

ABSTRACT

Sheet metal bending, being an important sheet metal forming process, employs a press brake with proper tooling to produce different bend components. The flexibility of the bending process is improved by the air bending technique, in which the different bend angles can be produced by solely controlling the punch travel into the die without the need for changing tool sets. Because of this versatility, the lead time is reduced in an air bending technique and hence it is commonly used in sheet metal industries. Steel sheets are widely used to manufacture various parts such as automotive panels, electrical cabinets and computer casings in the sheet metal industry, but the susceptibility to corrosion is their natural weakness. To overcome this galvanised steel sheets, with improved corrosion resistance, are preferred for high quality products. Since electrogalvanised (EG) steel sheets have better formability and surface quality, they are preferred over hot dipped sheets in many of the industrial applications.

The two important subjects related to bending processes are springback and bend force, which are influenced by various parameters related to material, tool and process. The substitution of EG steel for uncoated steel presents

challenges in understanding the springback and bend force as the coating modifies them. The investigations on air bending of sheet material have been carried out by many researchers but the experience with EG steel is limited. However, this research aims to study the influence of parameters on the bending behaviour of EG steel sheets that are subjected to an air bending process. Springback prediction is important to control the process and die design to achieve the desired shape of the product. The prediction of bend force provides a base to the designer for the die design and press selection. As traditional approaches to evaluate the springback employ trial and error procedures and rely on the expertise of designer, they are tedious, time consuming and expensive. Moreover, it is cumbersome to develop analytical models for springback and bend force predictions. These limitations lead to the development of empirical models associated with springback and bend force in this work.

This research comprises the experimental study and the development of empirical models on springback and bend force during air bending of EG steel sheets. The tensile tests were carried out to determine the material properties related to bending process. The EG steel sheets of different coating thicknesses were prepared. A detailed experimental study has been performed on EG steel sheets of various coating thicknesses to investigate the influence of parameters,

namely: coating thickness, orientation of the sheet, punch radius, die opening, die radius, punch travel and punch velocity on springback and bend force. It is observed that springback increases with increasing coating thickness, punch radius, punch travel, die radius, die opening, and punch velocity. The 90° orientation exhibits higher springback than 0° orientation. From the results, it is noted that zinc coating reduces the bend force, and it is further reduced with increasing coating thickness. It is found that the bend force is larger for larger punch radius, smaller die opening, and smaller die radius. It is also observed that the bend force is larger for 0° orientation than for 90° orientation. The bend force decreases with increase in punch velocity, and this influence is more on EG sheets than on uncoated sheets. Experiments have also been performed to analyse the effect of lubrication which is influenced by the parameters including the type of lubricant, surface roughness of the sheet, die geometry and punch velocity on springback and bend force. It is observed that the decrease in friction due to the application of lubrication increases the springback and reduces the bend force. This effect is evident in case of high viscosity lubricant, low surface roughness, larger die radius and higher punch velocity. The coating failure due to cracking has been studied using micrographs obtained from Scanning Electron Microscope (SEM). It is observed that cracking has not occurred as the coating deforms easily with the substrate. This research also encompasses the development of models for

the prediction of springback and bend force by two modelling techniques namely Response Surface Method (RSM) and Artificial Neural Network (ANN). The aforementioned parameters are considered as input parameters and springback/bend force as responses. Both the RSM and ANN models have shown good agreement with the experimental results. The direct and interaction effects of parameters on the responses have been studied using RSM model results. Besides, it has been found that the prediction accuracy of ANN model is comparatively higher than RSM model.

The research concludes that the experimental study significantly improves the understanding of bending behaviour of EG steel sheets in air bending process. From the industrial point of view, the RSM and ANN models provide a practical, rapid and quite robust prediction of springback and bend force. The application of prediction models in the industry to predict the responses improves the process and increases the accuracy of the product. These prediction models also eliminate the experimental trials and wastage of time which in turn improves the production and reduces the lead time. Furthermore, some future research directions are suggested to apply these modelling techniques for other responses such as bending allowance and residual stresses for EG steel sheets.