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Technical Report

Process design of cold forging with thick plate for seat recliner parts

Jonghun Yoon *, Hyowon Jeon, Junghwan Lee

Korea Institute of Material Science, 797 Changwondaero, Changwon, Gyeongnam 642-831, Republic of Korea

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ABSTRACT

A seat recliner is a device that connects the seat back with the seat frame. It can be used to adjust the lean angle. An important component of a seat recliner is the sector tooth, which has thus far been manufactured by the fine blanking process. In this study, we propose the use of the cold-forging process as an alternative in order to achieve improved mechanical stiffness and reduced weight. To apply the cold-forging process, the entire forming process is divided into two stages in order to improve the dimensional accuracy of the tooth part of the sector tooth. Uniform plastic deformation is induced by the design of the preform on the contacting area in the sector tooth by simultaneously using a bending and a forging mechanism. By the proposed process design for the two-step cold forging process, the mechanical stiffness and surface roughness of the test product can be improved. Furthermore, the weight can be reduced by 10% by applying a 3.6-mm-thick plate instead of a 4.0-mm-thick one. Finally, the number of forming stages can be reduced without sacrificing the dimensional accuracy of the sector tooth and increasing the punch load.

1. Introduction

In recent years, automakers have been strongly focusing on the design and manufacture of lightweight automotive parts in order to increase fuel efficiency and reduce emissions without sacrificing on vehicle safety and ride comfort. Two research approaches for light-weight design and enhancing the dimensional accuracy of forming parts are explored simultaneously since a large amount of electric and hybrid vehicles are manufactured and demand for those abruptly increases recently.

A seat recliner is a device that connects the seat back and the seat frame. It can be used to adjust the lean angle, thus improving the ride comfort; furthermore, it is designed to guarantee passenger's safety. A seat recliner consists of a sector tooth, a pawl tooth, a plate holder, a cam, and a spring, all of which are packed into a guide ring as shown in Fig. 1a. The sector tooth is one of the most important components of the seat recliner. It has 180 microgears along the boundary and three steps in sectional shape, as shown in Fig. 1b. A sector tooth should be manufactured by a process that guarantees dimensional accuracy, especially in the microgear part; furthermore, the process should be a high-productivity one in order to satisfy the increasing demand in the automotive market.

Thus far, the sector tooth has been manufactured by the fine blanking process [1,2], which involves piercing, embossing, step forming, gear forming, and blanking with progressive dies, as shown in Fig. 2.

However, the manufacture of forming parts using the fine blanking process with progressive dies involves the following drawbacks:

(1) As shown in Fig. 3a, microcracks are easily generated during fine blanking because severe plastic shear deformation is locally imposed on the plate during step forming, which degrades the mechanical stiffness of the sector tooth. To deal with this problem, a plate that is thicker than the initially designed thickness needs to be used; however, it is then difficult to realize a lightweight design.
(2) The shape design can be optimized only to a limited extent in fine blanking because this process can only be used to construct a shape that can be obtained by stretching out the initial material (Fig. 2) by fixing both sides of a plate. The neck between each step is a vulnerable part of the sector tooth, and it is necessarily quite narrow unless the initial plate is sufficiently thick.
(3) Considerable scrap is generated during the fine blanking process when a rolled plate is used as the initial plate.

As an alternative, in this study, the process design of net-shape cold forging of a thick plate is examined by finite element (FE) analysis. The cold-forging process improves the mechanical stiffness of the sector tooth, increases the material recycling ratio, and reduces the weight by 10%; furthermore, it involves only two stages, compared to three in the fine blanking process.

Recently, many innovative production processes have been revised to deliver high performance components to automotive

* Corresponding author. Tel.: +82 55 280 3839; fax: +82 55 280 3849.
E-mail address: jhyoon@kims.re.kr (J. Yoon).

