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Effect of number of cycles on mechanical properties of Al sheets using corrugative and straightening method

Susheelkumar Vijapur, M Krishna, H N Narasimha Murthy
Research and Development, Dept. of Mech. Engg., R V College of Engineering, Bangalore-1

Abstract: *The aim of the work was to study the effect of number of cycles on hardness and tensile strength of Al sheet materials processed by corrugative and straightening method. Al sheets were processed for up to 30 cycles using specially designed and developed geared corrugation and roller straightening setup. The microstructrure, tensile and hardness studies were done as per standard methods. The microstrucral study showed that finer grain refinement seen at 20th cycle then it grain dissolution could be seen. The experimental result showed that the hardness and tensile strength increasing with increase in number of cycles and reach maximum (105 Hv and 405 Mpa) at 21st cycle then they decreased due to grain dissolution.*

Key words: *Al sheets, corrugation and straightening process, microstructure, mechanical properties.*

I. Introduction

The process of severe plastic deformation (SPD) is gaining great interest in material science because it is useful to refine microstructures to the sub micrometer or nanometer levels [1], which leads to improved strength with good ductility. Researchers are working on SPD different techniques namely equal- channel angular pressing (ECAP) [2-4], high pressure torsion (HPT) [5], hydrostatic extrusion (HE) [6] and repetitive corrugated and straightening (RCS) [7-8]. Many methods are limited to smaller size, heterogeneity and larger wastage of specimens. But CRCS method can work for cotinuous structures and reduce the wastages.

Pandey et.al [9] designed a new technique called continous repeatative corrugation and straightening system (CRCS), which produces contious strips without wastage of materils in a single cycle. Few reserachers were working on effect of CRCS on mateials such as precipitation [9], strain hardening [10], and heat treament [11] processes. They were observed that the ductility of the samples expressed by relative elongation insignificant drop. Micro-hardness of the CRSC samples increased from about 100 to about 150 HV. The similar strength characteristics for the samples increased. However few researchers successfully worked on strengthening CRCS method but no information is available to date on the level of homogenity achieved in processing by CRSC method. Hence the objectives of the work were to investigate number of cycles of CRCS on homogenity mechanical properties hardness and tensile properties and which was justified with microstrucutue.

II. Experimental studies

In the present study the CRSC process is applied to the Al 6061 sheet the chemical composition are given in Table 1 of dimension 50 x 30 x 1 mm sheets. Al sheets brushed and clean with aceton to remove dirt and rust. The special CRSC was designed and developed using a pair of gears for corrugation and pair of rollers for straightening. The Al sheets are passed through the gears and roller contionously for strenngheing, each process is one cylce. The same procedure continues for 30 cycles. Three specimens were used for every cycle that is 1 cycle- 3 specimen, 2 cycles: 3 spciemen, so on. CRSC processed specimen polished with different grade SiC papers using automatic polishing machines. Then to obtain mirror finish, the specimen polished on velvate surface with diamond paste. The Keller's reagent was used as the etchant and the chemical composition is 2 ml HF, 3ml HCl and 5ml HNO3 to obtained grain size. After surface preparation, microstructure analysis was carried out on all the specimens using optical microscope. The specimens are tested for Vickers microhardness (HV) using Micromet-5101 device, with a load of 200g for duration 20 seconds. Tensile tests were performed at room temperature with universal testing machine at cross head speed of 0.5 mm/min, having gauge length of 75mm, thickness of 12.5mm and shoulders of 30mm. three reading were taken for each cycle.

Table1. Chemical composition of Al 6061 (mass %)

Fe	Cu	Si	Zn	Mn	Mg	Cr	Ti	Al
0.16	0.19	0.71	0.04	0.02	0.94	0.08	0.03	Bal

III. Results and discussion

3.1 Microstructure

The CRCS process up to thirty cycles has been successfully performed without shape defects of specimen. Fig. 1 shows the optical microstructures observed at the transverse direction plane of the specimens produced by different cycle of CRCS process. Fig. 1(a) shows the microstrucure of ascast spcimen, which exhibits strong wire texture and measured average width is aroud 70 µm. Fig. 1(b) shows 5 cycles CRCS spcimen shows less significant effect on size of the grain boudaries which can be measure arround 60 µm simillary even 15 cycles CRCS specimens shown in Fig. 1(c). 20 cycle CRCS grain strucure (Fig. 1(d)) is refined and microsturre of the specimen evolves into a strucrue with a considerable fraction of low angle of boudaries. The grain boundaries changes 70 to 30 µm. For 25 (Fig. 1(e)) and 30 cycles (Fig. 1(f)) the grain boundaries no more change but grain boudaries dissolve with in the matrix alloys.

Hence Corrugation and straightening of Al 6061 sheet metal up to 22 cycles will give a good improvement in the grain refinement and even interfaces can also be seen. After 22nd cycle the grain refinement in the Al 6061 alloy gets disolute. As the Si and Mg are flattened more the strength of the material improves.

