A SIMPLIFIED PREDICTION APPROACH FOR LOCALIZED UNSTABLE SPRINGBACK DUE TO OIL CANNING EFFECT

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ABSTRACT:

Dimensional precision is a major key factor for robust automated production. Springback is one of the most important effect to reduce part geometry level. Also unpredictable springback such as oil canning effect which has eliminates compensation possibilities to ensure part geometry. In this paper the prediction of oil canning effect in forming simulations is presented. Simple prediction approach with clamping forces have been investigated and compared with real measurements.

Keywords:

Springback, Buckling, Oil Canning

INTRODUCTION:

To being updated for new generation style and technology is very important for car producers. Car producers trying to reduce new models development schedules. Reduction of tooling time may most effectively possible with shortened try-out times. Commissioning dies in a limited time have become vital issue for the business. In the other hand dimensional tolerances and Cp/Cpk values becomes more stretch for adaptation of serial robotic production and increased quality benefits. Because of all that reasons dimensional and visual quality aspects have to be guaranteed in virtual environment such as FEE analysis. Springback of the sheet material has to be calculating correctly and make interventions such as compensating springback.

[1] Springback is normally measured in terms of difference between the dimension of fully loaded and unloaded configuration. Tool shape and dimension, contact friction condition, material properties, thickness of sheet, sector angle are the major parameters that affect the springback. The determination of springback by means of trial and error technique not only increases the cost for the manufacturing and repair of the tool but also waste a lot of time, causing delay in the development of the product.

[3,4,5]Generally, every simulation of springback phenomenon in sheet metal forming comprises two major steps: loading (actual forming of a product) and unloading (springback). Two different methods can be used to simulate the unloading step.

Instantaneous tool release is the method which is commonly used in industrial practice due to its computational efficiency. When using this method a change of the blank shape during the unloading is calculated in one increment. All contact forces are suddenly removed, transformed into the residual forces which are then reduced to zero. The material response is calculated under the assumption of fully elastic deformations in the complete model.

[6]On the other hand Surface defects are understood to be the result of elastic recovery of non-uniform strain distribution in forming.

Neighboring regions strained by different amounts will have unequal elastic recovery and therefore differing residual stresses. Negative (i.e., compressive) residual stresses may lead to buckling instability in the lower strained region. Such problems are exacerbated with materials prone to greater degrees of springback, e.g., high strength steels due to their higher yield stress, or aluminum due to its lower Young's modulus

[11] Oil Canning or snap through buckling. It is a moderate deformation or buckling of sheet material, particularly common with flat sheet metal surfaces. This terminology also refers to the popping sound made when pressure is applied to the deformed sheet forcing the deformation in the opposite direction. (U.S. Department of Transportation – FHWA, 2007). Though not a permanent deformation, oil canning deformation is a very important phenomenon in certain applications like automotive hoods and doors where the customer may perceive the temporary deflection as a poor vehicle quality or a weak design. The oil canning phenomenon is shown in (Fig. 1).

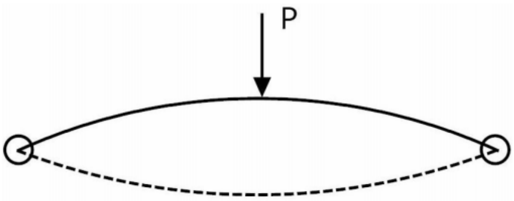


Fig. 1 Oil canning

Buckling resistance of a panel is defined by the limiting load that a panel can carry without undergoing sudden large deflections. Singly curved structures are simple arches or a curved beam structures having one direction of curvature. Shallow arches can be defined as an arch with a small rise to span ratio. Skvortsov and Bozhevolnaya (1997) have used this criterion for classifying an arch as shallow or non-shallow by considering the 2 2 h S/ ratio, if 2 2 h S/ 1 <<< the arch can be said to be shallow. Dimensions h and S are as shown in (Fig. 2). Bradford et al. (2002) classified arches as shallow if the included angle is less than 90°. Symmetric buckling (Fig. 3) for an arch is the mode of buckling in which the buckled shape remains symmetric with the plane of symmetry of the initial configuration of the arch.

