

# Nonlinear Analysis of a Superplastically Formed Automotive Fender

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**Abstract** - Superplastic forming (SPF) is a close to net-shape forming process which offers numerous favorable circumstances over traditional forming operations including low forming pressure under low flow stress, low die cost, more plan adaptability, and the capacity to shape hard metals to frame complex shapes. However, low production rate because of moderate forming procedure and restricted prescient abilities gives absence of precise constitutive models for superplastic deformation, treated as a hindrance to the widespread utilization of SPF. Late progressions in limited component apparatuses have appeared while breaking down the complex superplastic forming activities. These devices can be used effectively so as to create improved superplastic forming methods to build up the future materials. To present the talk referenced over an investigation of superplastically formed front Fender vehicle board utilizing ABACUS programming is expounded here. Present work comprise of a finite element simulations of superplastic shaping of aluminum 5182 and 8090 composite sheet in to the front fender board of vehicle is completed at 460° C-500° C temperature to evaluate the pressure tonnage, % tonnage and stress and Energy.

**Key Words:** Automotive Fender, Nonlinear Analysis, Tonnage, Forming, Superplastic Forming, Lightweight, etc.

## 1. INTRODUCTION

Aluminum car parts made utilizing a hot blow forming procedure are diminishing vehicle weight and expanding the fuel efficiency of today's cars. In any case, before General Motors (GM) and the Department of Energy (DOE) supported research in this innovation, blow forming of aluminum was not a suitable procedure for automakers. The earlier blow forming procedure called superplastic forming (SPF), was not appropriate for the industries' high-production rate requests, and the materials required for SPF were too costly multiple times the expense of standard, non-SPF, aluminum sheet metal. In this way, carrying SPF to the automotive industry required growing minimal effort SPF composites and quicker forming cycles. Diminishing the expense of SPF composites likewise required exhibiting the practicality of SPF to both the automotive and aluminum industries. DOE started a program of joint-supported research among GM and Kaiser Aluminum, with the Pacific Northwest National Laboratory (PNNL) giving an impetus to urge GM to create aluminum blow forming processes. In light of early

research, General Motors perceived the intrinsic constraints of superplastic forming and pushed ahead with the commercialization of a propelled blow forming procedure, called Quick Plastic Forming. The outcome is financially savvy, higher-volume fabricating innovation that is delivering lightweight parts for the present vehicles.

## 2. AIM

The aim of this project is to determine the % tonnage, blank holder pressure, stress and strain energy for an automotive fender.

## 3. METHODS AND METHODOLOGY

An analysis of super plastically formed front Fender car panel using ABAQUS software is presented here. This work consist on a finite element simulations of superplastic forming of aluminum 5182 & 8090 alloy sheet in to the front fender panel of car is carried out at 460°C-500°C temperature to estimate the pressure tonnage.

STEP 1: Create Auto fender design using SOLID EDGE.

STEP 2: Import to ABAQUS/CAE and mesh with appropriate mesh.

STEP 3: Perform Explicit Nonlinear analysis for the two materials using ABAQUS/Explicit solver.

STEP 4: Compare the alloy materials for the block pressure, stress and energy for the forming process.

