

INVESTIGATIONS ON DEEP DRAWING OF HIGH STRENGTH STEEL SHEETS USING TEXTURED DIES

ABSTRACT

In sheet metal forming, surface texturing of dies is a potential method of modifying the die surface by creating dimples or microcavities on the surface. The surface texture can influence tribological performance resulting in significant changes in friction, formability, and forming load. In view of this, the present thesis deals with investigations on deep drawing of high strength steel (Dual Phase steel of grade DP600) sheets using laser textured dies.

The surface texture parameters such as dimple size, depth and area density affect friction, formability and forming load. Also, defining a constant friction coefficient based on the Coulomb's law is the most common practice in FE simulation of deep drawing. Therefore, it is necessary to incorporate the effect of process variables on the friction coefficient for more accurate prediction of drawability and drawing load. Using advanced friction models, the real time friction coefficient value can be incorporated in the simulation instead of assuming a constant friction coefficient value and it is particularly important for a textured die. Therefore,

in this work, a setup for strip drawing experiments has been designed and developed to study of the effect of texture parameters on coefficient of friction in strip drawing of DP600 steel sheets using laser textured dies. The effect of process variables (normal load and sliding velocity) on the coefficient of friction in strip drawing using the textured dies has been studied and a regression model has been developed to predict the coefficient of friction. Using the experimental data, the coefficients in a pressure and velocity dependent friction model have been determined.

FE simulation of deep drawing of DP600 steel sheets has been carried out incorporating variation of friction coefficient with contact pressure and sliding velocity through the pressure and velocity dependent friction model. In the material model, Swift hardening law has been used to plot the flow curve using the coefficients determined from uniaxial tensile tests and hydraulic bulge tests. The yield surface, defined using the BBC2005 yield model, has been used to incorporate the effect of anisotropy. To determine the coefficients in the yield criterion, the required stress ratios and plastic strain ratios were experimentally determined from uniaxial tensile tests and the biaxial properties were determined by cruciform biaxial tensile tests.

To validate the predicted drawability, drawing load, and thickness variations, textured dies for deep drawing have been designed and developed using laser surface texturing with the optimum texture parameters identified using the strip drawing experiments earlier. Two deep

drawing dies, one with texture only in the flange region (TF) and the other with texture in both the flange and the die corner regions (TFC), have been used in the experiments.

The textured die showed better tribological properties resulting in lower friction coefficient in strip drawing of DP600 sheet than an untextured surface in conditions similar to that exist in flange area in a deep drawing process. The microcavities on the textured surface help in storage, transportation and distribution of lubricant and wear particles, leading to a more stable friction coefficient. The combination of 125 μm cavity diameter and 10% texture area density has resulted in the minimum friction coefficient. The effect of process parameters (normal pressure and sliding speed) has been found to be more significant with textured dies than with untextured die in strip drawing.

In deep drawing of cylindrical cups, the textured die with texture in both flange and die corner regions resulted in about 10% improvement in the maximum draw depth and a reduction of 8% in the peak drawing load as compared to the untextured die. Texture present in the die corner radius provides effective lubrication which leads to a decrease in friction by maintaining a lubricant film between the contacting surfaces. It helps smooth flow of metal into the die cavity reducing the load required to draw the blank. A maximum thinning of 21.5% has been observed for the untextured die and the textured dies showed a significant reduction in the maximum thinning which is 20.4% and 17.5% for TF die and TFC die, respectively. In the case of TFC die, a more uniform reduction in friction leads to more uniformity in strain distribution leading lower thinning in the punch corner region.

The simulation of deep drawing with PVDF friction model incorporates the variation of friction coefficient with speed and contact pressure. The error in the prediction of maximum load is 11% using a constant friction coefficient and it decreased to 3% when the PVDF model is used. When compared to the initial blank, a large reduction (52.6%) in the average roughness value (R_a) has been observed in the wall region of the cup drawn using the textured die with a lower viscosity lubricant and a reduction of 32.9% has been observed with a higher viscosity lubricant.

Keywords: Deep drawing, Laser textured dies, Friction, Lubrication, Dual phase steel, FE simulation