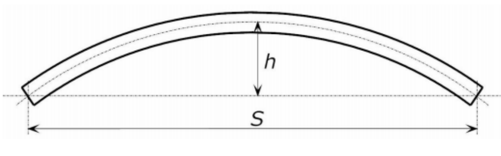


Fig. 2 Shallow arch

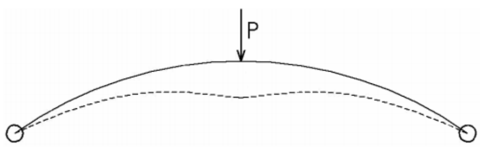


Fig. 3 Symmetric snap through buckling mode

If there is any oil canning effect on sheet panel it must be detected in process generation phase hence it will cause wrong springback compensation results and undesired part geometry in car body.

FEA Modelling

[10]The use of initial forming models for subsequent dent predictions is a new concept. Historically, researchers have omitted this step and made simplifications regarding material properties in their finite element dent models. Typically, in order to capture panel pre-strain, a tensile test would be performed on a formed panel; however, this is not possible unless a panel has already been produced. This method does not allow for optimization of a panel early-on in the design cycle. Only recently have coupled explicit/implicit finite element codes become available, such as LS-DYNA and ABAQUS Explicit/Standard. These codes can simplify the process of transferring data between the various simulations. However, there is still a requirement for considerable user intervention between each stage. The finite element models can capture the forming and springback processes quite well and could be used for a subsequent denting analysis; however, the amount of pre-processing work required to convert one of these models into a subsequent denting model has been prohibitive.

Autoform is one of the software for body panels such as fenders, doors or inner parts most of simulation software have generated predefined set up templates automatic meshing and mesh refining and also it has. But there has not been any predefined template for buckling models in simulations; it has not completely possible to see any oil canning effect with post processing of simulation results.

In this research it has decided to use springback tools such as clamps as denting models.

A simple cup geometry have been defined which has expected an oil canning effect due to recent experiences form industrial applications like jar cups. Stress strain distributions dimensional changes and reaction forces will be investigated with the geometry defined (Fig.4.) ,(Fig.5.). Simulations have done in implicit code with Autoform.

Fig. 4 – Cup Geometry

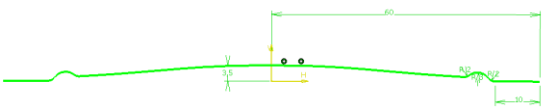


Fig. 5 – Section View Cup Geometry

Forming stage made with clash forming without any pressured binder. Non homogeneous stress distribution objected that guarantee the phenomena.

Simulations have been done with DC 04 coated mild steel material, material characterization has been defined with real material tests. [7]Tension test with 3 directions as 0°,90°,45°, Correlation has made with Hydraulic Bulge Test. FLC Curve has generated with Arcelor R9 Calculation which is presented in Autoform (Fig.6.). Simulations made with final Validation Settings with a very fine mesh. Min. time steps limited as 0,1mm.