## 4. GEOMETRY OF MODEL

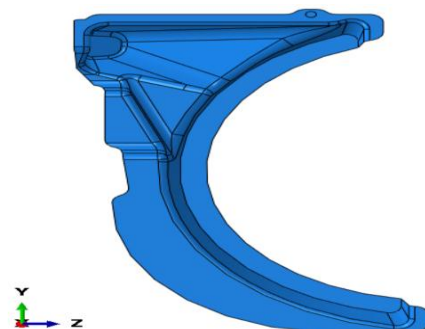


Fig -1: Front View of Fender

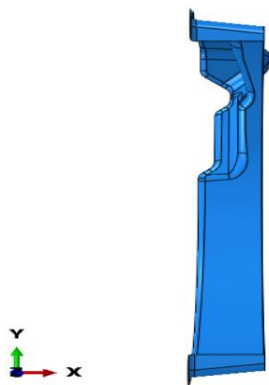


Fig -2: Side View of Fender

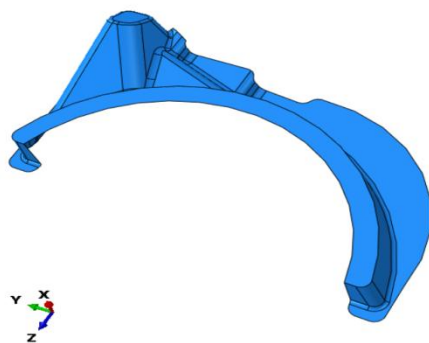


Fig -3: Isometric View of Fender

As the first step of processing is design, a geometric design of the fender geometry has been designed with the help of SOLID EDGE is shown in above figure. Based on the feasibility and the shape of the formed product, choice has to be made between a 3- D solid model & 3-D Surface model. This is essential to obtain accurate results with low computational cost. Complex assemblies & geometries can be generated using specialized modeling software's and these models can be imported into the finite element analysis software as an IGES file format

**5. MESHING**



Fig -4: Meshing of Fender

**Table -1:** Elements and Nodes Count

Total number of nodes	23655
Total number of elements	23574
Element type	Linear Quadrilateral and Triangular Elements

A finite element method (abbreviated as FEM) is a numerical technique to obtain an approximate solution to a class of problems governed by elliptic partial differential equations. Mesh is created using shell type of element with appropriate size to capture the precise stress and deflections. Linear quadrilateral elements of type S4R and linear triangular elements of type S3 are used to create the meshing. The accuracy of the results is greatly dependent on the size of the elements. The finer the mesh, greater is the accuracy; however this increases the computational time.

**6. MATERIAL PROPERTIES**

Create the material first, by applying the material properties of Aluminum alloy 5182 and assign the material to the component elements. The material properties of aluminum alloy 5182 are as shown in table 2. For generating the material 8090 aluminum-Li alloy we need to apply the material properties of it. The material properties of 8090 Al-Li alloy is as shown in table no.3.

**Table -2:** Material properties of 5182 Al-Mg alloy

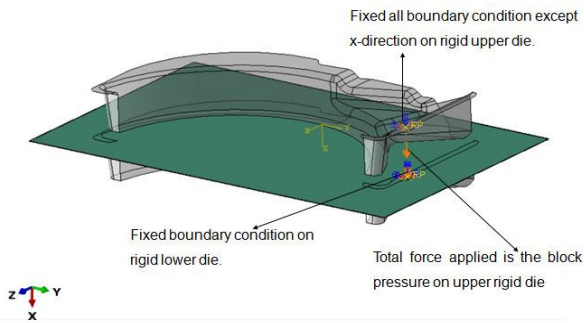
Sr. No.	Symbols	Parameters	Values
1	E	Young's modulus	70000MPa
2	$\mu$	Poisson's ratio	0.3
3	TS	Tensile strength	348MPa
4	$\epsilon_o$	Pre-strain coefficient	0.029
5	N	Strain-hardening exponent	0.24
6	K	Strength coefficient (Power law equation)	623.1MPa
7	YS	Yield strength	265.5MPa

**Table -2:** Material properties of 8090 Al-Li alloy

Sr. No.	Symbols	Parameters	Values
1	E	Young's modulus	77000Mpa
2	$\mu$	Poisson's ratio	0.34
3	TS	Tensile strength	480MPa
4	$\epsilon_o$	Pre-strain coefficient	0.017
		Strain-hardening	

