Simulation Study on Influence of Blank Alignment in Deep Drawing of Circular Cups

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The blank alignment in deep drawing process is very much essential for draw of quality parts. The use of FE simulation software to predict the forming quality of various sheet metal forming processes such as deep drawing, enhances the efficiency and lowers the development time and cost. The deep drawing tests through numerical simulation were conducted to determine the effects blank alignment error with center of the die and punch tool assembly. The deep drawing tests were conducted on AA6111 aluminum alloy with 2.5 mm, 5 mm, 7.5 mm and 10 mm alignment error. The deep drawing process was simulated using the FE code PAM-STAMP. Having knowledge on error tests helps to take preventive measures for proper alignment in drawing of defect free parts.

***Keywords*:** Deep drawing, Blank alignment error, FE simulation, PAM-STAMP

1. **Introduction**

The deep-drawing process is extensively used in various industrial applications such as beverages, automobile and household applications. The experience gained in past years is being used in present days for the design of new and complex parts. The optimisation process with good understanding of the process and the parameters involved using finite element methods lead to considerable saving of time and money at initial stages of the design. The deep drawing have been studied for better understanding experimental tests as well as numerical simulation tests [1,2].

The stresses and strains induced in different zones of the blank during the forming are the main reasons for failure of the component. The stress state in deep drawing process is really a complex phenomenon, involving compression in the circumferential direction and tensile stresses in longitudinal direction as shown in Figure 1.

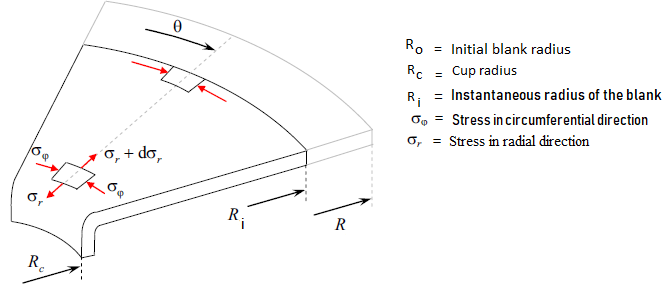


Fig. 1. Stress state in flange portion during deep drawing

The wrong design results with defective parts and deflections of the tool set. A procedure was discussed how to include deformations of tool sets in standard forming simulation at low additional computational cost, using PAM-STAMP by Mark Vrolijk et al [3].

1. **Modelling of Tool Setup**

In the present days, the use of 3D modelling softwares such as inventor, solid works, Pro-engineer and CATIA has been increased drastically in the design of tool and die set. The modelling of deep drawing process setup was done with the use of computer aided design tool, CATIA V5. The functional surfaces of the tool were created and saved in \*.igs format and it was imported into PAM-STAMP 2G software for numerical simulation. The material considered was AA6111 aluminum alloy with 0.9 mm of thickness. The tool setup modelled was as shown in Figure.1 and tool measurements considered for design are shown in Table.1. The mesh was created by choosing proper size of element that mainly influences on time of computation and quality [4]. The size of the blank considered was 120 mm blank and the tests were conducted with intentional misalignment balk with toolset by 0 mm, 2.5 mm, 5 mm, 7.5 mm and 10 mm to know the effect of alignment error on physical and mechanical properties of the component generated.

Table.1: Tool parameters used for modelling and simulation

|  |  |  |
| --- | --- | --- |
| Tool | Parameter | Qty |
| Punch | Diameter | 80.0 mm |
| Nose radius | 5.5 mm |
| Die | Diameter | 81.5 mm |
| Shoulder radius | 5.50 mm |
| Blankholder | Inner diameter | 85.0 mm |
| Outer diameter | 250.0 mm |
| Blank | Diameter | 120 mm |
| Thickness | 0.9 mm |
| Young’s modulus | 70 Gpa |
| Poison’s ratio | 0.3 |
| Plasticity law | Hill |
| Material type | isotropic |
| Hardening law | Hollomon |

1. **Simulation Tests**

The simulation process consists of pre-processing, simulation and post-processing. The processing consists of defining the model of the physical problem. The simulation, which normally is run as a background process, is the stage in which PAM-STAMP solves the numerical problem. Depending on the complexity of the problem it may take few seconds to days depending upon the configuration of the computer. In post-processing we can evaluate the results of the simulation, such as stresses, strains, color contour plots, animations, deformed shape plots and X–Y plots.