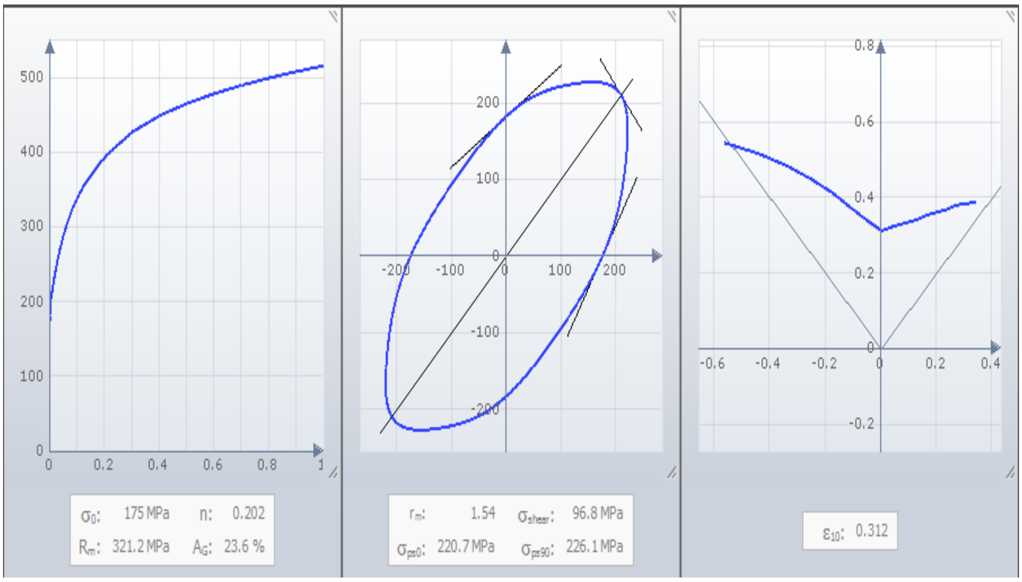


Fig. 6 – Hardening curve have generated from Bulge Tests

SIMULATION CONCEPT

Oil can effect causes by non-homogeneous strain and stress distribution as well stressed around a soft region. But this type of inspection not always clarifies the phenomena. Always need some physical simulations which have an additional tool contact over sprunk part. Measure force and geometry level [8]. Hence this type of inspections are very late for after the stamped panels, there will be any compensation or elimination opportunity in process stage.

The simulation of physical tests are investigated in some papers as [9] Simulation Analysis Of Dynamic Dent Resistance On Auto Body Panel by S.M.Chavan, Dr.R.B.Hiremath The simulations is carried with non-linear transient dynamic explicit analysis using Ansys - LSDyna software.

However it is difficult to define force controlled punch tools in an implicit code, also tool movement steps need to defined fix values and simultaneously spring back calculation has to be done for every defined step.

To avoid those difficulties and create a suitable inspection for Autoform, The concept designed as to investigate phenomena by clamping tools in springback stage (Fig.7).

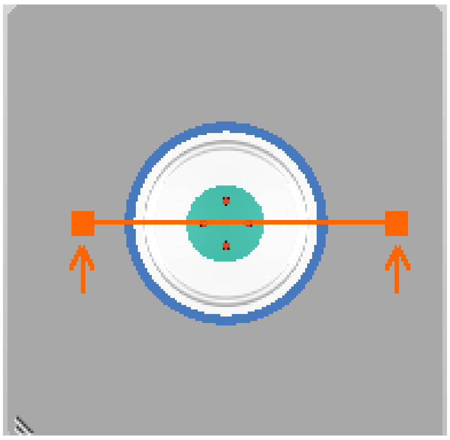


Fig.7 Clamping tools distribution on specimen

Tool support has defined out of the ring, 4 clamping have defined as supporting from above the sheet. Clamping positions have changed manually in Z direction. Springback simulations have been calculated for every clamping position. In simulation, reaction force is calculated from the clamp position. Reaction force in the jth position of clamps is defined as,

$$Sum(Force)j = \sum k\ (Fc),\ k\ (1,2,3,4,\ldots)$$

where Fc is the single clamp force and k is the position of the clamp. Some amount of reaction force have been expected, reaction force data saved for each simulation and monitored.

The matter of fact of phenomena that is expected to nonlinear reaction force distribution, if there is an oil caning effect.

SIMULATION RESULTS

Before the Force investigation, final major stress distribution before and after springback have been analyzed. The major differences before springback between explains that springback amount of these segments will be different (Fig.8).

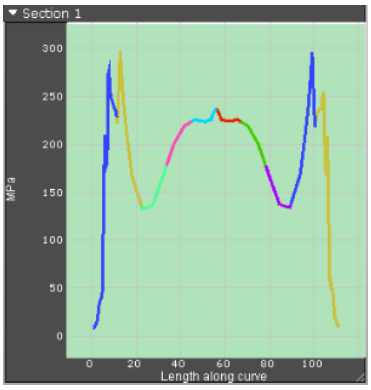


Fig.8 Major stress distribution in center section

When geometry considered with this stress section, higher levels of stress on ring form can be explained as high level of forming on that region, but a significant difference between center and the ring formed region. The stress accumulation on center which has a soft region around will be present oil caning effect.