5	N	exponent	0.24
6	K	Strength coefficient (Power law equation)	859.45 MPa
7	YS	Yield strength	323MPa

**7. Loads and Boundary Conditions**

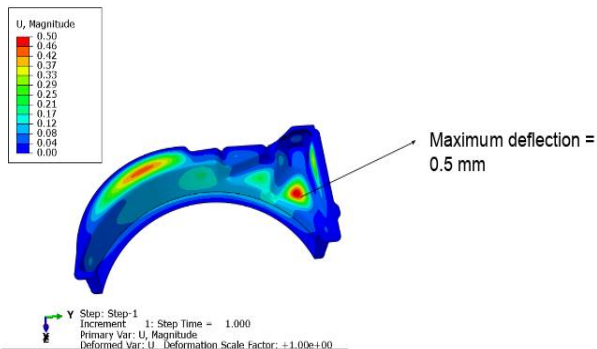


**Fig -4:** Loads and Boundary Conditions

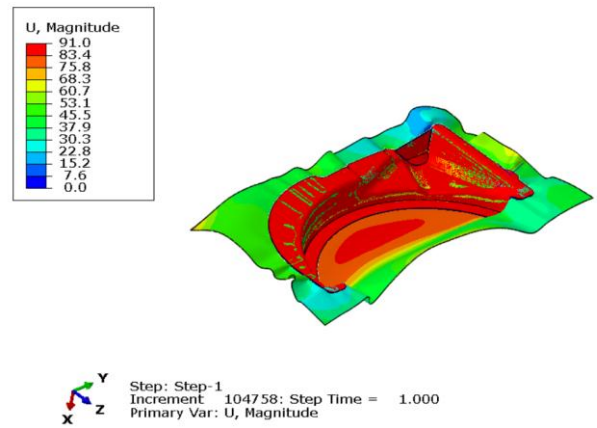
Assign the initial boundary conditions. This involves constraining all the degrees of freedom of the nodes associated with the clamped portion of the sheet. Apply the loads associated with the complete finite element model. In the case of Abacus specify the blank holder, blank holder pressure level on the elements of fender. Also apply temperature load of 460<sup>0</sup> C to the all elements of component.

**8. RESULTS AND DISCUSSIONS**

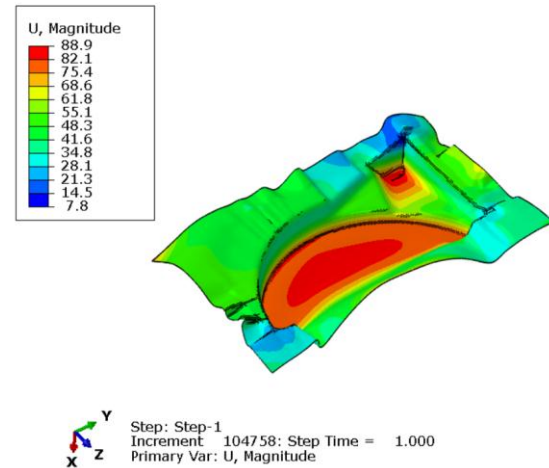
One of the main results in a forming analysis is the percent thinning of a component after it has been superplastically formed. From the Fig 5 it can be seen that, the maximum deflection in the fender thickness is 0.5 mm (initial thickness = 1 mm). The maximum deflection shows the amount of thickness reduction by 50 %. This result shows that the deformation capability of the provided Al alloy sheet will satisfy the need of the superplastic air bulging of the fender.