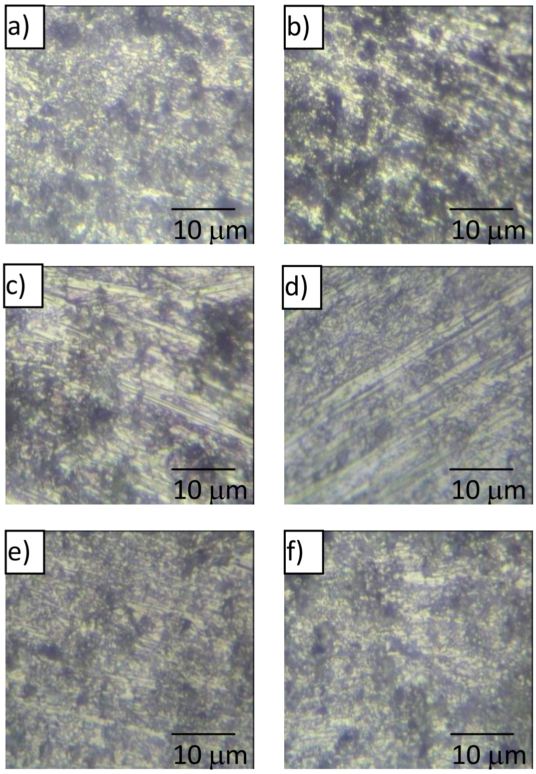

Fig. 1 Optical microstrucure of CRCS processed specimens a) ascast, b) 5 cycles,c) 15 cycles, d) 20 cycles, e) 25 cycles and f) 30 cycles

3.2 Hardness

Fig. 2 shows the effect of number of cycles on micro-hardness of the Al alloy sheet materials. The increase in Hv continues through subsequent cycles and this is due to the well-established reduction in grain size during CRCS process. The homogeneity in the material increased with increase in number of cycles at the higher cosntat strain. The hardness values increased with increase in number of cycles and reach maxtimum at 20 cycles then it decreaseed. The hardness value of the specimen before CRCS processing was 42 Hv, then increase linearly utpo 20th pass and the maximal hardness value was obtained at 20th cycle was 105 Hv. With the increase in number of cycles the hardness value decreased and remained constant from 27th to 30th pass.

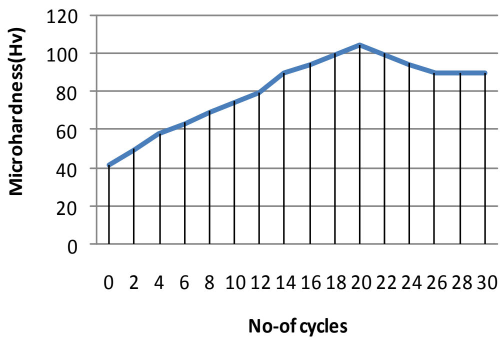

Fig. 2 Varaiton of microhardness of Al alloy with number of CRCS cycles

3.3 Tensile strength

Fig. 3 shows change in mechanical properties as a fuction of number of CRCS cycles. Fig. 3(a) and Fig 3(b) show the ulitmate tensile strength and yield strenth, they are increased by 11.23% and 12.25% after processing at 20th cycle of CRCS process. Maximal strengthening was achieved at 20th cycle of the CRCS process. Further processing caused decrease in the ultimate strength and yield strength of the material. Fig. 3(c) shows initially, the ductility of the material increased reached maximum at 10th cycle then it decrease upto 20th cycle then it remains constant. This is due to work hardening in the CRCS process caused a large decrease in ductility of the material and increase in strength. The initial tensile strength of the Al 6061 before processing by CRCS was 364 Mpa and the value of tensile strength increased after processing by CRCS to 405 Mpa, at 20th cycle the maximal value of strength was obtained.

IV. Conclusions

This study was aimed to investigate mechanical properties and microstructure in Al 6061 alloy sheets processed by CRCS method. Based on the obtained results, the following conclusions can be drawn:

- The CRCS process effectively reduced the grain size of Al 6061 alloy sheets, demonstrating the CRCS as a promising new method for producing ultra fine grained metallic sheets.
- The optical microscope analysis of microstructure of Al 6061 alloy sheet after CRCS (21 passes) revealed the finer grain size.
- Micro hardness value of Al 6061 alloy sheet before processing by CRCS method was 42 Hv, it increased to about 105 Hv after processing by CRCS method.

- The strength characteristics of the investigated sheet such as yield strength and ultimate tensile strength increased after processing by CRCS method.

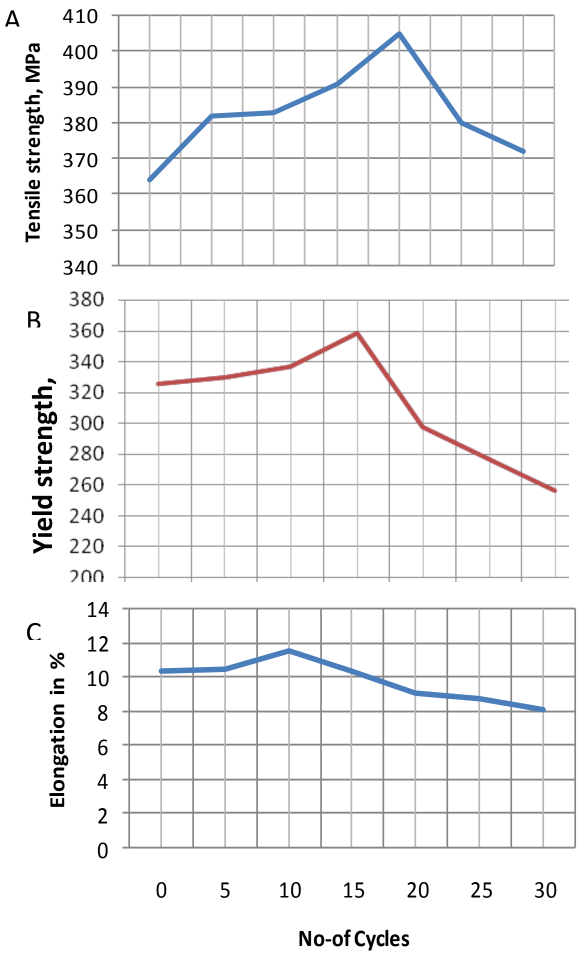

Fig. 3 Changes in mechnical properties of Al alloy with number of cycels in the CRCS process

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