# Educational and Research Issues Concerning Virtual and Real Forming of Sheet Metal

**Raghu Echempati,** Assistant Professor and
**Sarang Likhite,** Graduate Student
Mechanical Engineering Department
Kettering University
1700 W Third Avenue
Flint, MI 48504
810-762-7835
rechempa@kettering.edu

*Keywords:*
Metal Forming, Aluminum cups, friction, polyurethane sheet

## ABSTRACT AND INTRODUCTION

The aim of this paper is to discuss the educational issues concerning real and virtual simulation of sheet metals such as steel, magnesium and aluminum. Although expensive, aluminum and magnesium are being viewed as promising candidates in some of the automotive stamping applications. The philosophy explained in this paper deals with providing concurrent experience of real and virtual forming of sheet metals to engineers.

There are several manufacturing processes like Casting, Molding, Metal Removal, Metal Forming, etc. Several different kinds of materials like metals and non-metals like plastics, ceramics and composites are considered to manufacture engineering products. Choice of a particular material depends on the type of application.

One of the major challenges and goals in manufacturing is to see how to transfer several different ideas generated out of both experimental and theoretical research in to a state-of-the-art technology that can be applied to manufacture better quality products.

Research, both in terms of better modeling of a manufacturing process and experimentation concerns with conducting parametric product and process design studies in order to produce near net shape (final shape) of a product. Computers no doubt are very helpful in advancing this research. Computer simulation of a manufacturing process can help in better visualization and understanding the different stages as a product is being shaped. Computer simulation deals with mimicking on a computer what it takes to do a prototyping of a product in the real world.

While we learn to “think with hands” as we make prototypes and products, we learn to “think with the knowledge attained” as you perform simulation studies. It is very important to properly validate the results of a computer simulation with real experiments so that scientific tools can be eventually generated eliminating or reducing the need for making costlier and time consuming prototypes.

Metal forming is divided in to bulk forming and sheet metal forming. Processes like rolling, forging, extrusion and drawing fall under bulk deformation, while bending, blanking, drawing, hole-expansion and stretching fall under sheet metal forming area.

Kettering University in Flint, MI offers a sheet metal forming class (MfgE-404) based on understanding the principles behind formability of real sheet metals and a new virtual forming class (ME-510) based on simulating the real sheet metal process on a computer. Both classes need a basic understanding of manufacturing process and engineering materials. In addition, a good understanding of virtual forming requires a basic knowledge of solid modeling and finite element techniques. These two courses are unique to Kettering University.

Kettering University is also very supportive of promoting undergraduate and graduate education and applied research in the real and virtual metal forming area. Many stamping industries promoted this idea of a combined real and virtual forming experience gained by engineering graduates. The mechanical and the manufacturing engineering departments are working together to achieve these goals. A NSF/CCLI proposal has been submitted last year (not funded). A revised proposal again is being prepared for submission to NSF. Recently, Kettering University funded a research initiation and improvement (RI/I) grant that deals with comparing the formability of sheets made of aluminum and magnesium with steel.
Vegter, Pijlman and Huetink [1] in their paper discussed the deviations that occur due to experimental errors. Uniaxial tensile tests (ASTM E 646) were conducted on aluminum samples to predict inconsistencies in the strain state. Kuwabara and Bael [2] presented the experimental and analytical results of biaxial tensile tests to predict the yield locus of aluminum alloy 6XXX-T4. Kim, et al [3] discussed the analysis of wrinkling initiation and growth of aluminum A6114-T4 deep drawing process with controlled blank holding force. Bifurcation algorithm is introduced in the elastic-plastic finite element method.

Several benchmark studies have been undertaken to predict punch force, thinning and several other characteristics of a deep drawn aluminum A6016-T4 cup [4]. The results show a lot of inconsistencies between the different studies thus necessitating the proper understanding of the material behavior and the measurement techniques used for such studies.

## RESULTS AND DISCUSSIONS

Several attempts have been made to simulate drawing of aluminum using the DYANFORM software donated by ETA. Drawing aluminum in a real stamping laboratory also proved to be very tricky and is totally dependent on the interface friction between the tools and the blank. Figure 1 shows some of the drawn aluminum A6111-T4 cups. Dynaform software has been successfully used to simulate cups made of steel. The thinning results of simulations compare well with experimental observations. All the material properties for steel were measured in the laboratory and were input in to Dynaform. Several simulation runs were performed with various binder pressures.

Fig 1: Aluminum cups drawn without any lubricant. Binder force = 6,000 lb approx.


Fig 2: Failure of repeatability tests without any lubrication

Subsequent stampings were done with reduced punch force of 1500 lb with no success of full draw depth. Additionally, the results failed repeatability tests when no lubricant was used. Figure 2 shows one such case with all the geometric and press parameters kept the same. Lubricant in the form of polyurethane paper inserted between the die and the blank showed dramatic improvement in the successful draw to full depth of the cup. The binder force seems to have little effect on this. Figure 3 shows the successive draws of the cup.

Fig. 3: Successive draws to full depth of the cup with polyurethane paper

While simulating aluminum cups, however, many problems were encountered. Several values of coefficients of friction were tried (0.33 for no lubrication and 0.13 with polyurethane paper) along with few combinations of binder pressure and the mass scaling parameters (dt2ms). Dynaform predicted wrinkling for binder force less than about 15,000 N. The friction value used is around 0.13. For the same other parameters, when the binder force is increased to 20,000 N (equivalent to about 15-psi binder pressure in the laboratory), the simulation shows less wrinkling effect. The authors encountered difficulty (at the time of writing this paper) with plotting the FLD for r-value than 1.0. For some grades of aluminum alloy such as 5182 the r-value is around 1.36, while it is less than 1.0 for 2008-T4 and other aluminum alloys. For successful draw simulations using DYNAFORM the most critical parameters seem to be mass scaling, anisotropy parameter, the stress strain data and the binder pressure. More runs and time are required to draw any meaningful conclusions in order to compare the real and virtual forming of aluminum cups.

Although the intention of this paper is to validate these experimental results by DYNAFORM simulations, complete results could not be obtained at the time of writing this paper. It is the intention of the authors to present the simulation results at the time of the conference.

## CONCLUSIONS

In this paper, an attempt has been made to simulate aluminum alloy 6111-T4 cups using real forming and virtual forming technique. The n and K values needed for the simulation (using DYNAFORM) have been obtained by actual material testing in the laboratory. Trial experimental draws in the stamping laboratory at Kettering University showed interesting results in that the full depth successful draws are possible only in the presence of lubricant such as polyurethane sheet between the die and the blank. The die entry and punch nose radii used are 5/16-inch each with clearance of 10%. Binder pressure seems to have little effect on successful draws. Trial simulations using 15,000 N binder load predicted wrinkling. Higher binder pressure predicts less severity of wrinkling. Further studies are in progress and are expected to be ready at the time of presentation of the conference.

## ACKNOWLEDGEMENTS

The authors acknowledge the generous donation of various grades of aluminum sheets by Alcoa through Dr. Kirit Shah. The continued support by Engineering Technology Associates with DYANFORM is sincerely acknowledged. Finally, the helpful work and suggestions given by Professor William J. Riffe of Kettering University is sincerely acknowledged.

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