

Reliability of Isotropic Model in Finite Element Simulation to Predict Wrinkling in Deep Drawing Process

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Abstract—Deep drawing is one of important sheet metal processes used in manufacturing industry. Efforts have been conducted for many years to use advance computing software in understanding the metal forming process. Finite Element (FE) simulation is considered one of the best methods. The accuracy of FE application however depends on the type of hardening model being used as part of the material input. The aim of this study is to investigate the reliability of isotropic hardening model in predicting wrinkling in deep drawing process. The finite element result and the experimental result are compared visually for similarity as an indicator of the reliability of the hardening model.

1 Introduction

Deep drawing is one of the sheet metal forming processes which is widely used in manufacturing industry. In the process, the blank is deformed by an action of a punch forcing the metal into the die cavity. The products usually have a complicated shape, thus undergoing several successive operations is vital to obtain a final desired shape. One of the major defects that occur in deep drawing operations is wrinkling. It is also known as surface distortions resulted from compressive stresses [1]. There are two critical places that tend to generate wrinkles which are at the flange and at the cup wall of the product. The wrinkling occurred because of radial drawing stress and tangential compressive stress during the stamping process [2, 3].

Until recently, the design of deep drawing tools were mainly gained through empirical and experimental learning and expensive trial- and- error processes. However, today the forming process are making use of finite element methods even in the early stages of die forming and process design.

Finite element simulation is an effective way to know whether it is possible or not to form a part without any defects. From a practical perspective, finite element simulation includes an input to simulate the model, a solution and an output which can be considered as a product prediction. To improve the simulation, it is necessary to have accurate information on the geometry of the tooling, the sheet metal properties, the friction coefficient of the tools and the sheet interface. In this present paper, the reliability of isotropic hardening model is investigated. This is being done by using the hardening model as material input to simulate deep drawing process. The software used for the simulation is Abaqus. The

material used for the investigation is 1mm stainless steel. The blank size is 100mm x 100mm. The die size is 50mm x 50mm with edges radius 2mm which is actually the desired square hole. The punch size is 44mm x 44mm with 2mm edges radius.

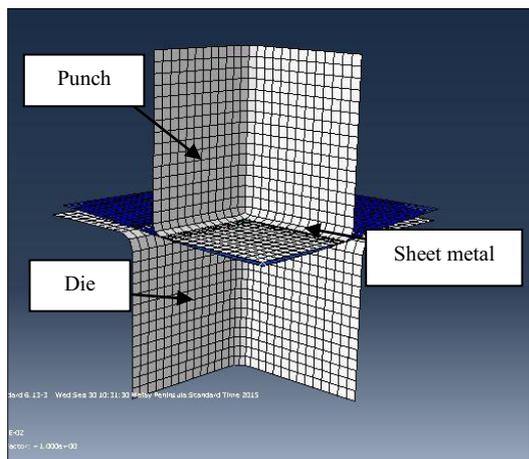
2 Finite element model

The finite element model consists of tools and blank. The tools are punch and die and the blank is the sheet metal. The tools are designed as rigid whereas blank is deformable part. The element used for the tools and blank is shell type. The coefficient of friction between punch and blank and between die and blank is 0.125. The value is taken from study conducted by Ayari and Bayraktar [4]. One quarter sector of the tools and blank been constructed for the simulation's model. The meshing size for the modeling is 1.5mm. The data for input material properties is acquired from tensile testing as shown in **Table 1**.

