INFLUENCE OF SHEET METAL THICKNESS ON FORMABILITY OF ALUMINIUM ALLOY 6061

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Abstract

The effect of sheet thickness on forming limits of sheet metal is an essential issue to know the correct thickness to which a product can be developed with adequate strength and ductility. In the present study the aluminum alloy 6061 is selected. The different thickness specimens are selected to perform formability test using different tribological conditions. It is evaluated that the formability of the material in study varies on thickness variation. It is also evaluated that under lubricated conditions formability increases in comparison to dry condition.

Keywords: Formability, Poly tetra fluoroethylene, Graphite Grease, Erichsen Index.

Introduction

Aluminum is a lightweight metal with low work-hardening rate and a face-centered cubic crystalline structure. Aluminum is one of the most widely used metals in modern aircraft industry. It is vital to the aerospace industry because of its high strength/weight ratio, corrosion-resisting qualities, and its comparative ease of fabrication. The outstanding characteristic of aluminum is its lightweight. Aluminum alloys can be divided in two groups wrought or cast alloys. Some of the wrought alloys are hardened by work hardening, while others are precipitation hard enable. Similarly, some of the cast alloys can also be hardened by precipitation hardening [1]. The casting alloys are suitable for casting in sand, permanent mold, and die castings whereas the wrought alloys may be shaped by rolling, drawing, or forging. Among the two, the wrought alloys are the most widely used in aircraft component production being used for stringers, bulkheads, skin, rivets, and extruded sections. Whereas casting alloys are not extensively used in aircraft applications. Aluminum combined with various percentages of other alloying elements such as copper, manganese, magnesium, and chromium form the alloys that are used in aircraft component production. Aluminum alloys having principal alloying elements such as manganese, magnesium, or chromium, or magnesium and silicon, show little attack in corrosive environments. On the other hand, alloys in which substantial percentages of copper used are more prone to corrosive action. The total percentage of alloying elements is rarely more than 6 or 7 percent in the wrought aluminum alloys. Aluminum is a light weight and high specific strength metal used for many applications with an expansive influence in day today life from covering dinner in the oven to providing structural elements of an aircraft. This alloy has good mechanical properties, easily welded and suitable for aeronautical applications. Generally it is used for wing and fuselage structures. The Six thousand series aluminum alloys are heat treatable and widely used in automotive industry due to their corrosion resistance and specific mechanical properties [2, 3]. One of the most commonly used heat-treatable aluminum 6061 is available in a wide range of sheet and plate products. It is used in auto body sheet, structural members [4]. Generally, this alloy has got unique characteristics, due to greater amount of alloying additions [5–8]. The common applications of aluminum 6061 alloy include heavy duty structures, pipelines, truck and marine components, high pressure and general structural applications.

Aluminum 6061-T6 alloy is a high strength alloy, containing magnesium and silicon as its major alloying elements [9]. It was developed as

"Alloy 61S," in 1935[9]. It is having good mechanical properties, good weld ability and aluminum alloy for general purpose use. Aluminum alloy, 6061 is available in pre-tempered grades such as 6061-O, annealed and tempered grades 6061-T6, solution zed and artificially aged, and 6061-T651 solution zed, stress-relieved stretched and artificially aged. Aluminum 6061-T6 has better structural strength and toughness. It also offers good finishing characteristics and can be easily welded. The weld joints in its –T6 condition s may lose some strength. Thus re-heat- treatment and artificially aging is inevitable. Aluminum 6061 alloy has good machinability. It remains resistant to corrosion even when the surface is abraded. It can be worked with ease workability. Generally in forming operation change of thickness is undesirable and different sheet thickness yields different formability.

