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The Effect of using Grease on the Surface Roughness of Aluminum 1100 Sheet during the Single Point Incremental Forming Process

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Abstract
Incremental forming is a sheet metal forming technique in which a uniform sheet is plastically deformed through the progressive action of a rounded tool. The movement of the tool is governed by a CNC machine. By this way the tool locally deforms the sheet through pure stretching deformation. In this research incremental forming experiments were carried out on Aluminum 1100 sheets to form a cone shape. Roughness was studied by varying the input parameters (tool speed, feed rate and lubricant). From the study, it was found that the surface roughness was improved as tool speed and feed rate increases. Also it was found that using grease improve the surface roughness compared with using the coolant oil.

Keywords*: Incremental forming, tool path, tool speed, federate, lubricant*

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INTRODUCTION

Incremental sheet metal forming is an innovative technology used to form complex shaped parts in small patch without using the traditional dies. It is based on the principal of layer by layer manufacturing, where the part is divided into number of horizontal layers. The contours of these layers are used to prepare the computer numerically controlled tool path. In this process a spherical shaped forming tool is moved through the CNC controlled tool path. The process can be performed on a universal CNC Machining Center and the sheet blank is usually fixed in the horizontal plane [1].

The main advantage of incremental forming is the absence of dies, making rapid design changes possible [2]. A lot of factors can affect the process, like sheet thickness, tool radius, tool speed, tool feed and type of lubricant used.

Durante, et al. [3] proposed a model to compare between the analytical and the experimental values of the surface roughness of a pyramid shape component. They found that the surface roughness decreases as the tool diameter increase.

Babu and Kumar [4] studied the effect of tool speed, feed rate, and step depth on surface roughness of steel sheets. They found that there was an increase in roughness with increase in spindle speed and decrease when tool feed rates were increased. Kim and Park [5] found that the formability is improved when a ball tool of a particular size (10 mm) is used; compared with hemispherical head tool, with a small feed rate and a little friction. Hamilton [6] used oil based lubricants with different kinematic viscosity to study their influence on the internal and external surface roughness of an oval shape. He concluded that the cutting fluid emulsion used as lubrication was not the best choice for creating a smooth interior surface.

In this work incremental forming experiments will be carried out on Aluminum 1100 sheets to form a cone shape. Surface roughness will be studied at different input parameters (tool speed, feed rate and lubricant).

EXPERIMENTAL WORK

The purpose of the experimental work was to study the effect of using grease on the surface roughness of Aluminum 1100 sheet during the single point incremental forming process. To do so; a clamping arrangement was designed and built. The experimental set-up consists of Aluminum sheets (200*200*0.6 mm). The mechanical properties are listed in Table (1). Holes were drilled at the edges of the sheet to hold it in the fixture as shown in Figure 1.

Table 1: *Mechanical Properties of the Aluminum Sheets.*

Ultimate stress (mm^2)	**Yield strength (N/mm^2)**	**Elongation (%)**
110	95	20

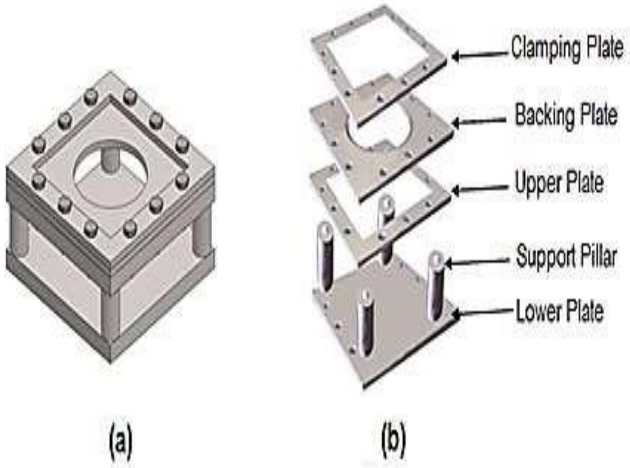

Fig. 1: *Clamping arrangement, a-Assembled b- Disassembled.*

A "Boxford" CNC milling machine was used to perform the work. The fixture was attached to the table of the machine as shown in Figure 2. The forming tool was a steel rod (30-HRC) with a smooth, hemispherical tip. Four different tools were used with tip diameter of (4, 6, 8, and 10 mm) as shown in Figure 3.

The cone base diameter was 80 mm and the depth was 35 mm with a draft angle of 45º. The motion of the tool was controlled through CNC programming of a series of incremental contours. The tool path profile consists of a three dimensional spiral, at each loop the punch moves both in the Z-direction to create the fixed depth to the blank, as well as it has an inward radial displacement. At the end of movement we obtain a conical shell as shown in Figure 4.