But this output is not completely a meaning full explanation for the phenomena. The major stress distribution after springback also investigated (Fig. 9).

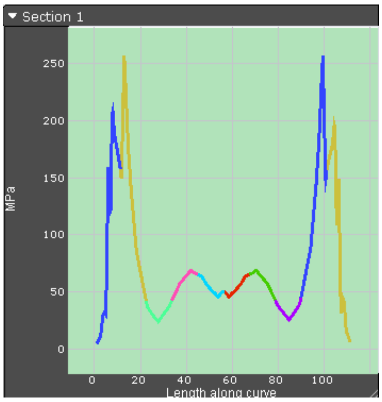


Fig.9 Major stress distribution in center section after springback

Major stresses have relaxed in center region but it still conserved in the outer ring. Major strain analysis indicates a clue for oil canning effect. But it is not literally result that judge there is an oil canning effect or not.

Equivalent plastic strain distribution has major control parameter tool and die business which use for plastic deformation level on panels. Due to EPS has controlled as figure 10. Results have parallel tendency with major stress values.

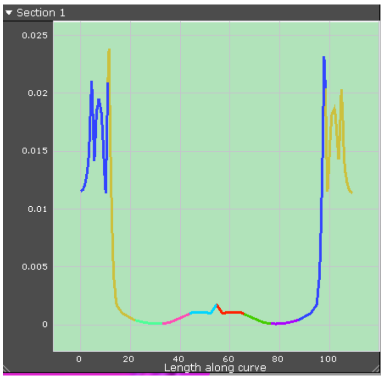
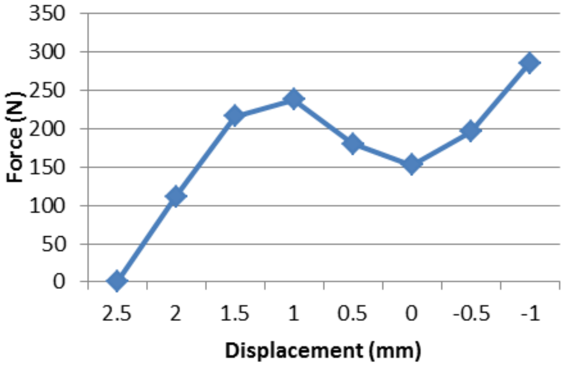


Fig.10 Equivalent plastic strain distribution in center section

Hence it may be a primary investigation that is defines the force analysis region for a complete part.

Clamping application have made for 8 different stages. Which is starts form Z(+2,5mm) till Z(-1mm) for every different distance stage (k) formulation of Fc calculated and presented as a graphic in (Graph 1).



Graphic.1 Force Application graphic

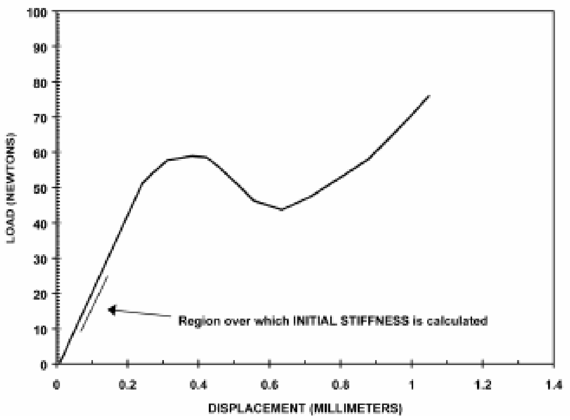


Fig.11 Schematic Load-Displacement Curve SAE J2575

(Fc) has not increased as a linear function, after Z =1mm the force has been decreased and increased in further distances. It has been compared with characteristics of SAE J2575 (Schematic Load-Displacement curve) (fig.11) for oil canning effect. Characteristics of two graphics have suited and it has exactly presented that there may be a real oil canning effect in real production.