**Fig -5:** Thickness Distribution

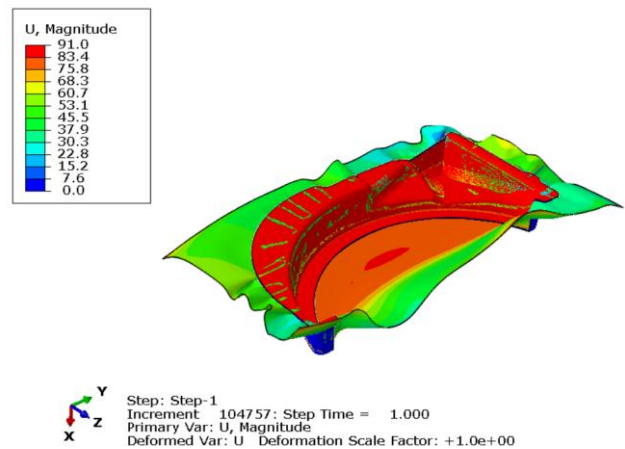


**Fig -5(a):** Total displacement 91 mm from initial position of the sheet & upper die.



**Fig -5(b):** Total displacement 88.9 mm from initial position of the sheet.

**Fig -5:** Displacement Plot for Al 5182



**Fig -6(a):** Total displacement 91 mm from initial position of the sheet & upper die.

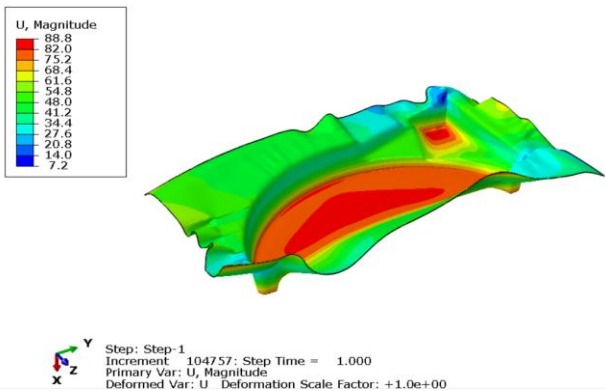


Fig -6(b): Total displacement 88.9 mm from initial position of the sheet.

Fig -6: Displacement Plot for Al 8090

In Fig.7 we can observe that, for the alloy Al-Mg 5182 maximum stress of 927 MPa is observed in the deep corner. As this is a sharp corner a high stress is observed. The stress in other areas is within 275 MPa excepting higher surface stress observed at few locations.

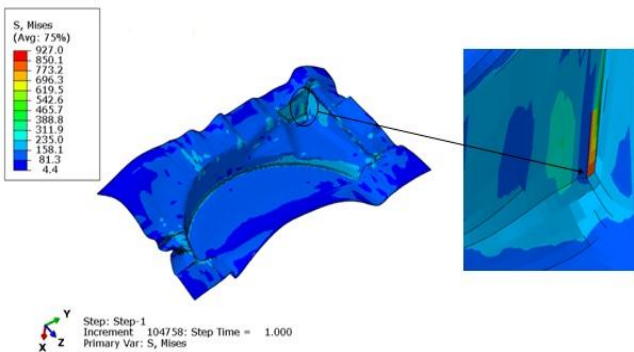


Fig -7: Stress Plot for Al-Mg 5182

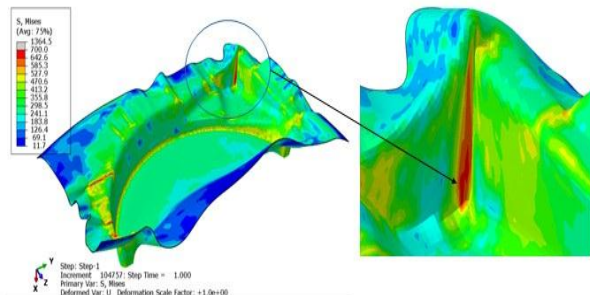


Fig -8: Stress Plot for Al-Li 8090

In Fig.8 we can observe that, for the alloy Al-Li 8090 maximum stress of 700 MPa is observed in the deep corner. As this is a sharp corner a high stress is observed. The stress in other areas is within 450 MPa excepting higher surface stress observed at few locations.