The effect of sheet thickness on forming limits of sheet metal is a controversial issue. According to some of the investigations the sheet metal thickness affects the forming limits curve, whereas the other researchers found that the thickness has insignificant effect on the forming limit diagram [10]. Generally, a single-thickness FLC constructed for a material is often used for all cases in the industry. It should be required that different forming limit curves should be used for different thicknesses to get the most accurate results [11]. The many experimental studies [12,-14] and theoretical [15] studies related to influence of sheet thickness on formability have been carried out on steel, still experimental studies on forming limits for Aluminum alloys are scare. Although it is specified that the thickness effect on the forming limits is significant, Hashemi et al. [10] have demonstrated that the absolute value of thickness has no influence on the forming limits of St14 steel sheet. The main difference between both researches is the type of the material and thickness reduction process [16]. The aluminum alloys have very complex forming behavior, and the emerging necking during biaxial stretching is difficult to observe. The deformation characteristic of aluminum alloys is different from that of steel due to different crystallographic structure. Thus the formability of the aluminum differs that of the conventional steels [17, 18].The formability is also influenced by different tribological conditions. Each lubricant applied during forming will have different coefficient of friction which affects formability of sheet metal. Thus the studies on different sheet thickness with different lubricant are scare. Under different tribological condition different deformation mechanism for a material takes place. Formability test is essential for each in coming lot of sheet metal to know their deformation behavior while manufacturing the product. Sheet Metal Forming generally ranges from simple bending to stretching, to deep drawing of complex parts. Therefore, determining the extent to which a material can deform is necessary for designing a reproducible forming operation. As mechanical properties greatly influence formability, and forming properties vary from coil to coil, it is essential to test incoming sheet metals.. There are different types of formability test methods. They are, Cupping tests-Flat bottom, Hemi spherical & Conical tests, Olsen & Erichsen test, Fukui cup drawing test, Uniaxial Tensile Test, Bending Test, Bend Test, Swift Cup Test, Limiting Dome Height Test, Viscous Pressure Bulge Test, Wrinkling Test, Yoshida Buckling Test etc.In the present study aluminum 6061 sheet of different thickness is tested for its formability studies using Erichsen cupping test die and punch and analyzed under different lubricating condition.

Erichsen cupping test

Modified Erichsen cupping test is one of the currently used formability test, which evaluate the ability of sheet metal to be formed into useful components successfully. The formability test index is identified as one of the most important formability test result that could be used on a routine basis by industry for grading, selecting and sorting of incoming sheet metals for manufacturing of various components. In older Erichsen test, the results obtained were uncertain, as there was no control of the clamping force. The test consists, of clamping a metal test piece under controlled pressure between retaining ring and die and pressing the test piece into the die by means of a penetrator having a spherical head, until the end (initiation of crack / fracture) is reached. The Erichsen cupping test is employed to evaluate the ability of metallic sheets and strips to undergo plastic deformation in stretch forming. A die with blank holder is designed as per standard of Erichsen cupping die and punch having spherical end. The advancement of punch is continued until an initiation of crack i.e., necking occurs. The depth of cup is measured as Erichsen index value and is a measure for the formability of the sheet during stretch forming. A schematic diagram of die and punch used for formability test is given in the Fig. 1.

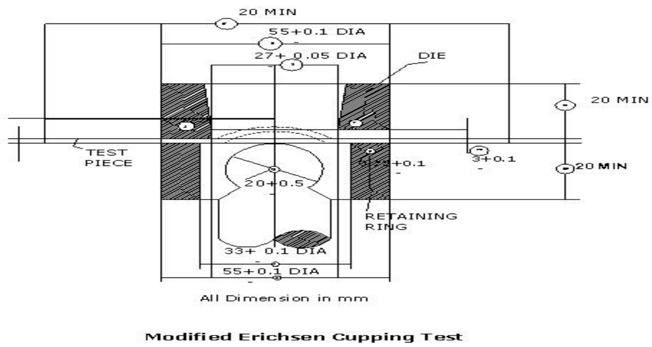

Fig.1. Modified Erichsen Cupping Test

Present Work

The material selected in the study is aluminum alloy 6061 -T6. The chemical composition (mass %) of the material is given in Table 1.

Table 1 Chemical composition of the material aluminum alloy

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
0.59	0.45	0.28	0.028	1.015	0.27	0.04	0.05	Bal

The Al 6061 samples of 9o mm diameters were prepared (Fig 2). To vary the strain state condition the circular samples were cut at both ends as shown in the Fig4. These samples were screen printed with circle of diameters 2.5 mm. Modified Erichsen cupping test was employed in this study. The set up used is shown in Fig.3. The sheet metal is clamped between a retaining ring using a stud and bolt clamp. Hold down force of 1000 kgf was employed using torque wrench. .