AN UNDERBODY PART EXAMINATION

Experimental results have also been determined in a real underbody part. Material is DC 04 mild steel and 0,7mm thickness. Part has been produced in 4 operations. First Drawing, Cutting, second forming and final cut in sequence (Fig.12).

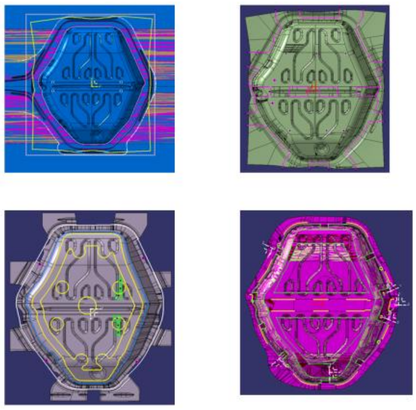


Fig.12 Process Lay-out

As a result of the experiment, strain results have been investigated after final forming operation. Under the %3 equivalent plastic strain (EPS) limits has defined as soft region (Fig.13). The springback level have been under the +/- 0,5 mm in those regions hence oil canning examination has not investigated.

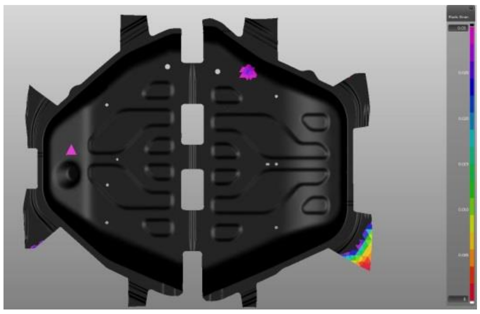


Fig. 13 Equivalent Plastic Strain Distribution, 2 soft regions have indicated as purple color.

On the other hand major EPS differences are another cause of phenomena [6], therefore major EPS differences have been investigated with a %10 margin. Two different zones have been uncovered that have EPS differences over %10. (Fig 14)

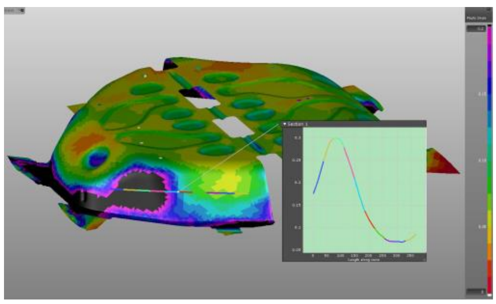


Fig. 14 EPS distribution on sprung part

Major equivalent plastic strain differences through two adjacent regions have gave to understand that may be oil canning in those regions. Concept simulation as defined in chapter 3 will be applied to simulate oil canning.

OIL CANNING SIMULATION ON PART

Concept simulation has been applied for both region, indicated as Region 1 and 2, (Fig12). EPS(equivalent plastic strain) max.%30 in region 1 and approx. %7 in region 2. Due to more strain and high tension in region 1 oil canning effect has not existed in simulations. Therefore results of region 1 have not presented.

Simulations performed as discussed in chapter 3. Sprung part has fitted over the fixed tools and 4 clamps have applied that prevent form part movement. 0,5 mm local displacement have determined in region 2 when springback examined in this condition, also non cutted scrap has aprox. 4 mm movement from the reference positon. Due to high springback of that idle portion, it have been decided to perform simulations with and without clamping (fig.15)