The size and type of element to be used in the analysis influences the results and 5 mm mesh size was used for reasonable accuracy. The freedom of die in all Cartesian coordinates for die and in X and Y coordinates for punch and die were locked. Applying constraints for tool movements is locking the degree of freedom in some directions, i.e., movement of the punch restricted to z direction. The tools i.e. punch, die and blank holder, in finite element simulation are considered rigid because they are extreme stiff compared to the sheet. For this reason the tool can be presented as a surface only [5,6,7]. The blank holder force depends upon the material properties, drawing ratio and the geometry of the cup to be drawn. The excessive blankholder force leads to thinning and low value leads to wrinkling. A constant blankholder force of 50 N applied for simulation. The constant punch force of 3000 N applied. The thickness is not uniformly distributed in the part produced in deep drawing. It was uniform at the bottom, least at the wall and thicker at flange area. But, due to the incorporation of alignment error in the process the thickness in unevenly distributed throughout the cup irrespective of bottom, wall and flange [8,9,10]. The figure 2 shows the CAD model used for simulation tests. In post processing the various characteristics were investigated from the results obtained in simulation. From figure 3 to 7 are the FLD plots showing the wrinkling tendency.

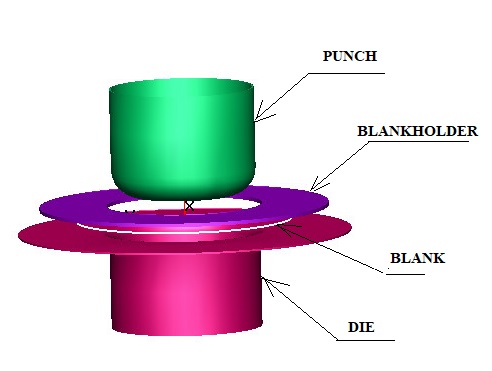


Fig. 2. Modelled tool setup for deep drawing

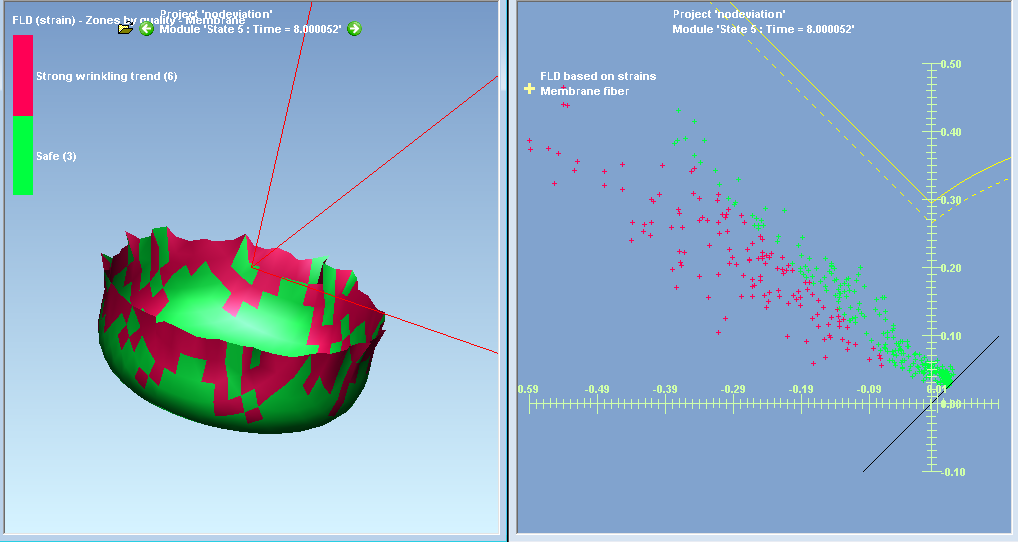


Fig. 3. FLD based strain diagram and the zones of wrinkling tendency with zero alignment error