The hydraulic punch moves down applying the force on blank. The material is drawn in to die. An initiation of crack i.e., necking was absorbed using digital camera connected with computer, and then punch motion was stopped. The three samples have been tested for each Erichsen value, and average of three samples result is taken in to consideration. The depth of cup is taken as Erichsen index value

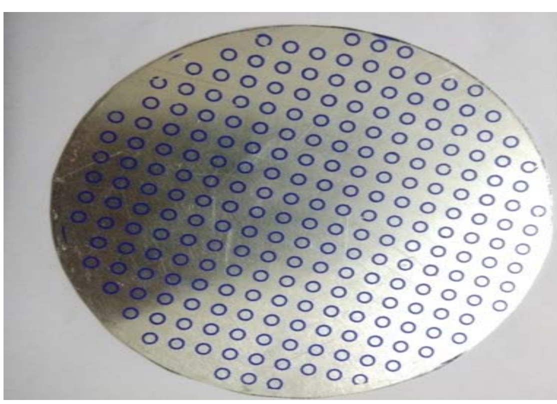

Fig. 2 Aluminum sample of 90 mm diameter

Fig.3 Setup used for formability test

Result and Discussion

The Erichsen index values for various conditions of testing are presented graphically in Fig.5. The graphs are plotted as- Erichsen cupping index (depth of cup in mm) on Y- axis and testing conditions on X-axis. The testing conditions are identified as Dry condition, using different thickness 0.5, 0.7and 0.9 mm. The different thicknesses of sheets were taken and samples of 90 mm diameters were prepared. Some samples were also cut at both ends with 10 and 15 mm diameters semi circles. The prepared samples were screen printed with 2.5mm diameter circle. The deformed circle after formability test is shown in Fig. 4.

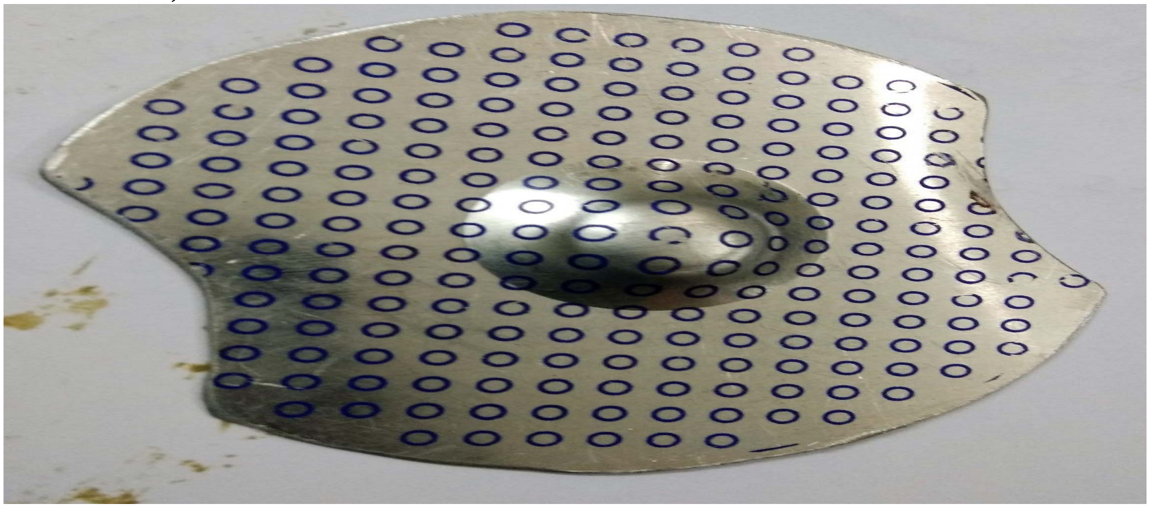

Fig. 4 Sample after formability test

Fig. 5 is a plot showing a comparison of formability index for the material 6061samples as received of different thickness. The data show the effect of various thicknesses on formability. It is observed that 0.9mm thickness has highest erection index value further the lesser Erichsen value for sample thickness 0.7 mm and the least Erichsen index value are obtained for sample thickness 0.5mm.Thus the greater thickness of sheet metal has more Erichsen index value.

