Analysis of Multi-thickness Plates by Successive Forging

Siti Sarah Taib[1], Liyana Tajul[1*], Hasnulhadi Jaafar[1], Mohd Sabri Hussin[1], Zamzuri Hamedon[2]

[1]Universiti Malaysia Perlis, Arau, 02600 Perlis Malaysia
[2]Universiti Malaysia Pahang, Pekan, 26600, Pahang Malaysia
[*] liyanatajul@unimap.edu.my

Abstract: The demand of lightweight vehicles is increasing due to environmental issues. To fulfill this demand, tailored blanks are utilized in the production of vehicles. Tailored blanks have been used in car body part such as center pillar and roof rails for the purpose of weight reduction where thickness distribution is being optimized. Tailored blanks are commonly produced by welding and rolling. Tailor-rolled blanks produced by rolling process has continuous thickness transition as compared to tailor-welded blanks and hence stress concentration is reduced. However, the rolling process utilized in the production of tailor-rolled blanks are not commonly available. Hence successive forging process was developed to control the thickness distribution by mean of presses. In this study, successive forging was utilized to control the thickness distribution of a plate by using upper and lower punches. The stroke is constant while the punch was designed to has three different thicknesses to achieve different thickness reduction. The feeding interval was varied for 10 mm and 17 mm. The thickness distribution, material flow and forging load for both feeding interval were analysed and compared with the conventional forging process using finite element analysis.

1. Introduction

The requirement of lightweight vehicle is increasing due to environmental concern and cost reduction. The decrease in vehicle weight helps in reducing fuel consumption and carbon emission. The increasing in part or component complexity to fulfil the functionality, avoid internal and external defects and weight optimisation has become a great challenge in manufacturing and automobile industries in order to ensure high quality parts and components [1]-[2]. Nowadays, weight reduction is achieved by utilising lightweight materials, thickness control and design optimization [3]-[4]. Lightweight material such as advanced high strength steel and aluminium are being used in the car body-in-white for this purpose. For thickness control on the other hand, weight reduction can be achieved by utilizing tailored blanks.

Tailored blanks are semi-finished parts that are produced by joining two or more different material or thickness by welding. Gautam and Kumar [5] analysed the formability of tailor welded blanks of high strength steel and found that the formability of tailored blanks reduces as compared to uniform thickness blanks. The non-uniform material deformation of thin and thick blanks and the weld line movement of tailor welded blanks lead to tearing during forming [6]. To overcome the stress concentration due to sharp change in thickness in tailor-welded blanks, rolling process has been used. Tailor-rolled blanks are blanks having thickness distribution that are produced by changing the gap between rolls [7-8]. The continuous thickness variation at the transition zones reduces the stress concentration hence improves formability. Yu et al. [9] applied tailor-rolled blanks on vehicle component for weight reduction and crashworthiness improvement. It was found that the vehicle component weight reduces by 12.8% and the energy absorption increases by 8.7%. However, producing tailor rolled blanks by rolling process can be costly and the process are not commonly available.

Successive forging has been introduced as one of the ways to produce components with variety of shapes and geometry. Tajul et al. [10-11] control the thickness distribution of a roof rail for hot stamping and developed a successive forging process to produce a long plate having an inclined cross-section. Since the demand of parts having thickness distributions are increasing, it is desirable to produce tailored blanks with multiple thickness by successive forging. Successive forging has shown the ability to produce components with much lesser forging load as compare to conventional process due to the small contact area between punch and workpiece. Hence, conventional mechanical presses having a relatively low cost can be used to produce tailored blanks. Furthermore, not much study has been conducted on this area. Therefore, this paper investigated the deformation behaviour of aluminium alloys AA6061 plates having thickness distribution produced by successive forging. The punch was design to give multiple thickness distributions hence fulfilling the requirement of multi-thickness part or comonent. The thickness reduction, material flows and surface quality are the parameters observed for this study. A conventional forging process was also simulated to understand the differences between both forging processes.

2. Successive forging process by finite element method

Successive forging involves repetitive compression process with a small contact area during each stroke. The compression area can be controlled based on the amount of feeding interval. Fig.1 illustrates the successive forging process by using upper and lower punches. After a compression is made (Fig.1.(a)), the upper punch is retracted to allow for feeding of the workpiece into the compression region (Fig.1.(b)). Then, the next compression will take place (Fig.1. (c)). With this approach, a more flexible forging