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Research Article

Finite Element Simulation of Oil Canning for Automotive Panel

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Abstract

Dent resistance is one of the major requirements for automotive body panel design. It depends on material strength, thickness, panel geometry/shape and outer and inner panel assembling. A detailed DOE study investigates effects of work hardening, thickness; bake hardening on the denting simulation results. Important parameter affecting CAE denting results are identified which in turn provides guidelines for production application. An FEM simulation method was investigated in order to predict a dent resistance and stiffness performance of automotive exterior body panels. The dent simulation was carried out with material models taking forming effects, such as work hardening and thickness variation into account. Acceleration compensation methodology for dynamic dent testing was successfully applied to calculate dent loads and applied energy in dynamic dent testing. The impact of strain rate on material binding and hardening in high speed dynamic dent resistance testing was studied. A finite element methodology, based on implicit numerical integration procedure, force simulating oil canning test on door assembly is presented. The sensitivity studies are conducted on three different grades of steel for the outer panel. Further studies are conducted to understand the effect of manufacturing (forming operation) on the oil-canning behavior of door assembly. Two finite element methodologies force simulating oil-canning test on closure assemblies are presented. Further reinforcement of the predictability of the methodology is demonstrated by an oil-canning simulation, using the implicit code, of a door assembly.

Keywords: *Automotive panels, Dent resistance, FEA, Oil canning, Stiffness*

1. Introduction

Higher oil prices and environmental awareness continue to drive demand for full-efficient vehicles. This demand has led to the development of higher strength, thinner gauge automotive sheet materials that are being used to reduced vehicle weight, and thus improve fuel efficiency. However, with increasing use of thinner sheet, dent resistance of the auto body will suffer, it become a critical issue for exposed panel application. When considering dent resistance, there are two different mechanisms by which panel can be dented. These mechanisms are generally termed static or dynamic denting, the difference being the rate of load application (Dylan thoms, 2001) (Li wang *et al*, 2005).

It is important to consider the implications on the oil-canning behavior during the pre-program design of automotive assemblies. It is impractical and prohibitively expensive to build many prototype modules and test for resistance to various loads. Reliance on validated CAE tools would be imperative in the design and development of such structure (Danielle zeng and Z. Cendric xia, 2005). Dent resistance in the automotive panel design is a key property to evaluate its ability to accurately predict panel's durability. Stiffness and dent resistance has correlation in the design of door, hood and roof outer panels, where it influences cosmetic quality of the vehicle and therefore customer satisfaction. So, Dent resistance mainly related to thickness of material, yield strength and geometry of part. The empirical equation is as follows (Andrzej Sikorski, *et al*, 2005).

$$DR \ \alpha \ K \times t^{a} \times YS \quad (1)$$

Where DR is the load to produce a dent at given size. K is constant, t is thickness, YS is yield strength, is an exponent usually between 2.0 and 2.4. Damages due to denting of exterior automotive panels are increasing due to light-weight design for improved fuel efficiency and its increasing utilization of thinner exterior panels increasing their propensity for denting and oil canning damage (R. Mohan Iyengar *et al*, 2003).

For the design of lightweight exterior panels, it is very important to meet dent resistance and panel stiffness requirements. It is known that thickness, yield strength and the geometry of the panel affect the dent depth and the stiffness. In addition, the forming

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conditions are also important factors to affect the performance. The Finite element method (FEM) to predict the dent performance is required to design and optimize the panel.The FEM prediction accuracy was evaluated by comparing results of FEM simulation with experimental results (Kentaro sato, *et al*, 2003).