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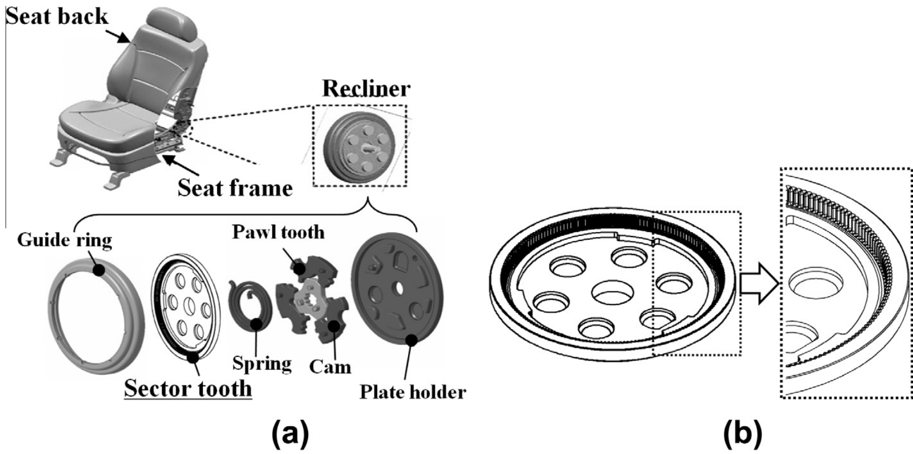

Fig. 1. Schematic components of seat recliner: (a) assembly of recliner; (b) sector tooth.

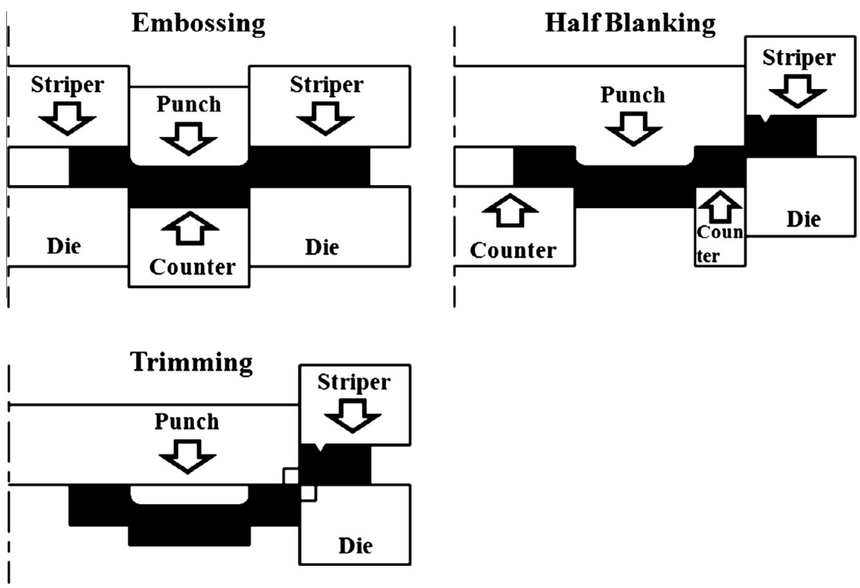

Fig. 2. Three forming stages in fine blanking process.

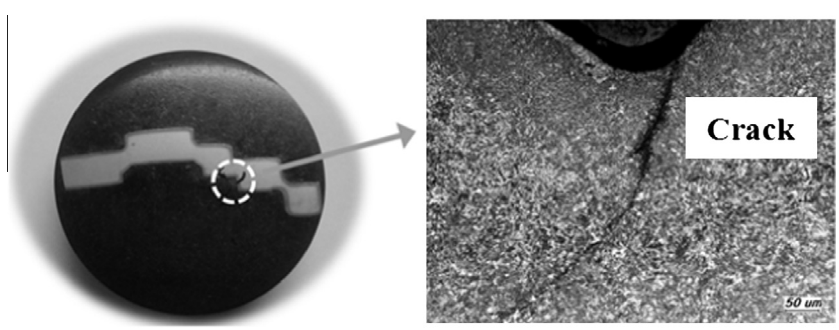

Fig. 3. Internal crack in fine blanking process.

industries with thick plate in which plate forging integrates bulk forming and sheet metal forming technique to enhance metal flow during the plastic forming process. Merklein [3] has defined this process as the sheet-bulk metal forming firstly, and Merklein and Tekkaya et al. [4,5] and Oyachi and Allwood [6] examined the effect of thickening of the initial plate during this process on the formability. Namoco et al. [7] investigated embossing and restoration process of sheet metal as a strengthening method to overcome thinning phenomenon during the sheet metal forming process. Urban et al. [8] optimized thickness distribution to enhance the product quality by designing the process chain. Tan et al. [9,10] have developed a two-stage plate forging process of circular tailored blanks having local thickening to reduce the press load. Mori et al. [11] demonstrated a plate forging process of a tailored blank