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A study on the extent of ironing of EDD steel at elevated temperature

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ABSTRACT

An experimental investigation has been carried out to determine the effect of extent of deformation (ironing) over the cup wall at elevated temperatures. Clearance between punch and die is varied to decrease the amount of deformation over the cup wall. The thickness distribution of the drawn cups at different temperatures and clearance is studied and it is found that even at elevated temperatures there will be a certain limit unto which clearance between punch and die can be decreased. For EDD steel sheet of 2 mm thickness this temperature appears after blue brittle regime in which material exhibits unusual strength. In this region punch load requirements increases which leads to necking at the punch corner and finally fracture in the initial stages of drawing operation. Upon increasing the clearance the quality of cups are similar to that in case of deep drawing operation.

1. Introduction

In conventional deep drawing, the drawn cups will have thicker walls at its rim than at its base if the clearance is larger than sheet thickness. Ironing is a process in which the wall thickness of a drawn cup is made uniform by the pushing of the cup through reduced clearance or ironing rings. Further, residual stresses are induced during deep drawing affecting fatigue strength of the part, promoting stress crack corrosion, or result in dimensional changes after the machining of the formed parts. Ironing can be used to reduce the residual stresses in deep drawn cups apart from imparting improved geometrical accuracy. In a deep drawn cup tensile stresses are formed over the outer surface and compressive stresses on the inner surface. Ironing gives characteristic distribution of residual stresses along the cup wall outer surface. Increasing the extent of ironing induces the compressive axial residual stresses over the entire wall outer surface which neutralizes the tensile residual stresses [1]. A FEM simulation of the ironing of a deep drawn cup has shown that residual stresses after ironing are reduced by 50–65% [2]. A large number of automobile components are manufactured by deep drawing followed by redrawing and ironing stages, e.g. the drum clutch is usually formed in 9 redrawing and 3 ironing stages. A method of reducing these numbers of stages during forming and also to improve formability of material is warm forming. Parsa et al. [3] carried out rigid-plastic finite element analysis of the two-stage forward and reverse redrawing process. Baillet et al. [4] used an explicit finite element method in the analysis of the aluminum can ironing process.

Although the deep drawing process of high strength/low formability metals has an extensive industrial application area, deep drawing at room temperature has serious difficulties because of the large amount of deformations revealed and high flow stresses of the materials [5]. Thus; crumples, wrinkles and earings will occur on the product surface because of the anisotropy of the materials. Elevated temperatures decrease the flow stresses and increase the formability of the materials and thus deformations become easier. The effective basic mechanism in pressing is plastic deformation. Because of this, deformation temperature has to be determined by taking this point into consideration. The advantages of warm sheet metal forming method are as follows.

1. Metals can be formed which cannot be formed at room temperature.
2. By the way, manufacturing of light and high strength products becomes possible.
3. Press forces decrease.
4. The probability of defect formations on product surface decreases.

Conventionally the flow forming process is used to form hollow metal blanks over a rotating mandrel and the material is allowed to flow axially along a rotating mandrel. The process is generally used to produce cylindrical components. In forward flow forming process the material flows in the same direction as that of roller but in backward flow forming the metal flows in opposite direction. The forward method is normally preferred because in the

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backward method, worked material is required to flow over the length of the mandrel, making the material more susceptible to distortion like bell-mouthing at the free end of the blank and loss of straightness. Moreover, backward flow forming is normally prone to non-uniform dimension across the length of the product.

Deep drawing at elevated temperatures has not yet become an industrial application and for this reason it has some indefiniteness. Literature scope about forming at elevated temperatures is limited and not enough at the time. For this reason, determination of the parameters and the computer simulation of the manufacturing process are prior stages that have to be realized for further studies. When the literature about this subject is scanned it is seen that there are quite enough studies with aluminium and magnesium. But there are only a few studies with titanium and steel. There must be a lot more studies for the development and common applications of the process. The needed temperature for steel sheets is quite high and this situation should be the reason for the low number of studies about this material [6].

Van Den Boogaard and Húetink [7] observed that the formability of Al–Mg alloy sheets can be improved by increasing the temperature in some parts of the sheet and cooling the other parts when simulated by the cylindrical cup deep drawing at different temperature gradients of the tools and blanks. Chen et al. [8] investigated combined isothermal/non-isothermal finite element analysis (FEA) with design of experiments tools to predict appropriate warm forming temperature conditions for 5083-O (Al–Mg) sheet metal blanks, deep drawing and two-dimensional stamping cases. To achieve increased degrees of forming, different temperature levels should be assigned to the corner and body of the die and punch. 25–250% elongation ranges were seen. They found that the formability of Al-5083 alloy is greatly dependent on the temperature distribution of the die and punch. It is also observed that the optimal temperature distributions for warm deep drawing and warm two-dimensional stamping were not identical. In the present work, cylindrical deep drawing tests with reduced clearance (ironing) were performed with EDD sheets of 2 mm thickness at various clearances between punch and die and at temperatures in the range of 200 °C–600 °C.

2. Experimentation

In the present research the clearance between punch and die is kept smaller then the sheet thickness so that there is deformation of the material over the cup wall. Three different dies, to provide 40%, 25% and 10% reduction in thickness, are used to study the effect of “extent of deformation” over the cup wall thickness and maximum diameter that can be drawn safely at a particular temperature without fracture. Since every material has its own coefficient of thermal expansion due to which it expands upon increasing the temperature. So the material for the dies should be such that it does not excessively change its dimensions otherwise the design of dies will change. Also tooling material should be able to retain its strength at elevated temperatures as there will be heavy friction between tool and the deformable material. So, for this purpose Inconel-600 material was chosen to make dies. An induction furnace was specifically developed to heat the blank. This system is designed to heat Iron maximum up to 700 °C. Another induction coil was provided around the lower die (Fig. 1) to heat it at a predetermined temperature. This ensures that thermal shock is not experienced by the blank and the drawing process can take place at a fixed temperature. Since the drawing operation is taking place between dies and the object is not visible during the operation, so temperature measurement system should be such that it does not make contact over either dies or over the blank. So, infrared pyrometers are used to measure the temperature of the blank at the time of drawing. Fig. 2 shows the view of the

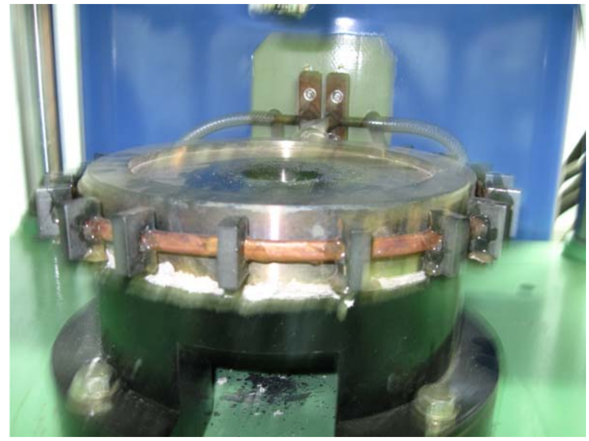

Fig. 1. Induction coil connected to the Inconel die for heating it up to 500 °C.

Fig. 2. Complete experimental test rig.

Fig. 3. A typical fracture at 40% reduction.