COMPARATIVE INVESTIGATIONS ON NUMERICAL MODELING FOR WARM HYDROFORMING OF AA5754-O ALUMINUM SHEET ALLOY

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ABSTRACT This study aimed to determine the proper combinations of numerical modeling conditions for the warm hydroforming of aluminum alloy sheets of AA5754-O by comparing with the closed-die hydroforming test results. Forming tests were carried out at different temperature (*25- 300°C*), and strain rate (*0.0013 - 0.013 1/sec*) levels; and corresponding simulations were performed. Thinning (*% t*) and cavity filling ratios (CFR) on the formed parts were taken as comparison parameters. Several numerical analyses employing different element types, solution methods and material models were performed to determine the best combination to simulate the actual warm hydroforming operation as accurately as possible. Results showed that relatively better predictions were obtained using isotropic material model, shell elements and implicit solution technique when compared with experimental measurements.

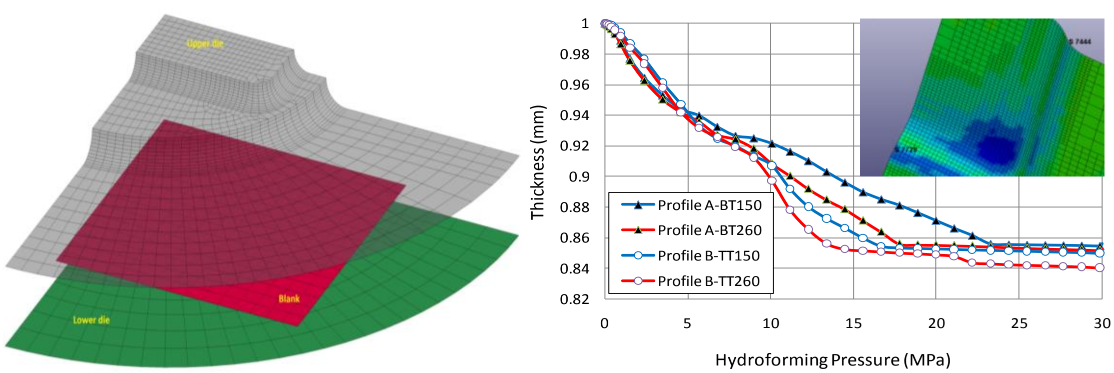
INTRODUCTION: Numerical analysis, especially the finite element method (FEM), is vitally important for understanding the complex deformation behaviors that take place during sheet forming processes. Anisotropic material models, which include temperature variation effects, have been widely used for better modeling of warm forming processes of lightweight alloys. For instance, Barlat developed a series of constitutive equations for anisotropy, and implemented those in past 20 years such as 3-parameter Barlat Yld89, Yld91, Yld96, YLD2000-2d, Yld2004 models. After him, several researchers implemented these models in their numerical modeling studies. However, thus far, the effects of material models, element types and solution methods on the numerical analysis for the warm hydroforming of aluminum alloy AA5754 have not been investigated in detail.

PROCEDURES, RESULTS AND DISCUSSION: Due to the nature of the process parts, a quarter-model of the closed-die warm hydroforming process, as seen in Fig. 1.a, was considered in the FEA to reduce the simulation time, and increase the model accuracy using relatively higher number of elements. A total number of 48 simulations were performed as presented in Table 1.

Table 1 List of Numerical Simulations Performed

Sim. Group No	Test Conditions	Material Models Used			Element Type		Solution Procedure		Flow Curve Data	
		Anisotropic		Isotropic						
		Three Parameter Barlat	*Barlat's YLD2000*	*Strain Rate Power Law*	*Shell*	*Solid*	*Explicit*	*Implicit*	*Tensile Test*	*Bulge Test*
1				✓		✓	✓			✓
2	a) 150˚C & 20MPa			✓		✓		✓		✓
3				✓		✓		✓	✓	
4				✓		✓	✓		✓	
5	b) 150˚C & 30MPa			✓	✓		✓			✓
6				✓	✓			✓		✓
7				✓	✓		✓		✓	
8	c) 260˚C & 20MPa			✓	✓			✓	✓	
9			✓		✓		✓		✓	
10			✓		✓			✓	✓	
11	d) 260˚C & 30MPa	✓			✓		✓		✓	
12		✓			✓			✓	✓	

Thickness variations with respect to pressure were presented for two elements that attained the maximum thinning values on the Profile A (S7444) and Profile B (S7728) contours as presented in Fig. 1.b.



(a) *(b)*

Fig. 1 (a) Quarter model of the closed-die forming process, (b) Effect of pressure on thickness change for elements S7444 and S7728 as indicated in the figure.

In order to analyze the effects of element type and solution procedures on simulation accuracy, thinning of the hydroformed parts were compared with the simulation results. Numerical and experimental thinning comparisons are shown in Figs. 2 and 3.

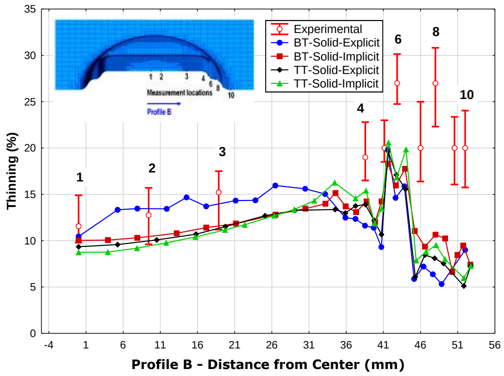


Fig. 2 Thinning distribution obtained using solid elements for the profile B at 260°C and 30MPa

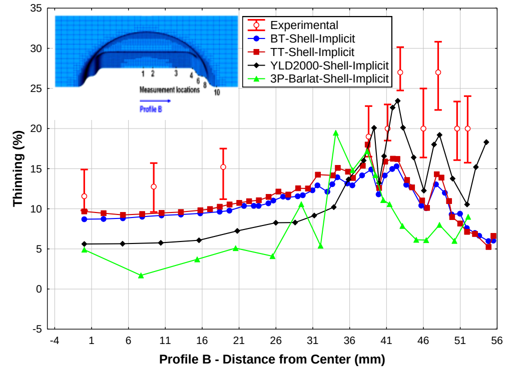


Fig. 3 Thinning distribution obtained with shell elements using implicit solver for Profile B at 260°C - 30MPa conditions.

As expected, increasing temperature and pressure values resulted in an increased cavity filling ratio and thinning. For the closed-die hydorforming problem discussed in this study, no significant benefit was obtained by using the anisotropic material models (3-parameter Barlat, and YLD2000) over isotropic material models (strain rate power law). It was reported in the literature that anisotropy of AA5754-O alloy is negligibly small. On the other hand, the locations on the part that underwent excessive thinning were predicted slightly better with the recently developed material models that take anisotropy into consideration. In comparison to solid elements, shell elements were found to be more appropriate to predict the thinning for the formed part. In this study, the best combination of numerical analysis was found to be "TT-Shell-Imp" with isotropic material model obtained through tensile tests, shell elements and implicit solver, which offered better prediction accuracy and a significant amount of saving in simulation time.

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