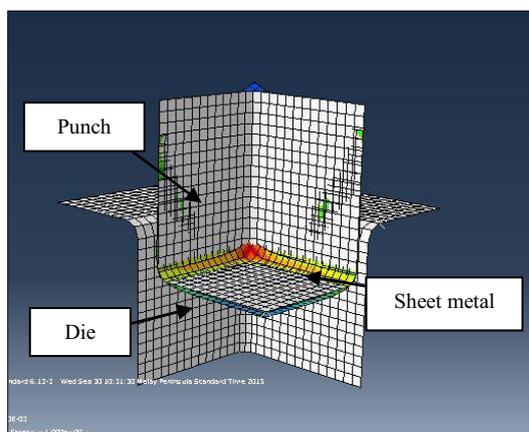
Table 1. Stainless steel properties

Young Modulus (Mpa)	210000
Poisson ratio	0.33

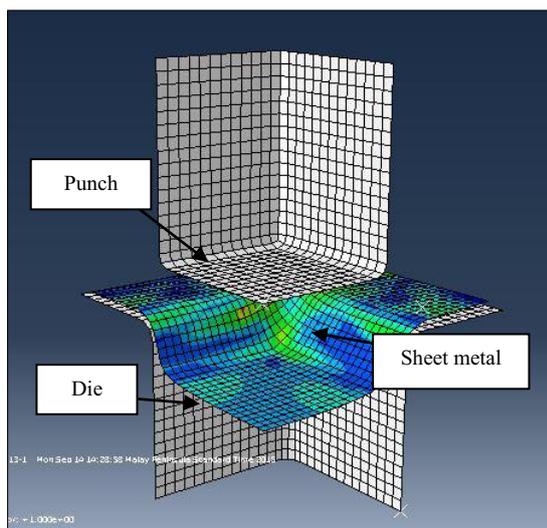
Figure 1 shows the FE model at the initial stage, loading stage and unloading stage.



(a)



(b)



(c)

Figure 1. Finite element model
(a) Initial stage (b) Loading stage (c) Unloading stage

3 Results and discussions

The FE result is compared to investigate its reliability and deep drawing process was carried out experimentally. Figure 2a and 2b show the tools and the hydraulic press machine that has been used.



(a)



(b)

Figure 2: Deep drawing experiment set up (a) Hydraulic press machine (b) Tools used in the experiment

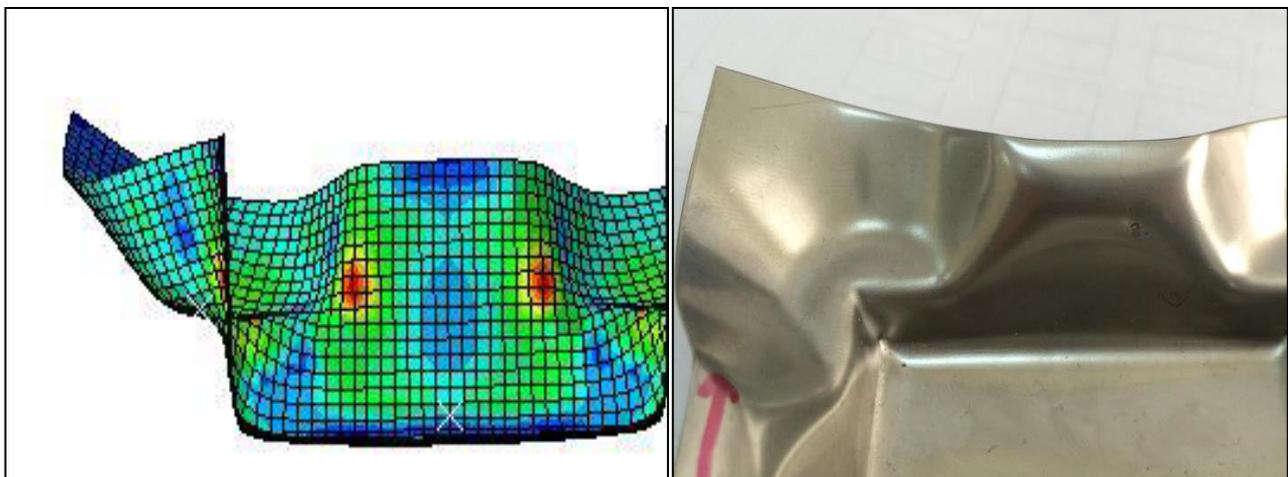
Figure 3 shows the experiment product from the process. The stainless steel sheet metal was successfully drawn for about 13mm depth into the die cavity.