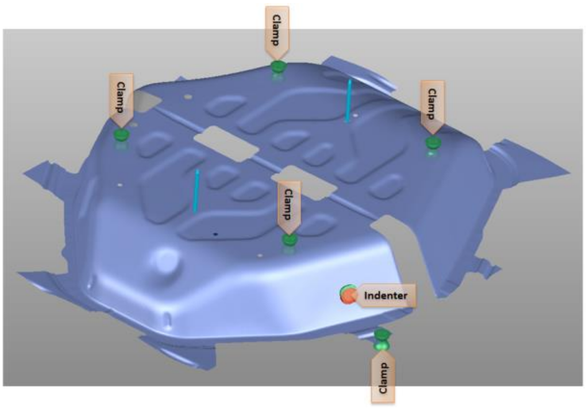
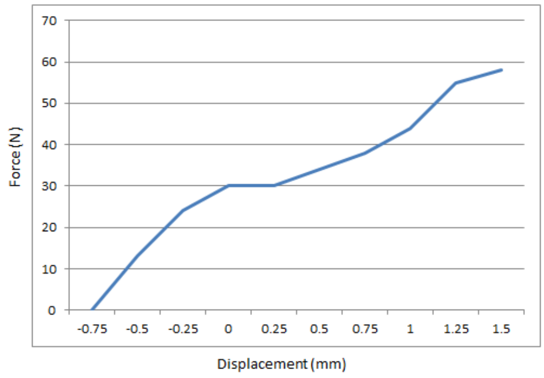


Fig.15 clamping of sprung Part

Four clamps applied as support where the local displacements max. exist and called as indenter clamps.

Ten simulations have performed for each indenter clamp positions, all clamps have displaced in same amount for each simulation. Indenter displacement have performed as 0,25 mm due to 0,5 mm local sheet displacement. Sum of the reaction forces for each step have presented as graphic (Graph 2).



Graphic.2 Indenter Reaction Forces

Results presented without clamping on idle scrap region however they have same force trend with clamping. As understand in graphic 2, increase of reaction forces have not been linear. Forces have decreased after 0,75 mm indenter displacement.

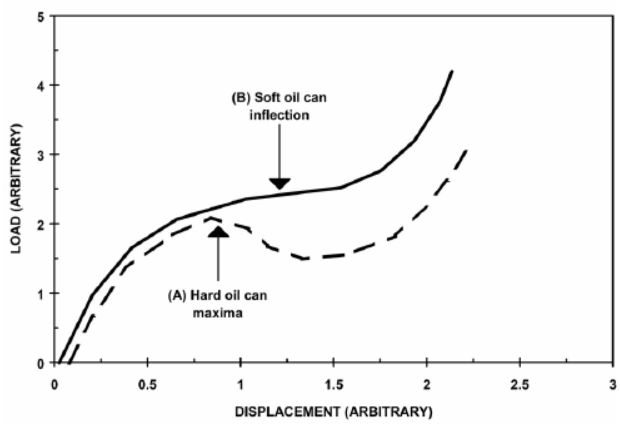


Fig.16 Schematic Load-Displacement Curves for Hard and Soft oil canning SAE J2575

Force increase trend have presented close characteristics with soft oil caning as SAEJ2575 in (fig.16). results may uncover that soft oil caning may occurs in this region.

REAL MEASUREMENTS

In the simulations oil canning effect investigated ad defined concept and results have demonstrated a soft oil caning may exists as Graphic.2. However it needs to confirm the results with real stamped part.

A test method have developed that measure the real reaction forces, deep drawn part used as a gauge. Part from Op 40 (second forming op.) which expected to oil canning effect has stand over the gauge. Deep drawn part has fixed to eliminate part movement over the reaction force. A dynamometer has an indenter to calculate to force over the sheet metal. Dynamometer have fixed to a linear moving machine and displacements have measured in 0,01mm precision (fig.17)

