducted.

In this paper, fundamental studies on direct sheet forming were carried out for better understanding of deformation and to provide information regarding the design and forming condition. The horn tube, which consists of circular and truncated conical tubes, is a rather simple shape but it is the typical shape of a closed section. It is selected for this study. Through this study, even in two-stroke forming from sheets to final shape, it is revealed that it can be broken down into several deformation modes.

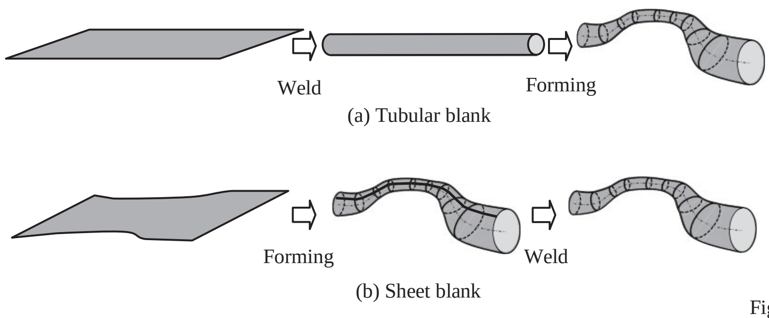

Fig. 1. Schematic of the manufacturing process for 3D closed section parts.

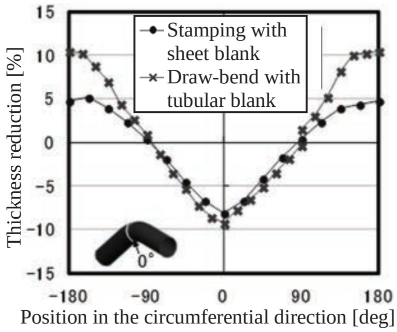

Fig. 2. Comparison of the thickness reduction between the bending of tubes and direct forming of sheets

2. Experiment and FEM analysis

Fig. 3 shows the dimensions of the horn tube used in experiments. The circular portion with 40-mm diameter and the conical portion with 6.7° taper angle were connected smoothly through the transient portion with constant curvature radius. Several kinds of steel sheets were used as blanks. Table 1 shows a range of tensile strength and thickness of blank sheets. Using the flat sheet blank, the horn tubes were formed through two procedures; U-shaping and closing (Fig. 4). Moreover, FEM analysis was used to investigate the deformation state and influence of dimensions. PAM-STAMP was used as the FEM calculation solver. Tensile test results of blank sheets were approximated by the swift type equation to use in numerical simulation. Comparison of the longitudinal strain on the edge of the horn tube between the measured and calculated values is shown in Fig. 5 as reference. The calculated strain distribution agrees well with the measured one.

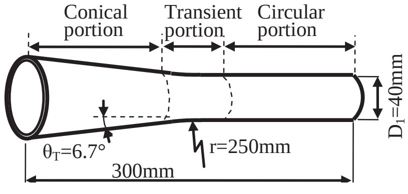

Fig. 3. Examined shape of the horn tube.

Table 1. Mechanical properties of blank sheets

Tensile strength [MPa]	440 - 980
Thickness [mm]	1.0 - 2.6