CHAPTER 2

LITERATURE REVIEW

Literature review shows that considerable amount of researches have been reported in experimental, modeling and analysis of air bending. The following relevant areas are reviewed: (a) Sheet metal bending and mechanics of springback and bend force, (b) modeling of bending process and (c) Interstitial Free steel sheet. Clear and credible reviews of previous important literatures are briefly discussed here. A number of researches have been carried out on the performance of bending processes.

2.1 SHEET METAL BENDING PROCESS

Sheet metal bending is one of the most widely applied sheet metal forming operations. The understanding of the bending mechanics is aimed at obtaining two kinds of information important for industrial applications. The first one is the springback prediction for die design and shape control. The second is an estimation of the bend force for selection of press capacity, strength analysis and design of dies. Vallance and Matlock (1992) studied the friction behavior of zinc-based coated sheet steels and laboratory scale friction analysis techniques that involve sheet sliding over cylindrical dies. Wenzloff et al (1992) introduced a new test procedure for the bending under tension friction test. Mai Huang and Gardeen (1994) presented a literature review of the springback of doubly curved developable sheet metal surfaces and provided a bibliography on the springback in sheet metal forming. Reviewing the literature, it is found that researchers have been studying the
phenomenon of springback for nearly six decades. There have been diverse efforts to evaluate and/or decrease springback in the sheet metal forming industry for a long time. Perduijn and Hoogenboom (1995) derived a simple explicit bending couple curvature relation for small and larger curvatures and they verified the model with experimental results. A simple approach for calculating bendability and springback in bending based on the normal anisotropic value, strain hardening exponent and sheet thickness has been presented as described elsewhere by Daw-Kwei Leu (1997).

You-Min Hang and Daw-Kwei leu (1998) described the effects of process variables like punch radius, die radius, punch speed, friction coefficient, strain hardening exponent, normal anisotropy on V-die bending process of steel sheet. Sanchez (1999) focused on a systematic analysis of testing equipment as a measurement system of the friction phenomena on sheet metal under plane strain. It provides experimental references in order to optimize the usage of lubricants and sheet metal. Weilong Hu (2000) proposed anisotropy hardening models with simple loading conditions that include exponential hardening model, linear hardening model and multi linear hardening model. Samuel (2000) analyzed the springback in axisymmetric U-bending processes with a finite element program and discussed the effect of tool geometry and blank holder force on the final shape after springback.

Aleksy et al (2001) conducted experiments on springback for dual phase steel and conventional high strength steel for a hat channel section with varying cross sections. They described the methodology of experiments and discussed springback related results. Livatyali and Altan (2001) presented experimental investigation to determine the influence of die corner radius, punch radius, punch-die clearance, pad force and sheet material on springback in straight flanging. Leo De Vin (2001) described the problems related to an oversimplification of the air bending process and explained the consequences
of applying models, standards or thumb rules. Streppel et al (2001) conducted the experiments on air bending that address the required punch displacement and the sheet length correction. Draw bend test for various die radii, friction coefficients and tensile forces was conducted by Cardeen (2002).


2.2 MATHEMATICAL MODELING

The mathematical modeling for process simulation has become a major tool in modern metal forming technology. Many researches conducted in the last three decades have indicated that springback has a very important role in sheet metal industry and studied how this permanent physical variation can be avoided. The challenge is how to predict the springback and thus
design a tooling to compensate for the amount of springback. It helps in predicting the springback, bend allowance, bend force etc., of sheet. As early as 1957, Gardiner derived a generalized mathematical analysis for springback corrections in the pure bending of materials such as aluminum, nickel, titanium and ferrous alloys. In later work, Johnson and Yu (1981) followed the work of Gardiner to give a theoretical analysis of springback in bi-axial, elastic-plastic pure bending of a rectangular plate. Tylan Altan et al (1993) described a complete mathematical model for plane strain sheet bending to predict springback and the maximum bending load on the punch and die.

De Vin et al (1996) described the material behaviour with Swift’s equation and the change of Young’s modulus under deformation. Zhang (1997) developed a new model for strain calculation in plane strain bending and also compared with Hill’s pure bending model. Elkins and Sturges (1999) developed an analytic bending model, which provides insight into the material and geometric variables that affect springback. Nan Song et al (2001) discussed springback prediction approaches such as analytical model, numerical simulation using finite element methods and the mesh free method. Effect of strength and process parameters on springback has been studied by many researchers but that of anisotropy has not been studied by many.