While most real world denting is dynamic in nature it is common to use pseudo-static denting test to evaluate dent resistance. In contrast dynamic denting test generally only result in ‘good’ or ‘bad’ relative rating of the dent resistance of a panel assembly. Various drop weight tests has been used by Johnson and Schaffnit, Painter *et al* and Thomas to study the effects of material properties and sheet thickness for dynamic dent resistance of automotive body panels. The procedure utilized in the previous static dent resistance test was further developed and adapted for high speed testing and used for a basis for a new, single loading incremental dynamic dent test (Hua-Chu Shih, *et al*, 2005). The dent resistance of automotive closure panels is an important characteristic for both automotive manufacturers and consumers. Closure panel thickness is being reduced in an effort to reduce cost and weight, making it necessary to understand the dent performance of various material grades and panel thickness (G. Boudreau, 2004).

The finite element analysis (FEA) is widely used in vehicle structural design and process simulation.

2. Oil canning of door and hood assembly

The oil canning testing procedure is relatively simple. The door is simply supported near the four corners and the recommended test load is added incrementally at the testing location. After the maximum load is applied, the load is incrementally released. The residual displacement is measured after the entire load is released. Its quasi-static process and does not involve significant spring back.

2.1 Salient features and assumptions in the simulation

1. Flat circular indenter is simulated using a RIGID ELEMENT SPIDER (RBE2 element)
2. In the load steps made, UNLOADING loads are considered.
3. Contact between indenter and panel has NOT been modeled.
4. The effect of forming has not been considered.
5. Testing areas have been identified as
   a. Functional area – e.g. area around handles in doors
   b. Visible area (refer fig.1)
6. Geometries used in this analysis are typical representatives of those seen in outer panels in automotive structures.
7. In the unsupported span model considered, curvature and overall dimensions have been kept constant.
8. In all for 4 FE models, with combinations of material and thickness as 0.75 and 0.85 mm has been taken.

3. Schematic FE model of a door and hood

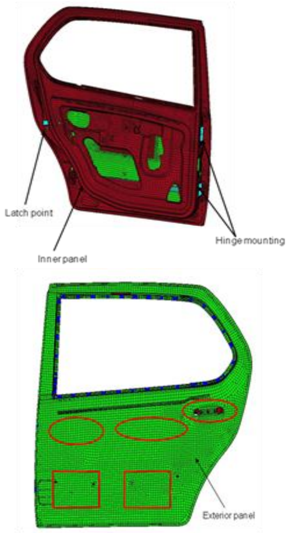


Fig.1 Schematic Door subassembly model

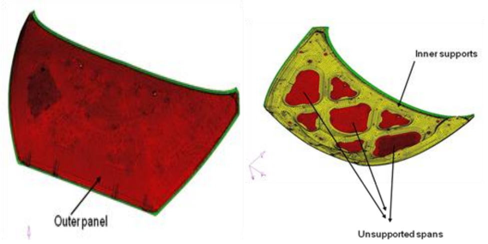


Fig.2 Schematic Hood subassembly model

4. Material properties

Two different materials (isotropic steels) are considered here for simulation. Table 1 shows the engineering stress-strain data used.

Table1 Material Properties

Sr. no.	Material properties	Steel
1.	Young's Modulus E (MPa)	2.07E+05
2.	Passion Ratio (µ)	0.29
3.	Density ρ (kg/mm³)	7.820E-06

The respective engineering stress-strain data for both the materials used for automotive panels represented in Table 2 and Table 3

Table 2 The engineering stress strain data for Material 1

Material 1	
Engg. Strain	Engg. Stress (MPa)
0	0
0.000783	161.875
0.021	189.62
0.163	241.725
0.298	233.973
0.151	240.818
198	242.801
0.241	241.725
0.298	238.68
0.351	234.377

Table 3 The engineering stress strain data for Material 2

Material 2	
Engg. Strain	Engg. Stress (MPa)
0	0
0.001	219.77
0.011	256.357
0.042	313.532
0.074	343.265
0.106	361.782
0.14	373.879
0.211	386.636
0.247	389.279

5. Boundary conditions for unsupported span model

Case I: Unsupported span model: It is isolated from the surrounding parts. Outer edges of the unsupported span are constrained by clamping all the nodes at the edges.