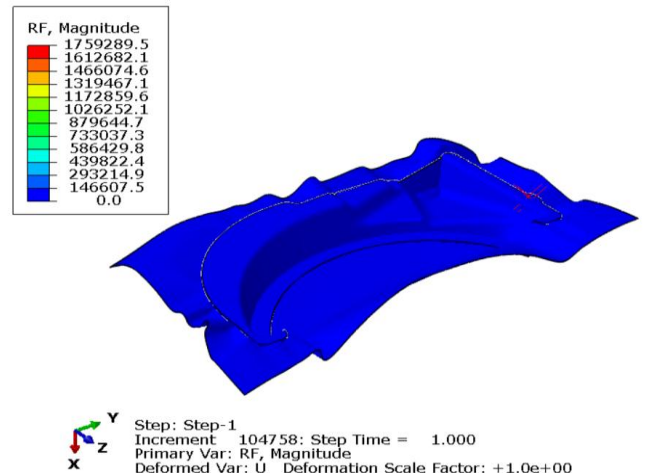


Fig -8: Blank Holder Pressure for Al 5182

Maximum reaction (estimated) blank pressure load = 1760 kN

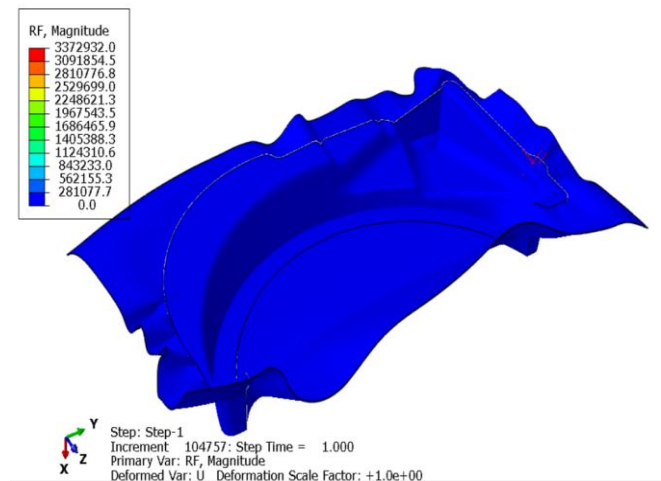


Figure 9: Blank Holder Pressure for Al 8090

Maximum reaction (estimated) blank pressure load = 3372 kN

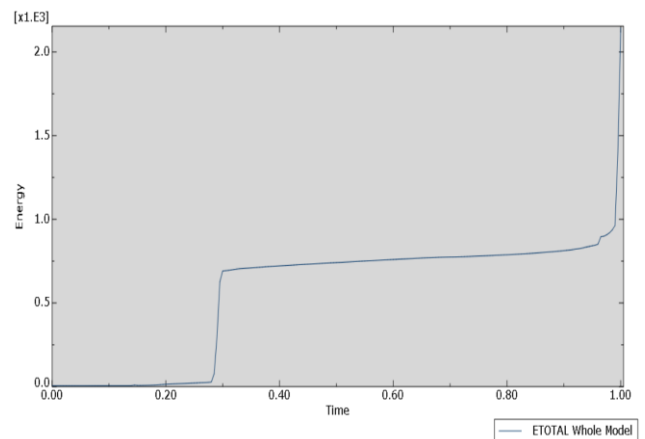


Figure 10: Total Energy vs Time Graph for Al 5182

Total energy variation as the blank pressure is increased.

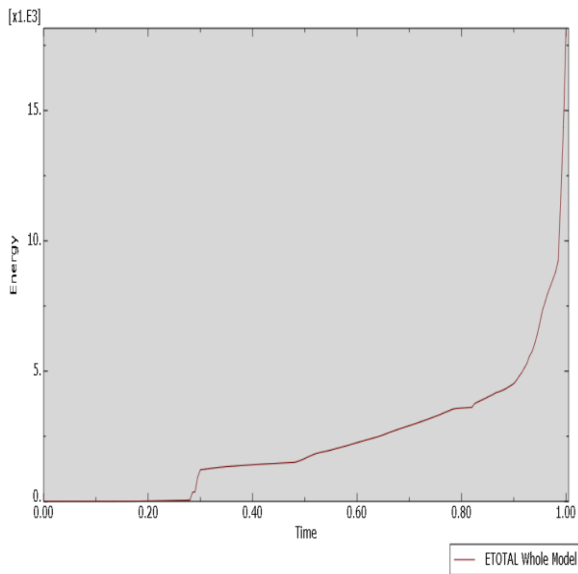


Figure 11: Total Energy vs Time Graph for Al 8090

Total energy variation as the blank pressure is increased.