Figure 3. Experiment product

Figure 4a and **4b** show the comparison result for both simulation and experimental results. A qualitative good agreement between the experiment and the simulation has been shown throughout the figures. The wrinkle formation at the flange and cup wall looks similar for both results. The blank rises towards the side wall of punch with the formation of wrinkling along the flange. This happens due to zero holding force applied. When the holding force is less than needed, there is a big tendency for the wrinkles to occur[5]. The other factor that could contribute to wrinkling defect in deep drawing process is the drawing depth. The greater die cavity depth, the more blank will be pulled down into the die cavity and the greater risk of wall wrinkling will occur. The wrinkling occurs once the punch increasingly moves down into the die cavity and the most affected region is at the cup corner [4]. Friction coefficient is another factor that influences wrinkling in deep drawing process. Surface quality of finish product, tool life and

drawability of sheet metal are well dependent on presence of good friction coefficient between contact surfaces. The friction condition enhances the flow of material into the die cavity. An appreciable increase on the frictional force between the blank and the tools is starting when the blank passes the die radius. As the contact condition changes, this is a tendency of increasing friction force and enabling a smooth flow of the blank into the die cavity, hence can prevent the wrinkling defect.



(a)

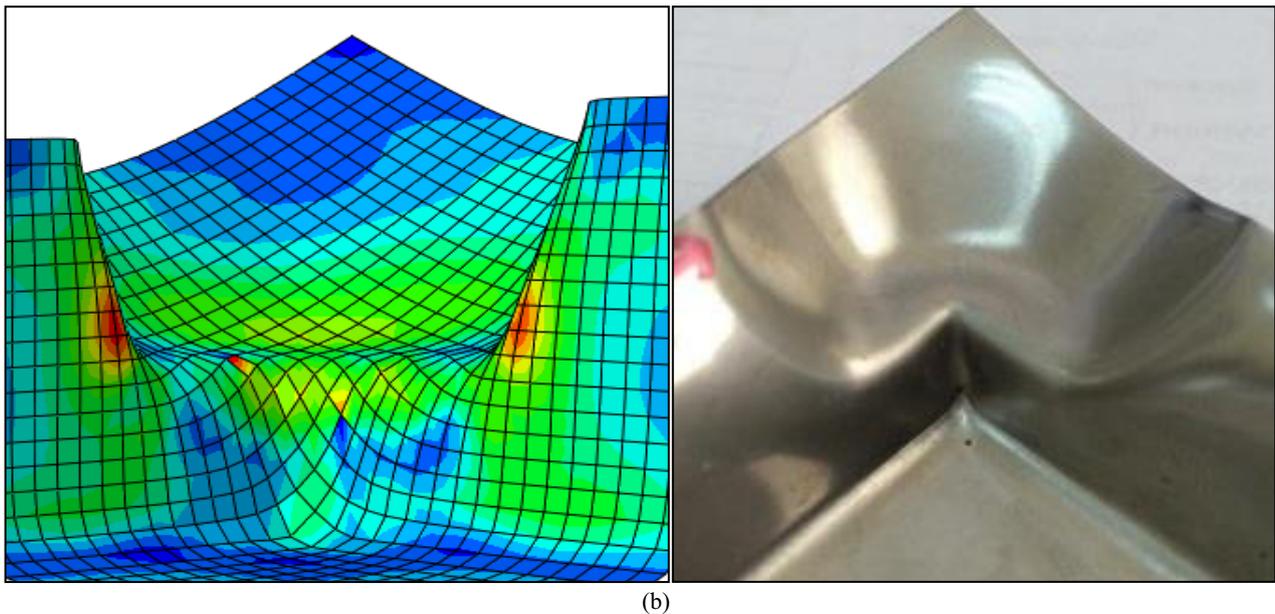


Figure4. Simulation and experimental results compared (a) half deformable part (b) one quarter deformable part

As a conclusion from this study, the finite element result was compared to the experimental result visually for any similarity. Further studies will be continued on testing the reliability of kinematic and mixed hardening model in predicting the wrinkling defect.

4 Further works

To improve the FE simulation in prediction of wrinkling in deep drawing process, there is a need to consider a constitutive model that takes into account the bending and unbending condition. For this purpose, kinematic and mixed hardening model had been acknowledged to provide the answer. Another study is already in final stage to test the reliability of kinematic and mixed hardening model in predicting the wrinkling behaviour in deep drawing process and the result will be publish in another publication.

References

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