ANALYSIS OF THE THINNING PHENOMENON VARIATIONS IN SHEET METAL FORMING PROCESS

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Summary. In many manufacturing areas such as the automotive industry (outer panels, inner panels, stiffeners etc...), the packaging industry (petfood containers, beverage cans etc...) and the household appliances industry (housings etc...), the control of the thinning variations in sheet metal forming process is a major point to study in order to ameliorate the final quality of the produced parts. In this framework, several bulge tests have been developed in order to study the thinning phenomenon during sheet metal forming processes. In this presentation, measurement of the thickness of the deformed specimens has been done using the ImageAnalyser software (based on an image analysis technique) developed by the CMAO research group in the LGP. The AISI 304L stainless steel has been selected as the tested material. Both a cylindrical and an elliptical die allowing the analysis of the thickness variation versus the load ratio and the anisotropy of sheet have been used in this work. In a second part of this communication, we present a numerical model based on the Hill 1948 anisotropic material model. The numerical results are discussed and compared with the experiments.

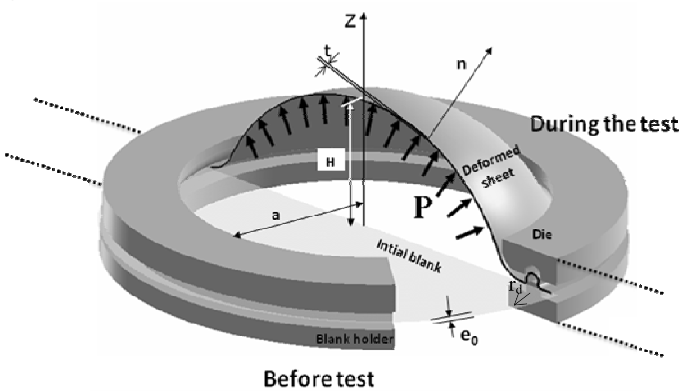
1 INTRODUCTION

Sheet metal forming is an important manufacturing process because of its high productivity and low cost for mass production [1]. More precisely, hydroforming process is an effective method for manufacturing complicated parts. This paper provides an experimental technique for measuring the thickness variation of a deformed sheet after loading. The experimental result are compared with the results of a numerical simulation obtained using the ABAQUS commercial software.

2 EXPERIMENTAL PROCESS

2.1 Bulge test

The circular hydraulic bulge test is widely used to get a biaxial stress *vs*. strain curve for sheet metal forming. This test has been used by many authors in order to study the material formability and to illustrate several defects in sheet metal forming process predicted by numerical simulation software [2], [3]… As presented in figure 1, a circular blank is clamped at its external boundary between a die and blank holder. A linearly increasing hydraulic pressure is applied to the lower surface of the blank. In order to study the anisotropy of the sheet, various circular and elliptic dies have been used. The experimental tests are performed on a 304L stainless steel. We observe a good repetitivity of the test for different pressure level, where the results are expressed in term of the applied pressure *vs.* the pole displacement (see figure 2).



Die profile Radius	r_d =6mm
Blank radius	r_b = 66.5mm
Sheet thickness (e_0)	e_0= 1mm
Die circular diameter	D_d=91mm
Die elliptical major axis	110mm
Die elliptical minor axis	74mm

Figure 1: Bulge test conditions

In order to determine the material parameters for the 304L stainless steel, many tensile tests along three different directions 0°, 45° and 90° have been performed. The optical strain measurement system Aramis (GOM mbH) have been used for the evaluation of the tensile tests and the identification of the stress-strain curve.

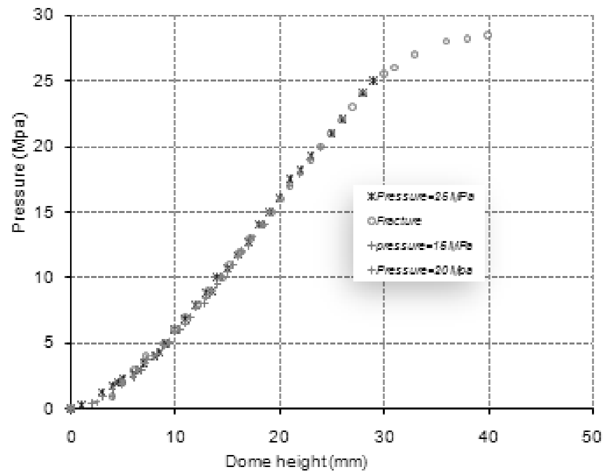


Figure 2: Results of the hydro bulging test with a circular die.

2.2 Thickness measurement

Since the hydroforming of sheet metal parts is nowadays widely used in almost all consumer products, many works have been done on this subject. Thinning localization is the major origin of most of the defects in hydroforming process. Many methods have been developed in order to determine the thickness of the deformed shape, such as a theoretical method based on the incompressibility hypothesis of the plastic strain [6]. In our approach, the thickness of the sheet is measured along a radial path for the circular bulge test and along the major and minor axis for the elliptic bulge test for several pressure levels. The core of the process consists of an image analysis technique based on the treatment of a digital picture by the home software ImageAnayser [5] developed within the LGP. Then, from the digitalized upper and lower surfaces of the sheet, the thickness variations are computed with the help of the *DynELA* software (see figure 3).

