Study of thinning effect from deep drawing process on crash analysis

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ABSTRACT – This study presents the effect of thinning on crash analysis results of a circular cup shape formed from deep drawing process. Forming and crash simulation of a circular cup was performed using Explicit Radioss code simulation solver. Circular cup shape formed from deep drawing with and without thickness effect was used to conduct explicit dynamic crash simulation. The effect of material thickness change from stamping process was studied. It was found that thinning effect from stamping causes the structural part to have a weaker crash response.

1. INTRODUCTION

Nowadays, many industrial fields tend to use numerical simulation to design and develop a product in order to reduce time and costs for the development. However, the simplicity of simulation approach in order to produce a product can cause negligence of important factor than can affect the simulation results. Crash simulation in automotive industries also has no exception. Traditionally, finite element (FE) crash simulation utilizes only the geometry of the structure without taking into consideration that the material of the single parts of the entire body structure may have changed their physical properties during the forming process [1]. In other words, the model is considered as virgin material. As a consequence from this assumption, the crash simulation will lead to inaccurate results.

Huh et al. [2] conducted a crash analysis on a front side member in an auto-body considering the effect of fabrication in order to quantify the forming effect on the crashworthiness assessment. Cafolla et al. [3] also studied about the forming to crash effect by including thickness change and plastic strain for the lower longitudinal (sub-frame extension). Recently, Zhang et al. [4] investigated the forming effects on crush response of tapered circular tube with graded thickness under axial loading and found that forming effects showed important influence on the increase of efficiency. All the above studies insisted that the crash analysis of auto-body structures should be carried out considering the forming effects for the purpose of reliable assessment of crashworthiness.

Due to the gap between the product design and the manufacturing process, the influences of manufacturing process on the material properties and thickness distribution is unknown and one would arbitrarily choose a high-value 'safety factor' to uniformly increase the thickness across the entire part in order to be on the safe side [5]. The present study is focused on the influence of thinning effect from deep drawing process to the crash response of a simple cup structure model formed by using plastic deformation process. This study only covers numerical analysis using finite element.

2. METHODOLOGY

In this paper, finite element simulation studies are conducted for a simple structure in the shape of a cup. A small scale of a cup model is used instead of large scale of full vehicle because of its simplicity. The methodology of this work is highlighted in two steps of simulations which starts with forming simulation and subsequent crash simulation in order to quantify the effects of thickness change from preceding process.

The forming simulation was performed using single action draw since a small and medium size parts are generally formed using these type of draw forming process in normal practices. The desired circular cup shape is designed from a draw forming tools set up which consists of a sheet metal as deformable steel blank and three rigid parts (die, punch and blank holder) with zero die clearance. A deformable steel blank with 1.2 mm thickness and 85 mm in diameter is meshed using 4-node quadrilateral element type with fine and coarse mesh. The number of elements and nodes is 1620 and 1641 respectively. The material formability is evaluated in order to determine the success of draw forming process into the desired shape as shown in Figure 1.

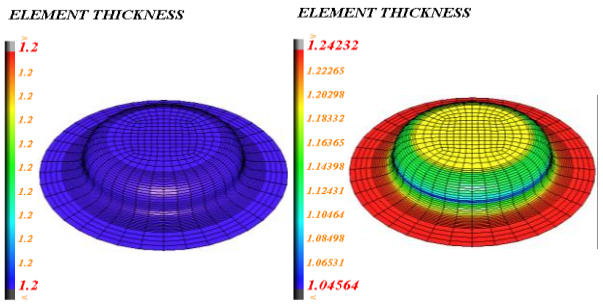
Figure 1 Desired shape of circular cup.

Numerical simulations of crash tests were performed using explicit code Radioss solver to present dynamic response of crash simulation. The geometric modeling consists of three parts: (1) moving rigid body (Impactor), (2) fixed rigid body (Base) and (3) deformable body (Circular cup shape). The impactor was moved at a constant velocity of 50 km/h or equal to 13.9×10^3 mm/s towards the cup. The coulomb friction between the impactor and deformable cup is assumed frictionless.

3. RESULTS AND DISCUSSION

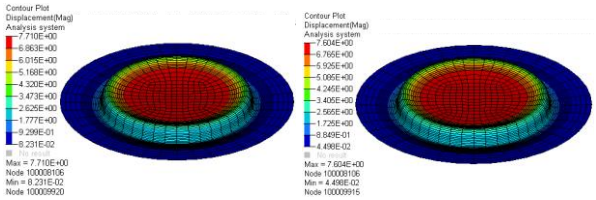
The results obtained between these two case studies is compared qualitative and quantitatively. The analysis results with and without thickness reduction from forming are showed in Figure 2. It is evident that there is change in thickness during forming process. There is thinning of 12.87% at the sidewall and 3.53% thickening at the flange. This is because the structural part undergoes deep drawing process.

The final deformed shape of the circular cup after impact for both cases are shown in Figure 3. Results shows that there is less significant difference in the collapse mode as both deformed in buckling mode. Since the circular cup model is set free to move and is not constrainted at any area, the upper surface of the circular cup moved downward while the flange area moved upward. The maximum and minimum displacement value displayed represented the distance of the upper surface and the flange of the cup respectively, as it is impacted. The reaction forces normal to the impactor are plotted with respect to the cup displacement in Figure 4.



(a) (b)

Figure 2 Thickness distribution for; (a) Without thinning effect (Uniform thickness), (b) With thinning effect (Non-uniform thickness).



(a) (b)

Figure 3 Circular cup deformation due to crash analysis; (a) Without thinning effect, (b) With thinning effect.

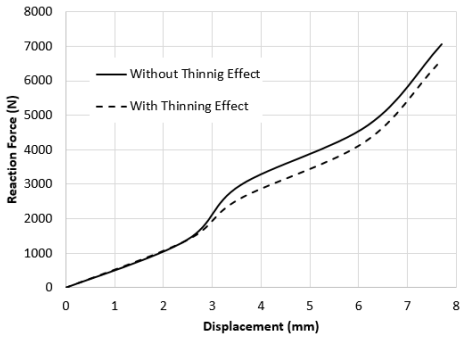


Figure 4 Reaction forces during the crash of the circular cup part.

Figure 4 shows that the reaction forces between the impactor and circular cup have high peak value when uniform thickness was considered in the crash analysis. The reaction force tends to decrease more with displacement in the case of analysis considering the thinning effects than without considering thinning effects. The results explain that the non-uniform thickness distribution with the thinned region can be considered as the initial defect of the circular cup part. This results also shows that the forming effects does influences the crash analysis results such as deformation and reaction force results.

4. CONCLUSIONS

Thickness distribution from thinning due to stamping plays a role as initial defects and could affect the crash response of a structural part. This would make a structure become weaker and the crash performance will significantly decrease. Even though the deformation mode gives less significant difference between the two cases studied, the reaction force between the impactor and circular cup part that consider thickness change was lower than other. This results shows that the structure became weaker and does proved that forming effects (thickness change) does affect the crash analysis results. Therefore, it is concluded that the forming effects need to be included in crash analysis in order to ensure the reliable assessment of crashworthiness.

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