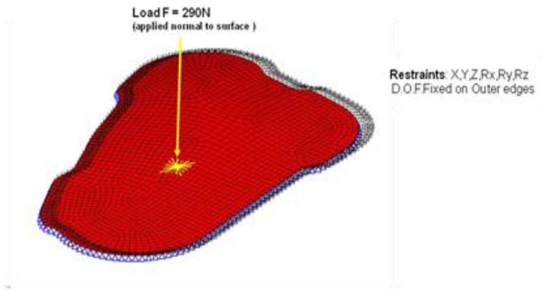


Fig.3 Unsupported model with Boundary conditions

6. Loading details

1. A max force 200 - 290N is applied
2. Load is applied in steps of 50N so study the force-deflection pattern in detail.
3. Loads are applied in similar way while experimental testing.
4. Unloading of the panel has not been done.
5. Applying load in steps helps :
   a. Control the minimum and maximum load increment in each subcase.
   b. While testing, loads near the instant of time where oil-canning occurs can be closely monitored.

7. Simulation results and discussions

Fig.4 and Fig.5 shows normalized displacement contour and normalized von-misses stress at the end of load application for two different materials with thickness value of 0.75 mm. Also, Fig.6 and fig.7 shows normalized displacement contour and normalized von-misses stress at the end of load application for two different materials with thickness value of 0.85 mm.

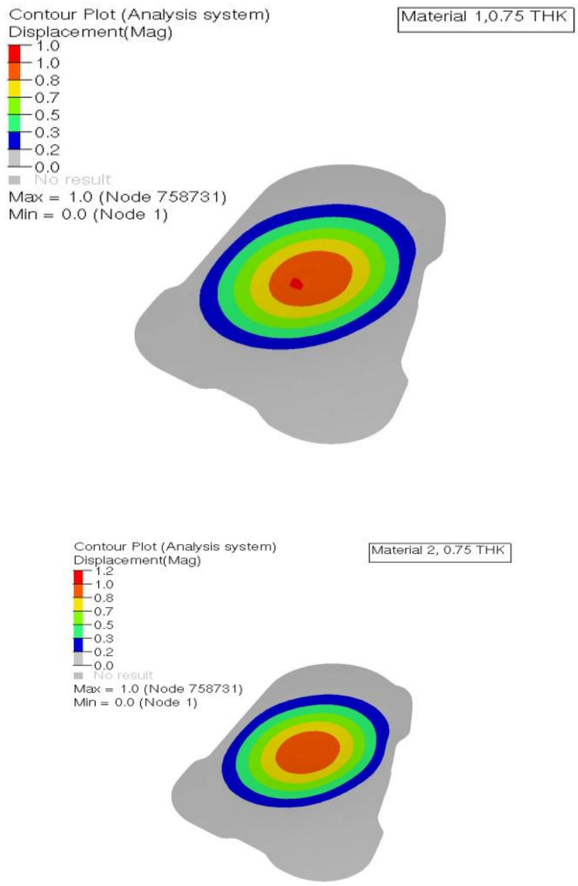


Fig.4 Normalized Displacement contour at the end of load application (for two different materials)

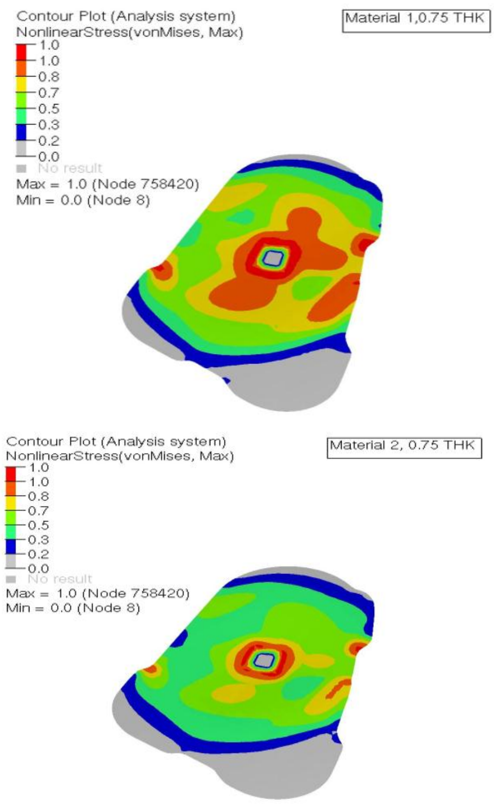


Fig.5 Normalized Von-misses contour at the end of load application (for two different materials)