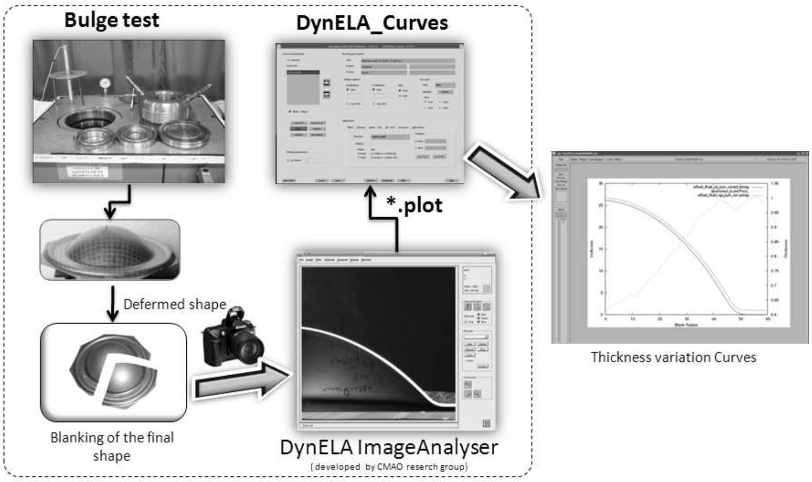


Figure 3: The experimental process of thickness measurement

3 NUMERICAL MODELISATION

A numerical model has been developed using the ABAQUS commercial software in order to predict the thickness variation during the process and allow a comparison with the experimental results. Figure 4 shows a comparison of the numerical results (a) and the

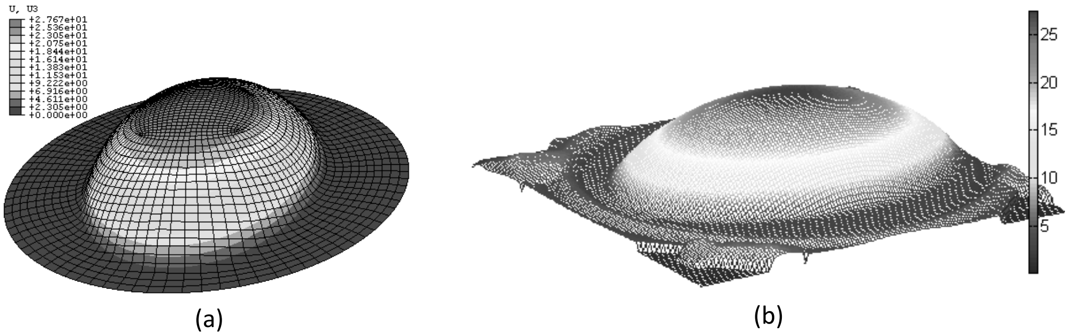


Figure 4 : Displacement results for an applied pressure 20 MPa
(a) Numerical results (b) digitalized experimental deformed part.

digitalized experimental deformed shape (b) for an elliptical bulge test. From this later, we observed a good correlation between the experimental and the numerical results. A prediction of the thickness variation by the numerical tool has been carried out, and the comparison with experimental results is reported in figure 5. This later presents the thickness variation along the major axis of the elliptical die.

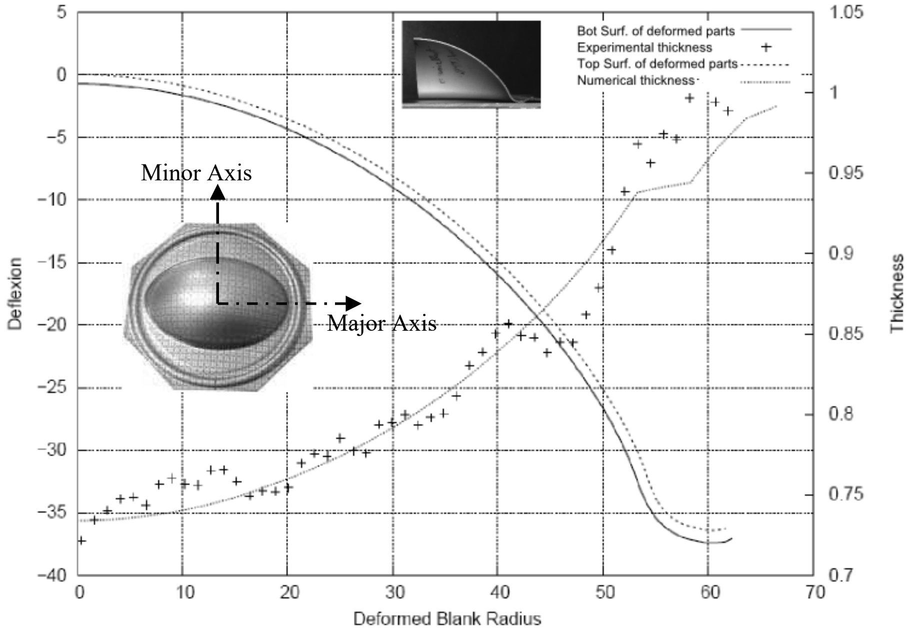


Figure 5: Experimental and numerical thickness distributions along the major axis of the elliptical shape

4 CONCLUSIONS

In this paper, an optical method has been used to measure the thickness variations for a deformed shape after a bulge test. This experimental work has been developed using two different dies (circular and elliptic) and after the identification of the material behavior from tensile tests. The thickness is measured for many pressure levels. The experimental results are compared with a numerical model using the Hill anisotropic yield criterion. We observe a good correlation between all results.

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