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Experimental and numerical analyses of sheet hydroforming process for production of an automobile body part

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ABSTRACT

An approach for substituting conventional manufacturing method of a three pieces shell fender by one piece has been proposed. This approach is based on sheet hydroforming process, which has many advantages over conventional stamping processes. For production of shell fender by sheet hydroforming, two possible manufacturing procedures have been evaluated numerically, namely; pure stretching and draw-in. In addition, results of both finite element simulations and experiments on small size specimens show superiority of draw-in procedure. The advantage of draw-in over pure stretching procedure has been explained using thickness variation measurements. Furthermore, the draw-in procedure of shell fender has been optimized with respect to initial blank size, fluid pressure and required tools using an explicit commercial forward finite element program. Finally, the effects of sheet material and fluid pressure on the required deformation force in laboratory scale have also been evaluated.

1. Introduction

Sheet hydroforming process is one of the new technologies that seems to be capable of satisfying the industrial requirements in the field of sheet metal forming. This technique, in which one of the tools is replaced by a soft tool was initially proposed about two decades ago, has many advantages over the conventional stamping processes. Sheet hydroforming has the ability to solve inherent problems and limitations associated with conventional processes. Typical tools for sheet hydroforming consist of a punch, a blank holder, a pressure chamber, and a rubber diaphragm that is used for sealing of liquid in the pressurized chamber as shown in Fig. 1. Sheet hydroforming advantages include, increasing drawing ratio, better surface quality, less spring back, minimizing thickness variations of the products, and reducing tooling cost especially for nonsymmetrical components, etc., that lead to possibility of manufacturing complex stampings with less difficulties with regards to rigid tools (Zhang and Danckert, 1998; Zhang, 1999; Kandil, 2003; Zampaloni et al., 2003; Lang et al., 2004; Zhang et al., 2003). For clarifying the ability of this process, sheet hydroforming has been subjects of many research works (Zhang et al., 2004; Yossifon and Tirosh, 1989; Thiruvarudchelvan and Lewis, 1999; Thiruvarudchelvan and Travis, 2003; Rimkusa et al., 2000; Ahmetoglu et al., 2004; Hein and Vollertsen, 1999; Novotny and Hein, 2001), and it has

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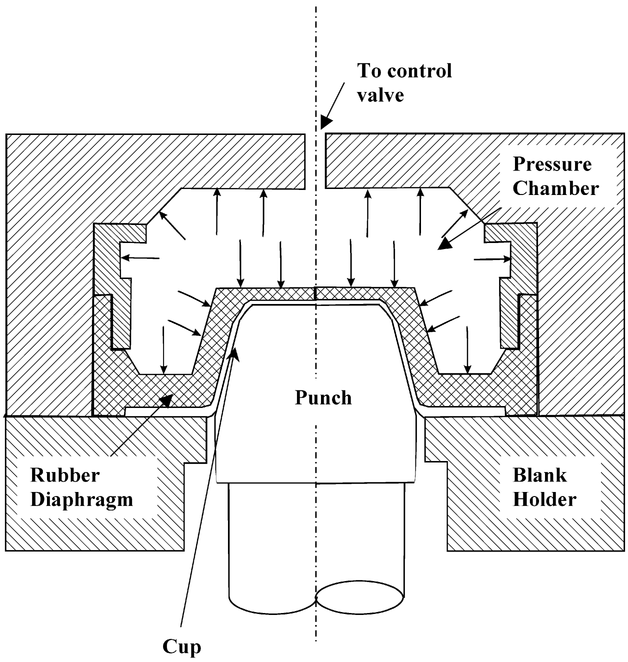

Fig. 1 – Schematic of sheet hydroforming process.

been proposed as a good candidate for production of stampings in automotive industry (Lei et al., 2000; Kang et al., 2004; Nakamura et al., 1994).

For design analysis, application of the conventional methods of evaluations for sheet hydroforming are very expensive and time consuming, while the numerical and simulation approach such as finite element method can enhance existing knowledge and reduce tool cost and lead-time. This is done by predicting formability and providing virtual tryout before tool construction in advance (Lei et al., 2000; Kang et al., 2004).