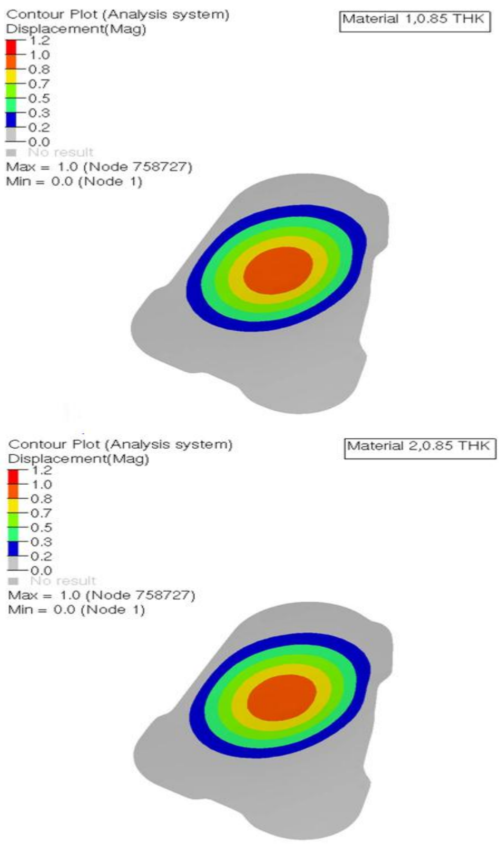


Fig.6 Normalized Displacement contour at the end of load application (for two different materials)

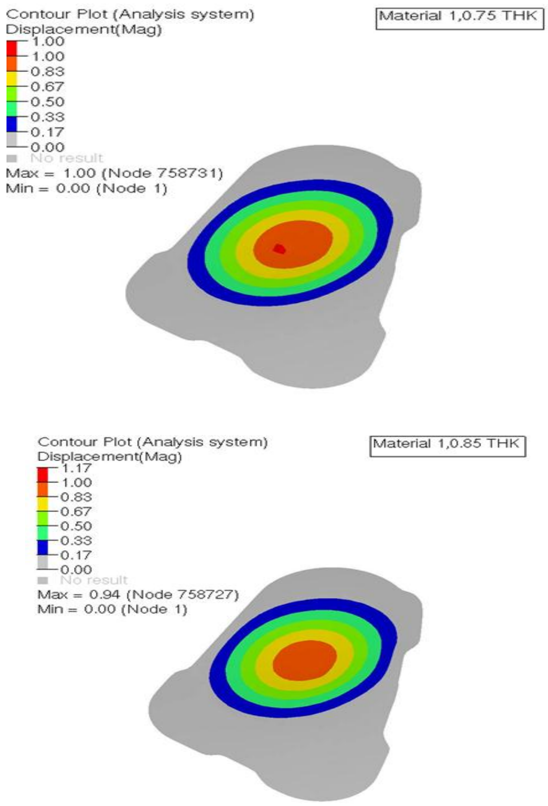


Fig.7 Normalized Displacement contour at the end of load application (for two different thickness gages)