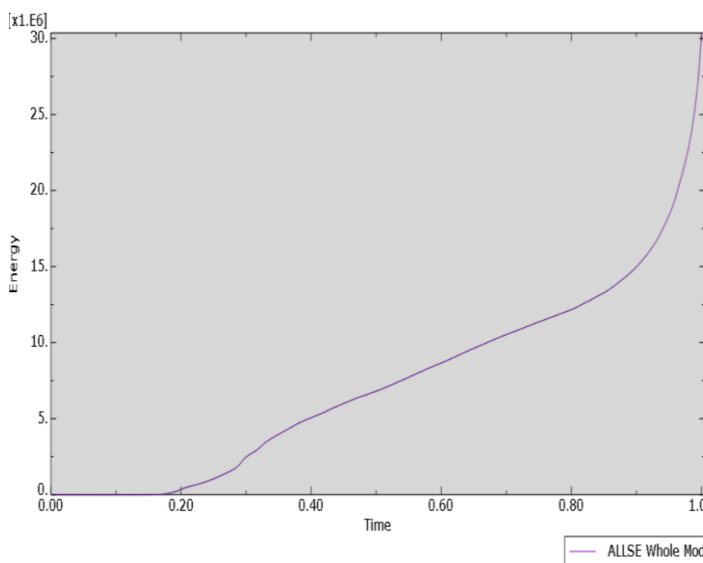


Figure 12: Strain Energy vs Time Graph for Al 5182

Strain energy variation as the blank pressure is increased.

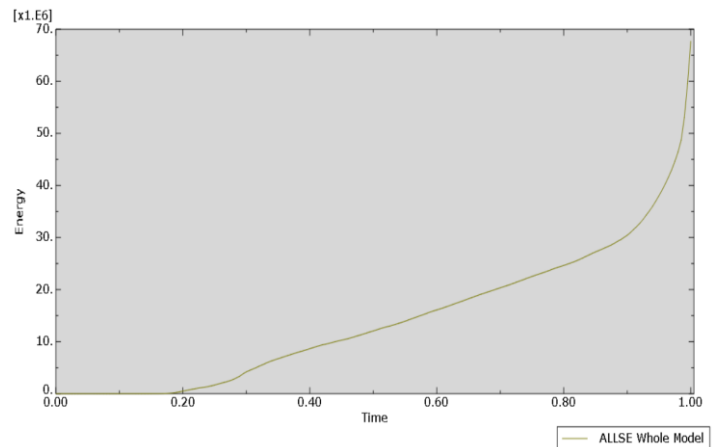


Figure 13: Strain Energy vs Time Graph for Al 8090

Strain energy variation as the blank pressure is increased.

## 9. CONCLUSIONS

- Explicit dynamic analysis is performed for estimating the blank pressure requirement for super plastic forming process. The analysis is carried out for two materials which are aluminum alloy 5182 and 8090 materials. The blank pressure is estimated to be 1760 kN for Al 5182 and 3372 kN for Al 8090 material.
- The displacements are the applied forces used in both analysis, and so the deflections are comparable and remain same in both cases.
- Stress levels are compared and maximum stress in the deep corner is found to be 927 MPa in Al 5182 material and 700 MPa in Al 8090 material. This shows a lower stress in the Al 8090 material.
- The total energy variation is recorded for both analysis, and there is a sudden jump in the case of Al 5182 at about 30% of the loading showing that the material is susceptible for the forming process of the considered geometry.
- These investigation show that although the blank pressure requirement is higher in the case of Al 8090, it is safer and suite the requirement of superplastic forming of the current design of the fender.

## 10. Scope of Future Work

- By Changing the type of alloys we can determine the Blank Holder pressure and Stress induced in the model.
- Additionally the study can be continued by conducting Impact analysis for the mentioned alloys.
- Further Vibration and Experimental Analysis can be carried out to determine the Mode Shapes and Frequencies.

- Further experiment can be improved to determine the effect of local strain distribution on the microstructure of Fender during Superplastic forming.

## 11. REFERENCES

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