Lumin Geng and Wagoner (2002) reported springback angles and antielastic curvatures for a series of draw bend tests using an anisotropic hardening model and sheet metal yield functions. Li et al (2002) presented simulation of springback with 2-D and 3-D finite element modeling. Jenn-Terng Gau and Kinzel (2005) proposed a model for springback prediction for aluminum sheet forming and material parameter to handle the Bauchinger effect. Peng Chen and Muammer Koc (2007) studied to predict the variation of springback in an open channel drawing considering the variation of material and process. An analytical model was proposed by

2.3 STATISTICAL MODELING

The statistical design can be used to obtain as much information as possible from a minimum number of experiments. Over many decades the bending of sheets and their springback has been studied by analytical approach and many useful results have been obtained. However, much less attention has been paid to the case of bending of sheets and springback through statistical approach. Delivering reliable, high quality products at a low cost has become the key factor for survival in today’s global economy. For this fact, the prediction of springback of the product at the design stage is very essential. Designing for quality is cheaper than trying to inspect after production. So, new philosophy, technology and advanced statistical tools must be employed to design the products of high quality at low costs. Response surface methodology is a collection of mathematical and statistical techniques which is useful for modeling and analysis of engineering
problems. George Derringer and Ronald Suich (1980) modified the Harrington’s desirability function approach and illustrated how several response variables can be transformed into desirability function. Inamdar et al (2002) studied the interaction effect using the design of experiments for each of the five different materials and analysing the springback. Senthilvelan et al (2003) developed mathematical models for P/M working process using regression analysis and the models could be used to predict the strength coefficient and strain hardening exponent of P/M copper performs. Ohata et al (2003) developed the material design support system for finding annealing conditions for sheet forming and tried to apply the RSM in order to attempt search efficiency.


2.4 ARTIFICIAL NEURAL NETWORK MODELING

The artificial neural networks have emerged as a problem solving technique for many metal forming problems. As the computation of springback is expensive, an ANN model applied for springback prediction leads to significant reduction in the computational time. There has been considerable focus on ANN over the last few decades as it is widely applicable with highly nonlinear and complex data.


2.5 INTERSTITIAL FREE STEEL SHEET

Narayanasamy and Ponalagusamy (2006) evaluated the forming limit diagram of interstitial free steel sheets of thickness 0.6 and 1.6 mm. Narayanasamy and Sathiya Narayanan (2007) evaluated the forming limit diagram for interstitial free steel sheets under different strain conditions and the tensile properties and formability parameters were correlated with forming limit diagrams. Narayanasamy and Sathiya Narayanan (2008) evaluated the fracture limit and wrinkling limit diagrams for various IF steel sheets.

2.6 SHORT COMINGS OF THE EARLIER RESEARCH

Study of process variables in sheet metal bending has been of considerable interest for a few years. Most of the researches use only aluminum or other commercially available materials and these studies do not consider the bending behavior of Indian interstitial free steel sheet during air bending process. Most of the earlier studies have been made on smaller curvature bending to explore various parameters on springback during air bending process and the studies on larger curvature bending has not yet been attempted. Most of the researchers have analyzed bending behavior of plain sheets and not perforated sheets. No research has been so far made to examine the effect of lubrication on the air bending of interstitial free steel sheet. This work attempts a study of the bending behavior with several combinations of
process parameters for plain and perforated sheets. The relation between springback and bend angle, bend force and bend angle of IF sheet during air bending process is examined. The effect of lubrication on the air bending of interstitial free steel sheet with two different lubricants namely SAE 30 oil and white grease is analysed.

Analytical approach can provide underlying physical insights of the springback. However it is usually developed by ignoring some unknown effects or assuming some ideal situations. As a result, accuracy of analytical based modeling is often undermined. With the aid of numerical methods, such as the finite element method and finite difference method, other studies aim to explore the nature of bending and springback of sheets. It is evident that accuracy of the FE model depends very much on the type of modeling technique, which is to be selected for analysis. In some cases it will be almost impossible to find an analytical solution for the entire deformation process. The empirical modeling based on experimental observations is appropriate in such cases.

In the field of sheet metal bending, very few studies deal with MRA/RSM for the prediction responses. A number of research works are currently being carried out in the development of prediction system for springback using the ANN techniques in sheet metal bending. The realization of an accurate system for prediction has not yet been achieved. An extensive study of the empirical modeling for the prediction of springback and bend force in the air bending process of IF steel sheet is conducted in this study and the accurate models based on MRA, RSM and ANN are proposed. The simultaneous optimization is carried out with an objective of minimizing the bend force and springback effect.