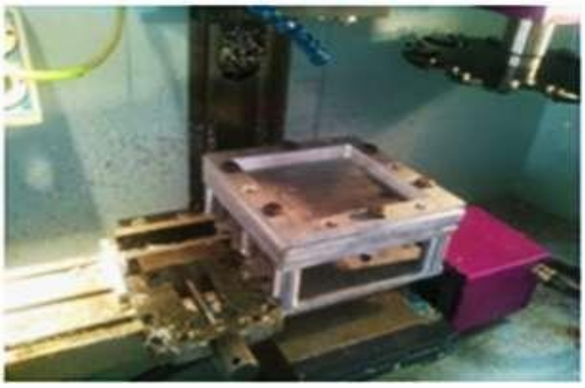

Fig. 2: *Fixture Mounting.*

Fig. 3: *Forming Tools.*

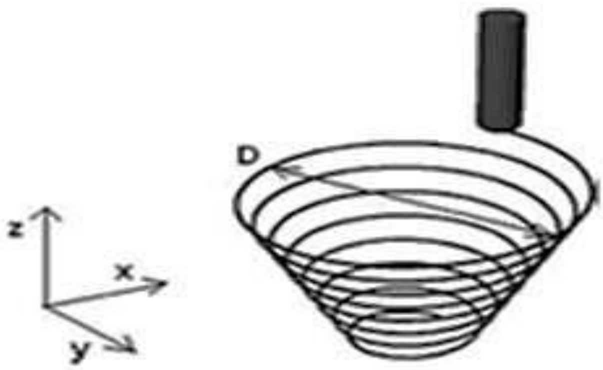

Fig. 4: *Spiral Path.*

A primary experiment was performed to consider the best tool tip diameter. The oil coolant was used as lubricant. Two more different experimental investigations were performed as follows: different spindle speeds (500, 1000, 1500 and 2000 RPM), different feed rates (200, 400, 600 and 800 mm/min). These experiments were performed with oil coolant and grease to compare the effect of using oil coolant and grease on surface roughness of the cone. Oil coolant properties and grease properties are listed in Tables 2 and 3, respectively.

Table 2: *Oil Coolant Properties.*

Acidity pH	**7**
Kinematic Viscosity (at 29^0 C)	**1.086**
Boiling Point ^{0}C	**95**
Specific gravity(at 25^0 C)	**0.991**

Table 3: Grease Properties.

Penetration	**275**
Average drop point(at 25^0)	**90**
Flash point	**180**
Specific gravity(at 25^0)	**0.875**

RESULTS

It was found that as the tool tip diameter increases, the surface roughness decreases, as shown in the Figure 5 and this is due to the increase in the rubbing surface area of the tool on the sheet (due to a larger contact area between the tool and specimen). The tool with the 10mm tip diameter gives the best surface roughness (Figure 5), this confirms with the previous studies on the effect of the tool radius [3, 5].

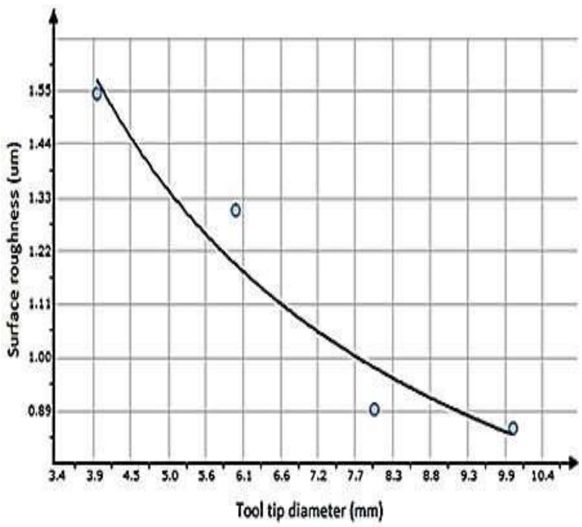

Fig. 5: *Effect of Tool Diameter on Surface Roughness. Feed rate=600 mm/min, spindle Speed= 2000 RPM, Coolant oil.*

Figure (6) represent the effect of speed on surface roughness for grease and coolant oil. It can be seen that increasing tool speed results in decreasing the surface roughness. This improvement is due to the stacking of the debris with the grease so reducing the ability for this debris to scratch the surface of the sheet.

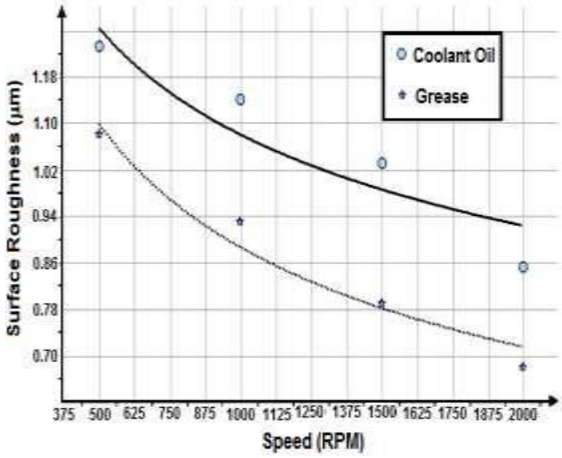

Fig. 6*: Effect of Feed Rate on Surface Roughness.*

Figure (7) represent the effect of feed rate on surface roughness for grease and coolant oil. It can be noticed that increasing the feed rate decreases the surface roughness of the cone and this is due to the shorter time to which the material is in contact with the tool tip.

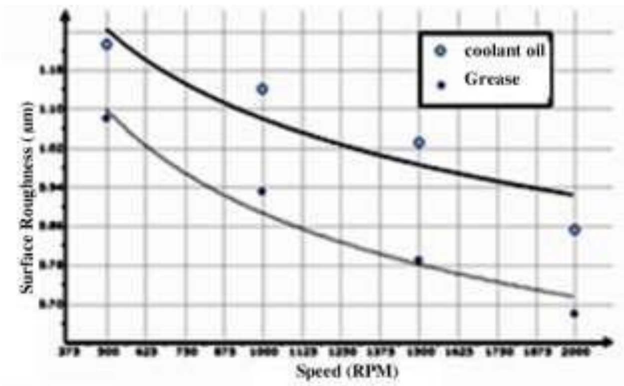

Fig. 7: *Effect of Feed rate on the Surface Roughness. Spindle Speed= 500 RPM, Tool Tip Diameter=10 mm.*

It can be concluded that grease can be used in incremental forming process to improve the surface roughness of formed parts.

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