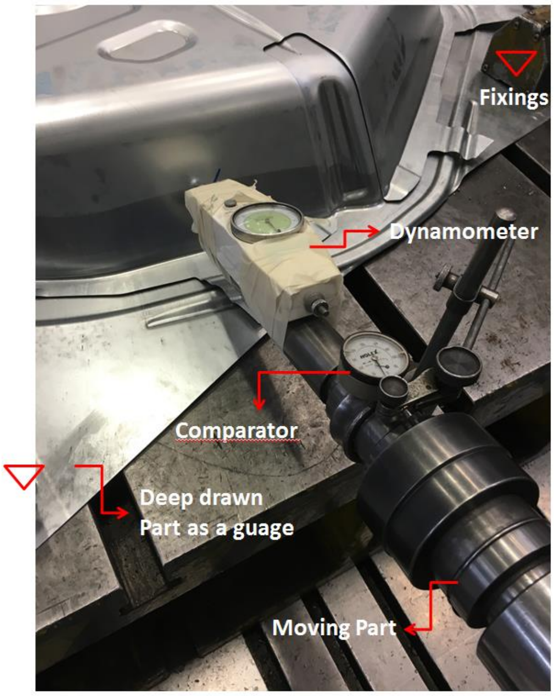
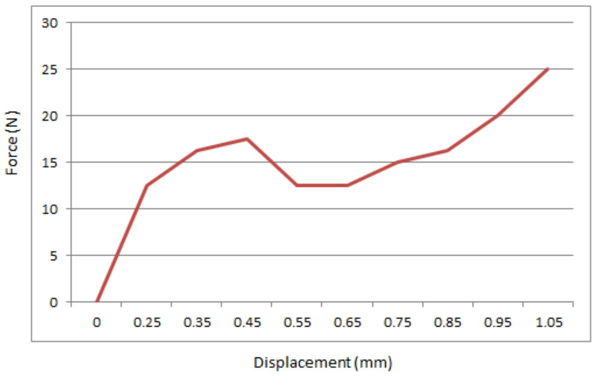


Fig.17 Real Measurement Set-Up

Forces have measured from every 0,25mm movement step, Forces have presented in graphic (Graph 3).



Graphic.3 Real Reaction Forces

Real forces have not completely fitted through the simulation results. It may explain that simulation conditions have not completely same with real production. However force has not increased linear. After 0,45mm indenter displacement that has seen that force has reduced and then increased again. The force trend may quiet similar as simulation. Also oil canning effect recognized by hand inspection on real part.

CONCLUSIONS

In many die process applications especially inner parts oil canning effect has been neglecting. In most cases that facing with oil caning after the production. The phenomena hinder that achieve desired robust dimensional quality. It brings noise and aesthetical problems in some cases.

In the presented paper a virtual inspection methodology have inspected. Fixing clamps have used as force appliers indenters in reality. The methodology may use during the die process generation stage that avoid time and money consuming oil canning effect.

REFERENCES

[1] Dieter GE. *Mechanical metallurgy. 3rd ed. London: McGraw-Hill; 1988.*

[2] Mark S. Graham *Proper design considerations can limit oil canning's visual effects www.professionalroofing.net 2015*

[3] T. Meinders, A.W.A. Konter, S.E. Meijers, E.H. Atzema, and H. Kappert. *A sensitivity analysis on the springback behaviour of the unconstrained bending problem. International Journal of Forming Processes, 9(3):365–402, 2006.*

[4] Y. Hu. *Quasi static finite element algorithms for sheet metal stamping springback simulation. In J.C. Gelin and P. Picart, editors, Proceedings of the 4th International Conference and Workshop on Numerical Simulation of 3D Sheet Forming Processes, NUMISHEET 1999, pages 71 – 76, Besancon, France, 1999.*

[5] A.P. Karafillis and M.C. Boyce. *Tooling and binder design for sheet metal forming processes compensating springback error. International Journal of Machine Tools & Manufacture, 36(4):503–526, 1996.*

[6] T. Dutton and E.Pask *Visualisation of surface defects in sheet metal.*

[7] *I.Gurbuz Enhanced Characterization and Die Design for Sheet Metal Forming in Automotive Industry 2014*

[8] SURFACE VEHICLE STANDARD SAE J2575

[9] S.M.Chavan, Dr.R.B.Hiremath *Simulation Analysis Of Dynamic Dent Resistance On Auto Body Panel (IJERA) ISSN: 2248-9622*

[10] D. Thomas *The Numerical Prediction of Panel Dent Resistance Incorporating Panel Forming Strains*

[11] M. Sonawane *Buckling Analysis Of Singly Curved Shallow Bilayered Arch Under Concentrated Loading*