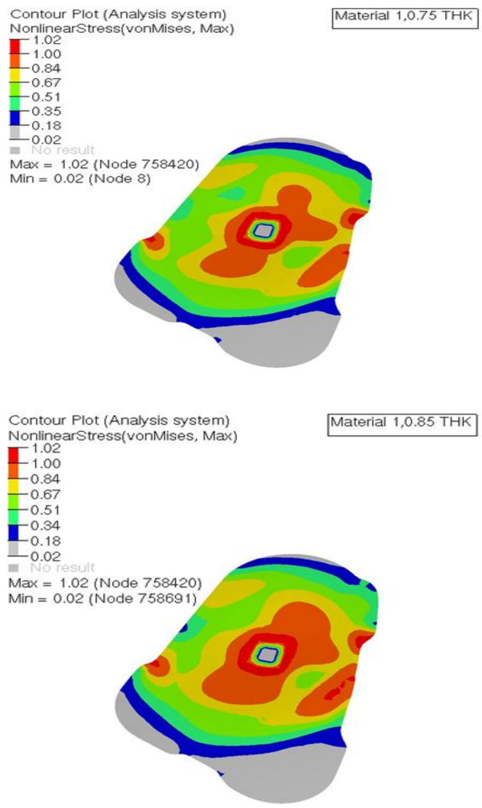


Fig.8 Normalized von-Misses stress contour at the end of load application (for two difference thickness gages)

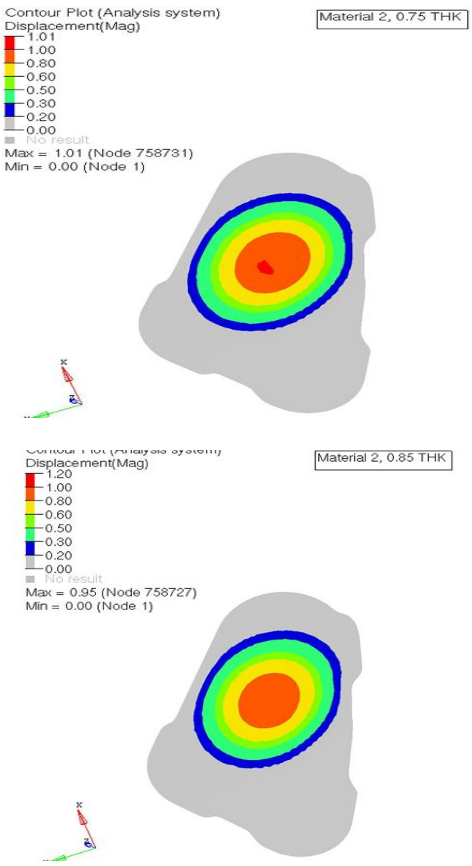


Fig.9 Normalized displacement contour at the end of load application (for two different thickness gages)

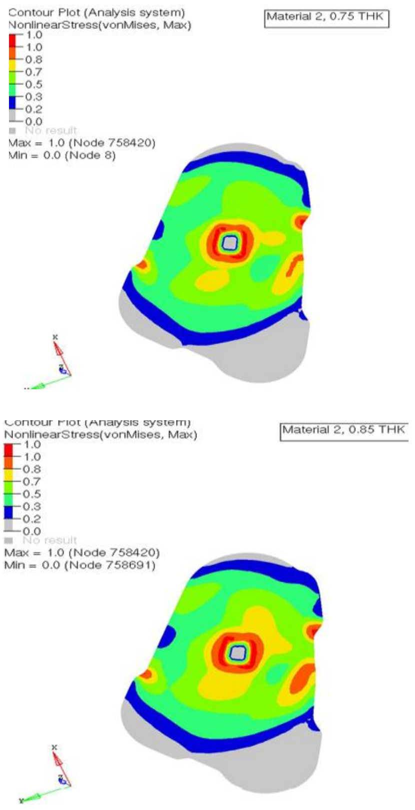
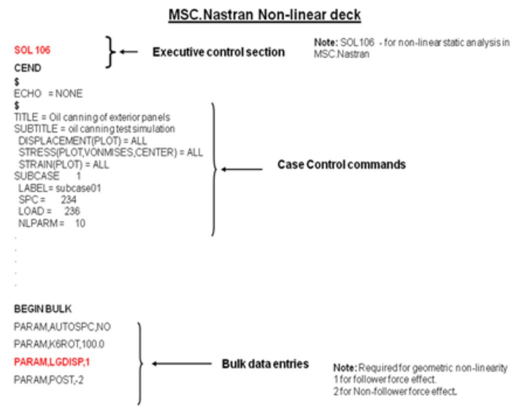
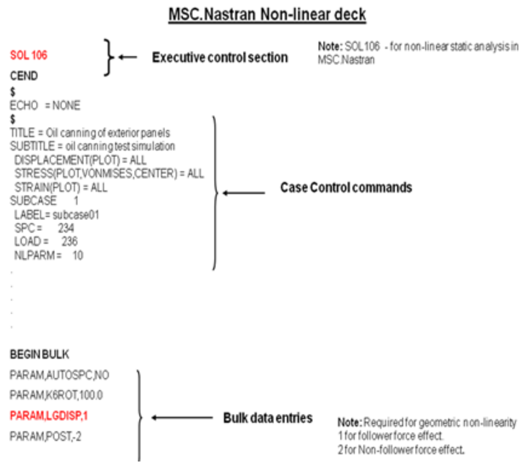