Since different strategies can be selected for production of any stampings, in this research it has been attempted to simulate the production of a complete hydroformed shell fender that substitutes two complex stampings, in order to select the best possible procedure. The manufacturing procedure of the mentioned part has been analyzed from the blank design to the final product. Then, in order to evaluate the finite element results, experimental examinations have been carried out on the down sized specimens. In the following sections, the simulation and experimental procedures and results will be presented.

2. Sheet hydroforming simulation

Based on the past experience, it is believed that sheet hydroforming using a punch is suitable and practical for manufacturing of nonsymmetrical complex shell fender that consists of two welded stampings (Parsa and Shahabizaheh, submitted for publication). For defining the best manufacturing strategy for production of complete shell fender based on numerical simulations, the shape and size of initial blank has been determined first. Since both stretching and draw-in production procedures seem to be applicable for manufacturing

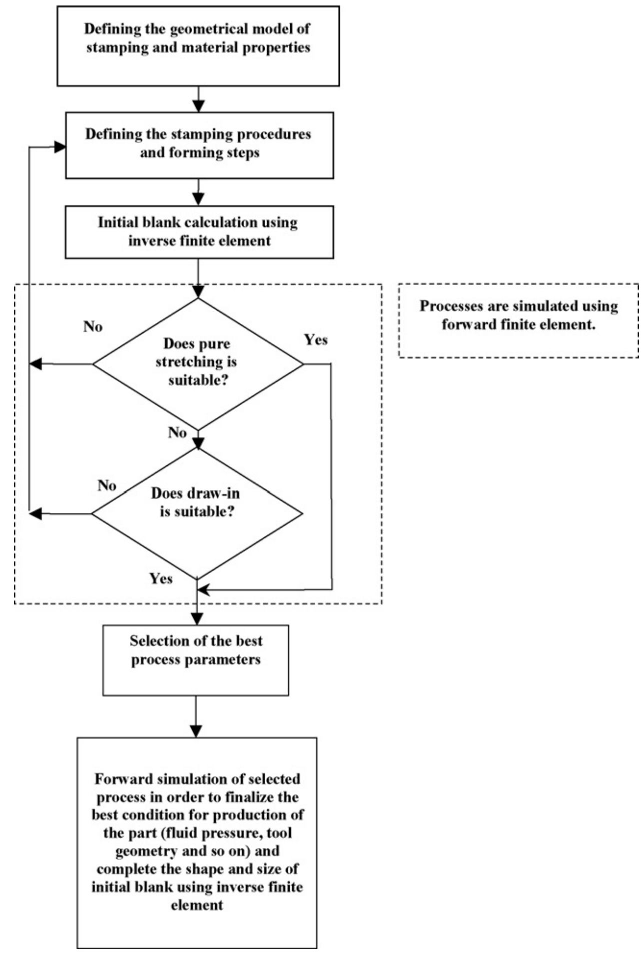

Fig. 2 – Flow diagram of the simulation steps.

of shell fender, capabilities of two methods for production of shell fender have been evaluated, numerically. Based on the evaluations, the best possible procedure has been selected for production of the shell fender. Then the sheet hydroforming process of integrated part has been optimized with respect to the constraint that exerted by the die and fluid pressure using a commercial finite element program with capability of large deformation simulation. Also the effects of sheet materials on the deformation behavior have been evaluated. Since sheet hydroforming experiments had been carried out on the 1:8 ratio scale of real size, hydroforming simulations were carried out on both real and small sizes. Fig. 2 illustrates, the simulation steps as flow diagram.

In the following sections brief discussions on the new integrated part, simplified model, simulation steps and assumed boundary conditions, will be discussed.

2.1. *Model description*

Two parts shown in Fig. 3 constitute the conventional shell fender. Normally three steps are required to make this specimen. These are (i) laser welding and pressing to make part A, (ii) stamping of part B, and (iii) finally joining of parts A, B. But by noticing capabilities of the sheet hydroforming process, production of complete shell fender in one step seems to be