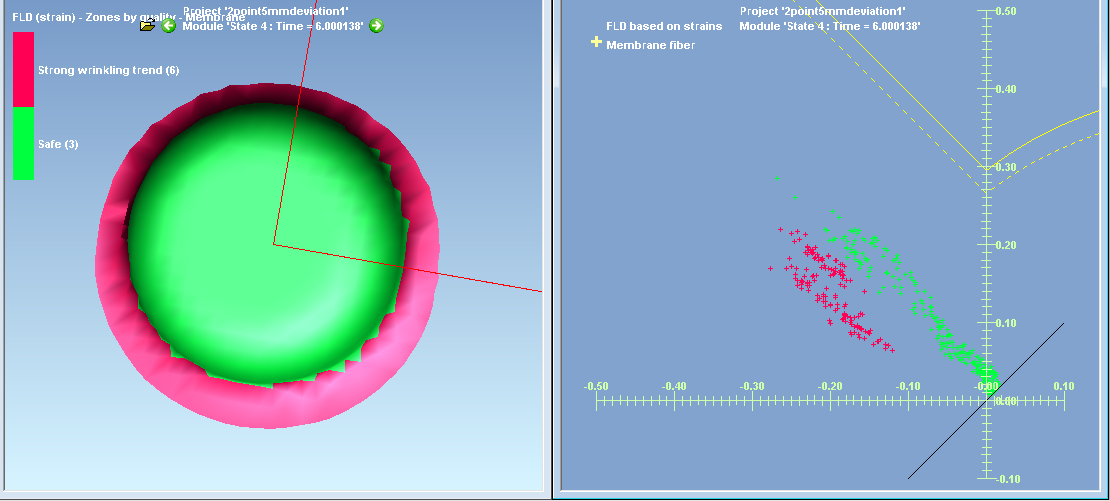


Fig. 4. FLD based strain diagram and the zones of wrinkling tendency in 2.5 mm error test

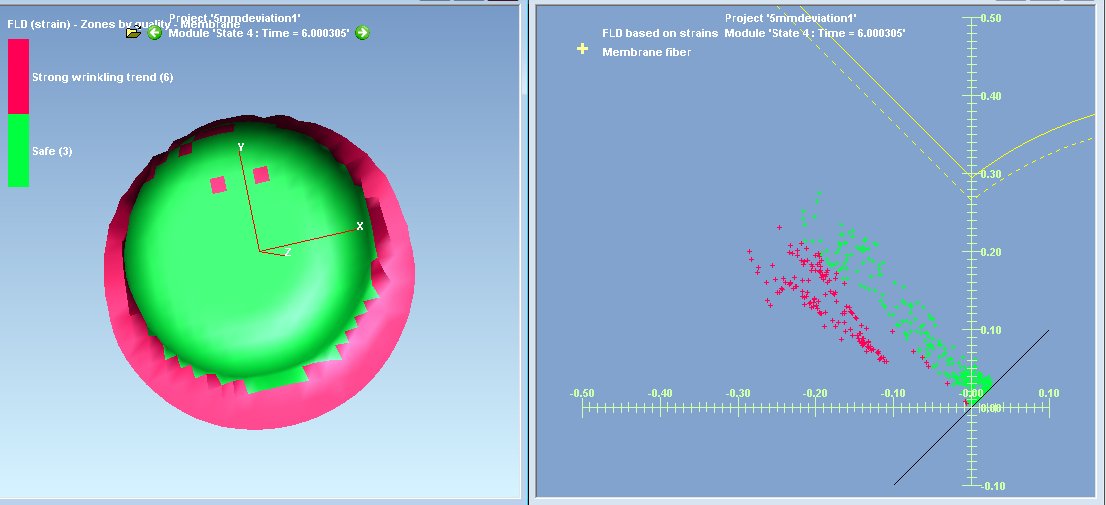


Fig. 5. FLD based strain diagram and the zones of wrinkling tendency in 5 mm error test

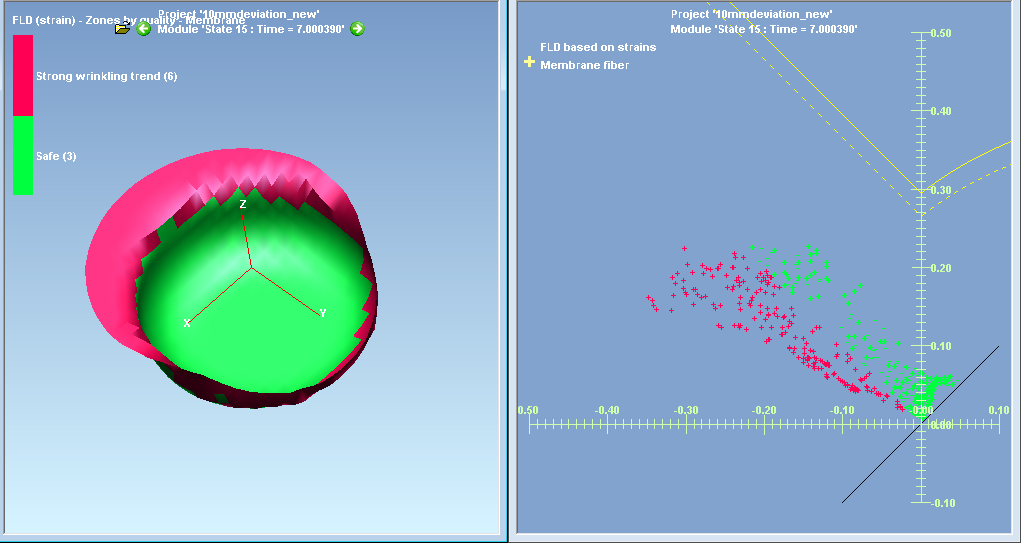


Fig. 6. FLD based strain diagram and the zones of wrinkling tendency in 7.5 mm error test