Fig.10 Normalized von-Misses stress contour at the end of load application (for two different thickness gages)





As fig.11 and fig.12 shows the comparison of load vs. Displacement Plot for unsupported span model for two different materials, two gages and two different constraints set.

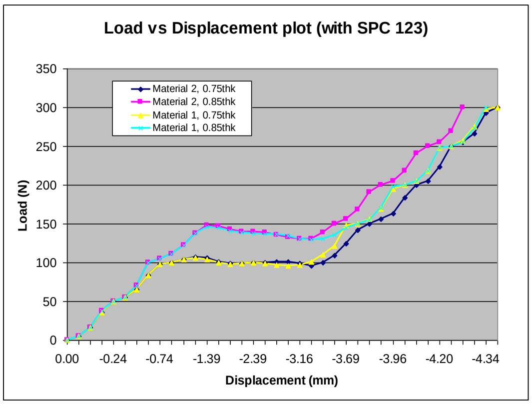


Fig.11 Comparison Load vs. Displacement Plot - for unsupported span model (two gages and two different material)

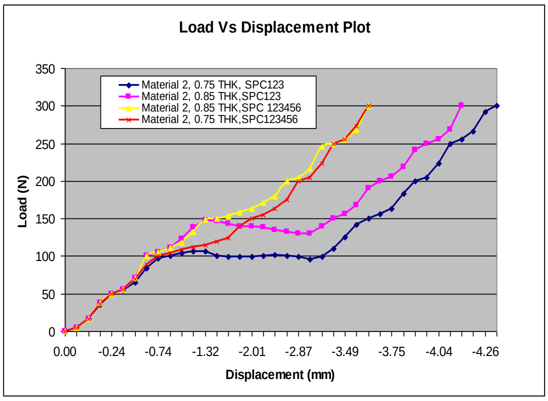


Fig.12 Comparison Load vs. Displacement Plot - for unsupported span model (two gages and two different constraints set)

From the graphs plotted for Load against displacement, it can be observed that

1) In the beginning, the tendency of the geometry to resist deflection is more
2) A certain application of load, the resistance falls abruptly and large deflection is seen without increase in load.
3) Then again, it is observed that the geometry starts behaving in a stiffer manner.
4) For same thickness, material with higher strength offers more resistance to oil canning.
5) For same strength, material with higher thickness offers more resistance to oil canning.

Conclusions

From the graphs plotted for Load against displacement, it can be observed that

1) In the beginning, the tendency of the geometry to resist deflection is more
2) After a certain application of load, the resistance falls abruptly and large deflection is seen without increase in load.
3) Then again, it is observed that the geometry starts behaving in a stiffer manner.
4) For same thickness, material with higher strength offers more resistance to oil canning.
5) For same strength, material with higher thickness offers more resistance to oil canning.

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