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STUDY OF BEND ANGLE ALLOWANCE FOR SHEET METAL FORMING IN AEROSPACE INDUSTRY

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ABSTRACT

Sheet metal forming is one of the major forming processes adopted for manufacturing thin walled components (thickness < 3mm) in aerospace and automotive industry. The final form and dimensions of the sheet metal components are affected by several factors such as material characteristics, thickness, bend radius, flange length, spring back, etc. Among these, spring back is considered to be the major factor affecting the bend angle on the component. Thus, to achieve the nominal bend angle, it is necessary to predict the bend angle on the form tool with due consideration given to spring back. This work proposes a relation for the bend angle on the form tool with respect to the nominal bend angle on the component for a given sheet thickness and material. The relation was verified for Al2024 alloy sheet metal components of thickness ranging between 1-2mm, and the results were found to be very encouraging.

Keywords: bend angle, spring-back, sheet metal forming, form tool.

INTRODUCTION

The role of sheet metal forming is significant in aerospace industry as majority of the components are made of thin sheets of thickness less than 3 mm. The dimensional accuracy of the component is of utmost importance in case of aerospace components as any deviation may have detrimental effect on the overall performance of the aircraft. This necessitates that the component is manufactured in a way conforming to the dimensions provided in the component drawing. It is a general practice for the shop floor that all the sheet metal forming is carried out using the empirical relations and tules of thumb captured with experience. The final dimensions of the component are affected by several factors such as sheet material, sheet thickness, bend radius, bend allowance, flange length, springback, etc. Among these, spring back is of major concern in obtaining the nominal bend angle on the component.

As per the standards practiced in aerospace industries, it is a usual practice that a form tool or block is fabricated providing a bend angle that is 2^o less than that of the nominal bend angle required on the component for sheet thickness less than 2.5mm. This will produce a component with a bend angle that is varying within $\pm 2^0$ of the nominal bend angle. This necessitates suiting the component during assembly. To avoid this additional work during assembly, an understanding of the spring back in sheet metal forming is essential. Thus, the bend angle provided on the form tool plays a major role in the variation of final dimensions in the sheet metal components. Several research papers [1-6] have investigated the spring back effect in sheet metal components fabricated using rubber press forming. In this work, an attempt is made to develop a relationship between the nominal bend angle 'θ_n' on the component to the bend angle 'θ_t' on the form tool based on the parameters such as sheet material, material thickness, bend radius, spring back, etc., by fabricating the parts using hand forming.

The main objective of this work is to formulate a proportionality constant for each sheet thickness and to establish a relationship between the two angles i.e., nominal bend angle on the component and the bend angle to be provided on the form tool with due consideration given to spring back. Several specimens of Al 2024 alloy sheet considering the bend angle and the sheet thickness were fabricated and inspected for the deviation between the nominal bend angle and the achieved bend angle using a given bend angle on the form tool.

EXPERIMENTAL STUDIES

For the experimental studies, a L-angle bend component is considered. The material used for the experimentation was Al2024 alloy.

Form block preparation

To start with, the current standard being followed at CSIR-NAL was considered as the basis for fabrication of form block. Form block is a solid block of material usually made of hylam, over which the sheet is formed to conform to the contour of the block with the application of pressure. Different form blocks with spring-back compensation are fabricated manually, with a bend angle reduced by 2^0 to that of nominal bend angle on component [7]. A suitable clamping plate of similar shape is used to keep the specimen sheet fixed on the form block during forming operation. A form block fabricated for the studies is shown in Figure-1.

Figure-1. Form Block.

Specimen preparation

Figure-2 shows the dimensional details of the L-angle Bend considered for the studies and its loft details for 80^0 specimens. The shortening length for the component is determined by using Equation (1).

$$Shortening\,Length = Total\,Length - [(R + k * t) * 2\pi\theta / 360] \quad (1)$$

where, R = Bend radius
k = Material constant (0.48 for Al2024)
t = Thickness of the sheet
θ = Bend angle

The specimens of 30mm x 80mm are cut from Al2024 sheets of different thicknesses and deburred. Four commonly used sheet metal of thicknesses 1mm, 1.2mm, 1.6mm and 2 mm while three angles - 80^0, 85^0, 90^0 with a common bend radius of 3mm were considered for the studies. Four specimens of each configuration were tested for the purpose. Bend line is marked on the specimen using the vernier height gauge mounted on the surface plate. The specimens are segregated and stored according the sheet thickness.

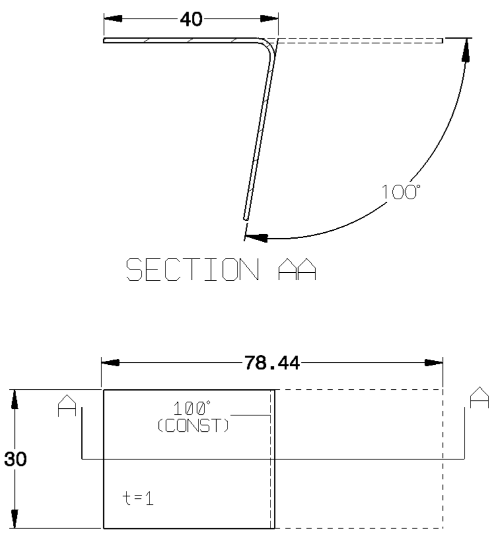

Figure-2. Dimensional details of specimen.