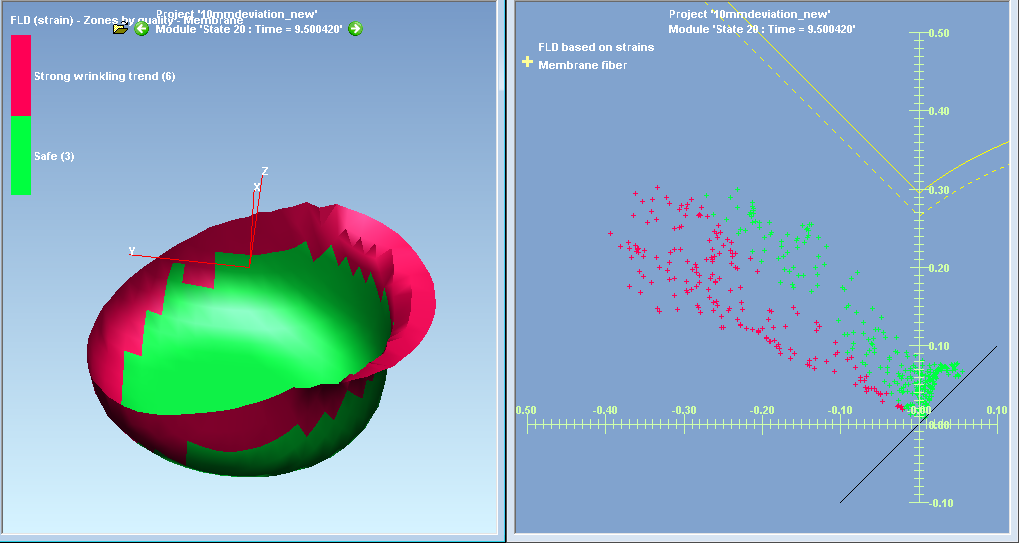


Fig. 7. FLD based strain diagram and the zones of wrinkling tendency in 10 mm error test

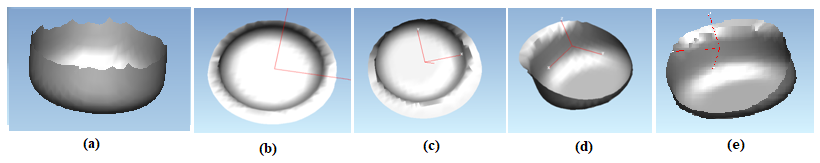


Fig. 8. Simulated cups in deep drawing with different alignment errors

Table 2. Stress and strain ranges found in simulation tests

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Blank deviation | | Zero deviation | 2.5 mm deviation | 5.0 mm deviation | 7.5 mm deviation | 10.0 mm deviation |
| Minor stress GPa | Min. | 0.240665 | 0.143634 | 0.085612 | -0.20112 | -0.47858 |
| Max. | 0.195565 | 0.188317 | 0.210781 | 0.352071 | 0.45099 |
| Major stress GPa | Min. | -0.03934 | -0.0275 | -0.02085 | -0.18434 | -0.33226 |
| Max. | 0.311012 | 0.314864 | 0.367124 | 0.469813 | 0.724431 |
| Vonmises stress  GPa | Min | 0.001934 | 0.004875 | 0.036241 | 0.03288 | 0.060316 |
| Max. | 0.377717 | 0.36475 | 0.354328 | 0.382752 | 0.423107 |
| Equivalent strain | Min. | 0.44315 | 0.138741 | 0.028431 | -0.05121 | -0.42552 |
| Max. | 0.849318 | 0.721351 | 0.67721 | 0.657873 | 0.605192 |

It was observed that the cup formed is not uniform and the strain diagram shows the strain at bottom of the cup is less at the top of the cup in comparison to the punch nose region of the cup. The cup has tendency to fail in further deformation at punch nose region. As the cup is fully drawn in this case found that the strains at the top of the cup is comparatively less than at the punch nose region. The FLD diagram shows that the top region of the cup was subjected to more negative strain i.e., compressive strain. At the bottom region the minor and major strains are equal as the blank at the canter can be subjected to equal biaxail strains. Figure 8 shows the simulated cups produced in different error tests. The table 2 and figures 9 to 12 gives the various forming properties found in simulation tests.