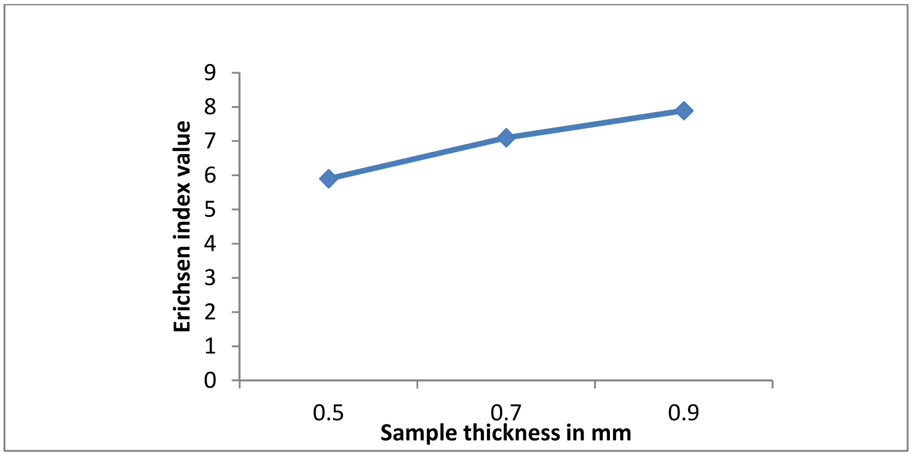

Fig.5 Erichsen index value for different thickness samples

Fig. 6 shows the erichsen index value for different thickness 0.5mm,0.7mm and 0.9mm. The 0.5mm sample was tested using different lubricant such as Yellow Grease (YG), Polytetrafluoroethylene (PTFE) and Graphite Grease(GG).Erichsen index value are presented in y axix and different lubricants on x axix.It is observed that the graphite grease has influenced maximum the deformation behaviour of material selected in study.It is also seen that the specimen of thickness of 0.9 mm has maximum Erichsen index value with graphite grease in comprision to other thickness and lubricant selected in the study.

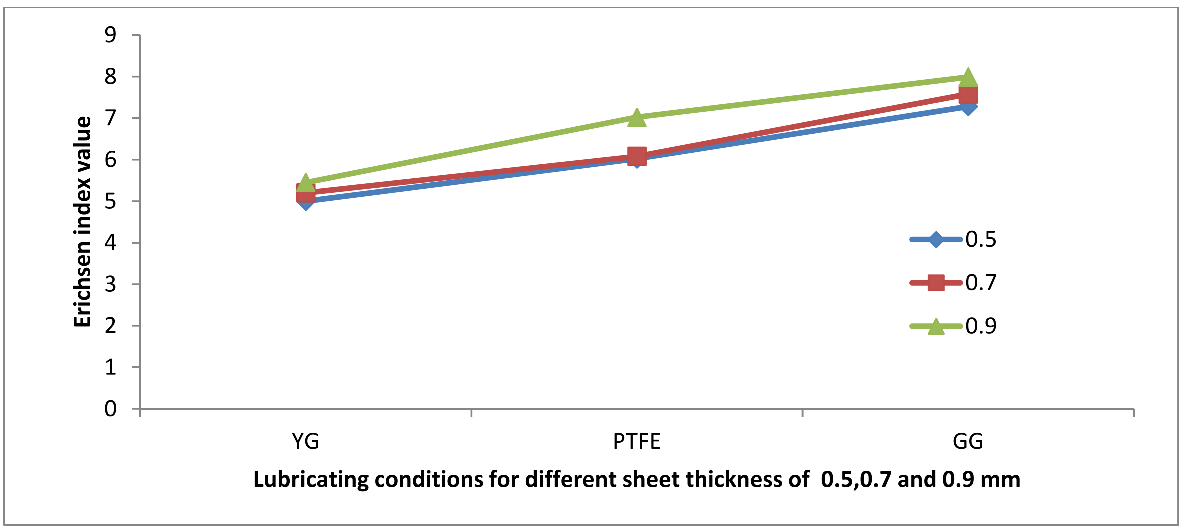

Fig 6. Erichsen index value for different thickness (0.5,0.7 and 0.9 mm)samples with different lubricants.

4. CONCLUSIONS

The formability of Aluminum alloy 6061 has been investigated. The variables included i) thickness of sheet metal ii) dry friction and with lubrication. Three types of lubricants were employed (Yellow grease, Graphite Grease and PTFE. The conclusion drawn are i) Thicker sheets exhibited better formability [19] with in the specimen of different thickness selected in the study. ii) The lubricant graphite grease has more influence on the formability of aluminum alloy in comparison to other lubricant selected in the study.

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