EXPERIMENTATION

The specimen and form block are fixed on the bench wise as shown in Figure-3. The sheet is bent over the tool using a flat polyurethane rubber pad and a mallet. The bend radius on the form block is reproduced on the component. Figure-4 shows the fabricated sheet metal component specimens. The component is inspected for the bend angle achieved 'θ_a' using a digital bevel protractor and the observations are tabulated accordingly. Based on the difference observed between the nominal and achieved bend angle, the form block is corrected to make the two closer. With the new form block with the above correction, the experiments are repeated. The correction is estimated using the formula shown in Equation (2).

$$\theta_a = \lambda * \frac{\theta_t}{t} \quad (2)$$

where, θ_a = Achieved bend angle
λ = a proportionality constant
θ_t = Bend angle provided on form block
t = Thickness of sheet

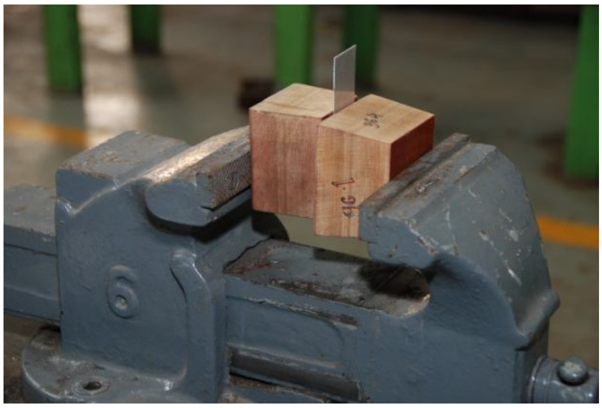

Figure-3. Experimental setup.

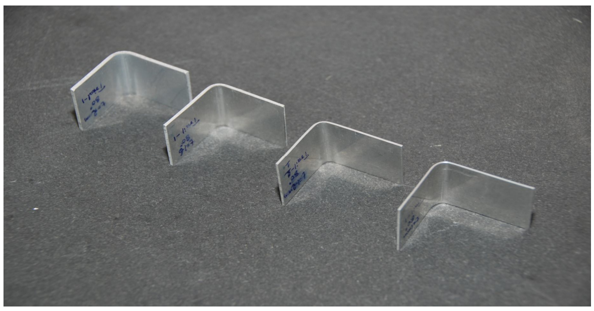

Figure-4. Fabricated specimens.

RESULTS AND DISCUSSSIONS

With the experimental studies, a proportionality constant 'λ' for each sheet thickness was devised and a relationship between the two angles i.e., nominal bend angle 'θ_n' on the component and the bend angle to be provided on the form tool 'θ_t' was formulated as given by Equation (3).

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$$\theta_n = \lambda * \frac{\theta_t}{t} \tag{3}$$

The above relationship was validated for all the four thicknesses considered for Al2024 alloy sheet for L-angle Bend component. The 'λ' values for various thicknesses are given in Table-1.

Table-1. Proposed 'λ' factors.

Sheet thickness (mm)	**'λ' factor**
1.0	1.017
1.2	1.216
1.6	1.613
2.0	2.006

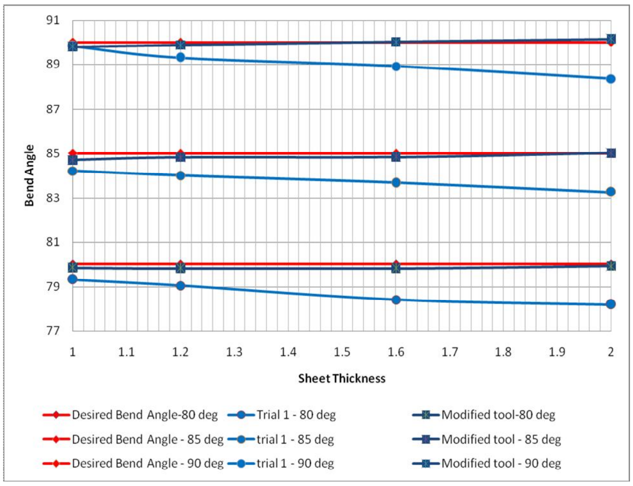

Figure-5. Nominal angle vs. achieved angle.

The inspection results for all the experiments are plotted in Figure-5 and it can be noticed that the deviations observed between the two angles are high. Also, it can be noticed that the spring back reduces with increase in sheet metal thickness. To optimize this deviation, a correction factor or proportionality constant 'λ' was formulated as in Equation (2) and individual form tools were fabricated based on the 'θ_t' obtained. With the new tools, the deviations observed were reduced by approximately 14%.

CONCLUSIONS

This work mainly focused on the effect of spring back on the achieved bend angle 'θ_a' on the sheet metal component. This work proposes a relation (Equation (3)) for the bend angle on the form tool, which is used for the fabrication of sheet metal components in aerospace industries. With this work, it was noticed that a little modification in the way of establishing the bend angle on the form tool is necessary. The proposed relationship is validated for two intermediate angles viz., 83^0 and 87^0 respectively. It was observed that the relationship predicts the bend angle on the form tool well for any angle for thickness ranging from 1 mm to 2 mm for Al2024 material and the results are within the acceptable tolerances [7, 8].

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