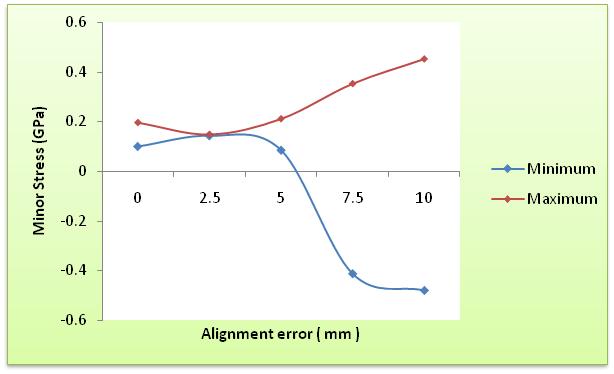


Fig. 9. Minor stresses with alignment error of nil, 2.5 mm, 5 mm, 7,5 mm and 10 mm

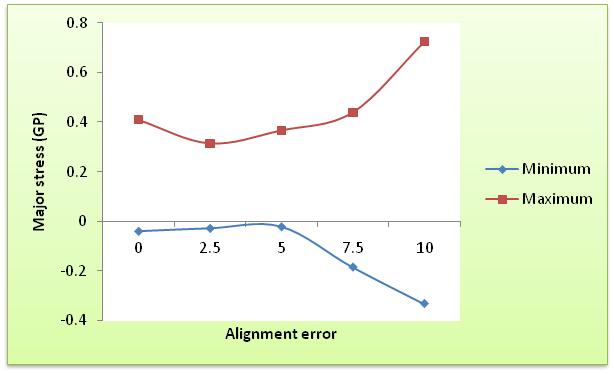


Fig. 10. Major stresses with alignment error of nil, 2.5 mm, 5 mm, 7,5 mm and 10

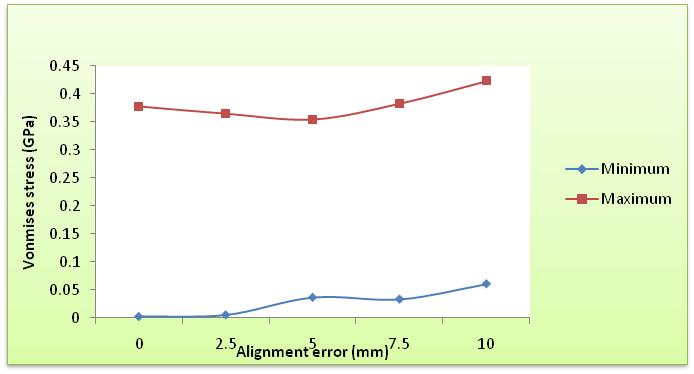


Fig. 11. Vonmises stresses with alignment error of nil, 2.5 mm, 5 mm, 7,5 mm and 10 mm

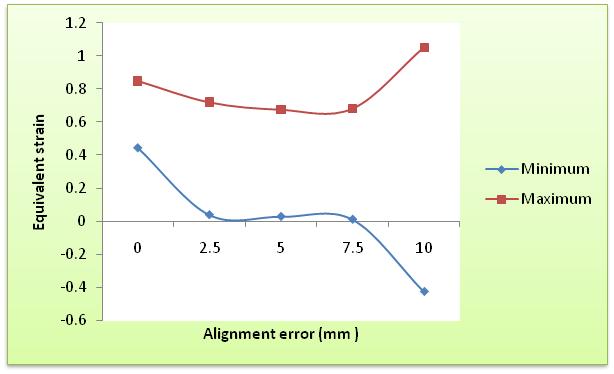
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Fig. 12. Equivalent strains for alignment error of nil, 2.5 mm, 5 mm, 7,5 mm and 10 mm

1. **Conclusion**

Using the numerical simulation, it was pointed out that the variation in the centre of blank to the centre of the tool setup has a significant influence on quality of the drawn part. It was observed that the minor stress, major stress and equivalent strain values changes drastically for 5 mm and after. So, it is very much essential to take proper care during blank placing in the deep draw tool setup for having uniform quality characteristics of 80 mm size cup production.

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