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Effect of Reversed Accumulative Roll Bonding Process on Microstructure, Mechanical Properties and Properties Inhomogeneity of AA1050 Alloy

Mojtaba Dehghan[1]*, Fathallah Qods[2], Mahdi Gerdooei[3]

1- Ph.D. Student, Material Sci. & Eng. Faculty, Semnan University
2- Associate Professor, Material Sci. & Eng. Faculty, Semnan University
3- Assistant Professor, Mechanical Eng. Faculty, Shahrood University of Technology

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ABSTRACT

In this research, 13 passes of ARB process are performed on AA1050 sheets. The microstructural improvement to achieve nanometer-sized grains during ARB process is studied. In this process, the sheets are rotated 180^{o} about the normal direction (ND) axis after each rolling pass and preheated before each one. The changing of strength and elongation of the ARBed sheets during the process are investigated by uniaxial tensile test in three directions (roll direction (RD), transverse direction (TD) and angle of 45^{o} toward RD); and then the inhomogeneity of mechanical properties in these is was measured. The least of inhomogeneity occurred in three, four and thirteenth passes of process. Finally, micro-Vickers hardness is investigated throughout thickness of the sheets in this process. The strength and hardness of sheets increased at the early passes and then did not changed apparently at the middle passes of process; and subsequently they decreased gently. The elongation of sheets decreased swiftly at the first pass of process; and then it increased slowly.

KEYWORDS:

Reversed Accumulative Roll Bonding, Nanostructure, Tensile Strength, Elongation, Inhomogeneity Index.

* Corresponding Author, Email: dehghan.mojtaba@yahoo.com

1- Introduction

Recent developments in fabrication of UFG materials have focused on using large strain or severe plastic deformation (SPD). Ultra-fine grain (UFG) materials having grain sizes smaller than 1 μm, are expected to exhibit superior mechanical properties, such as high strength, high corrosion resistance, high fatigue strength, and excellent super-plasticity[1,2]. The accumulative roll bonding (ARB) process imposes severe plastic strain on materials without changing the specimen dimensions, and UFG structure then after high strengthening is obtained [3,4]. In the ARB process, 50% rolled sheet is cut into two, then stacked to be the initial dimension, and then rolled [2,4]. Since the above mentioned procedures can be repeated limitlessly, it is possible to impose very large plastic strain on the materials in the ARB process [2,5].

2- Methodology

AA1050 Alloy (99.54 wt.% Al– 0.172Si– 0.157Fe– 0.01Mn) is used for this study. A sheet with 5 mm thickness is cold-rolled to 1 mm thickness and annealed at 430°C for 1 h to obtain a fully recrystallized material with an average grain size of 34 μm, which was the starting material. Two pieces of this sheet with dimensions of 1×40×200 mm^3 are stacked after degreasing surface with acetone and wire-brushing. The stacked sheets are inter-pass annealed at 200°C for 5 minutes and then immediately roll-bonded by 50% reduction in thickness (von Mises equivalent rolling strain of 0.8) by the use of a two-high mill with roll diameter of 110 mm. The roll peripheral speed was 6.9 $m.min^{-1}$, so that the mean strain rate was 12.4 s^{-1}. The roll-bonded sheet is cut into two, and the procedures described above are repeated. A procedure of cutting, stacking, inter-pass annealing and roll-bonding is referred to as one pass of ARB, and this process is repeated up to 13 passes, giving a total thickness reduction of 99.988% or an equivalent strain of 10.4. In this process, the sheets were rotated 180° about the normal direction (ND) axis after each rolling passes. The roll-bonding is carried out under dry conditions, i.e. without lubrication, introducing a very large shear deformation in the sample.

Microstructures of the deformed samples were characterized by scanning electron microscope (SEM). Thin foils parallel to the longitudinal planes (perpendicular to the transverse direction (TD)) were prepared by mechanical polishing and then etched in 50 ml Poultons reagent (12 ml HCl + 6 ml HNO_3 + 1 ml HF + 1 ml H_2O) + 25 ml HNO_3 + 40 ml of solution of 3 gr Chromic acid per 10 ml of H_2O. SEM operating at 20 kV was used for the structural observations for coarse-grained samples. The changing of strength and elongation of the ARBed sheets during the process was investigated by uniaxial tensile test in three directions (roll direction (RD), transverse direction (TD) and angle of 45° toward RD). Micro-Vickers hardness measurement was also carried out throughout thickness on the longitudinal planes of the ARB processed sheets at an interval of 100 μm along the ND, in order to show the distribution of local strength through the specimen thickness.

3- Discussion and Results

In the ARB processed sheet, the grains are elongated along RD and the thickness of the elongated grains gradually decreased with increasing the number of ARB passes. The grain thickness (d_t), length (d_l) and mean grain size (d_g) are shown in Table 1. The specimen, after 13 passes, filled with the UFGs with d_t of 486 nm and d_g of 938 nm, homogenously distributed.

Table 1. The grain thickness (d_t), length (d_l) and mean grain size (d_g) of ARB processed sheets

Sample	Annealed	1Pass	2Passes	7 Passes	10 Passes	13 Passes
d_t [μm]	35	12.8	5.11	1.18	0.61	0.486
d_l [μm]	33	23.2	17.27	3.5	1.65	1.39
d_g [μm]	34	18	11.19	2.34	1.13	0.938

The stress–strain curves of the ARB processed sheets at different ARB passes in RD, TD and angle of 45° toward RD are shown in Figure 1. The shape of the stress–strain curves at different ARB passes was similar to each other. The flow stress rapidly reached the maximum value, necking occurred, and then tensile fracture happened below 18% of total elongation. The yield strength, tensile strength and elongation (uniform elongation and total elongation) as a function of ARB passes are presented in Figure 2.

In order to investigate mechanical properties inhomogeneity in RD, TD and angle of 45° toward RD, uniaxial tensile test was done in these directions. The inhomogeneity percent of yield strength, tensile strength, uniform elongation and total elongation are displayed in Figure 3.

In order to clarify the distribution of the local strength, micro-Vickers hardness measurement is carried out throughout thickness of the ARB processed sheets.

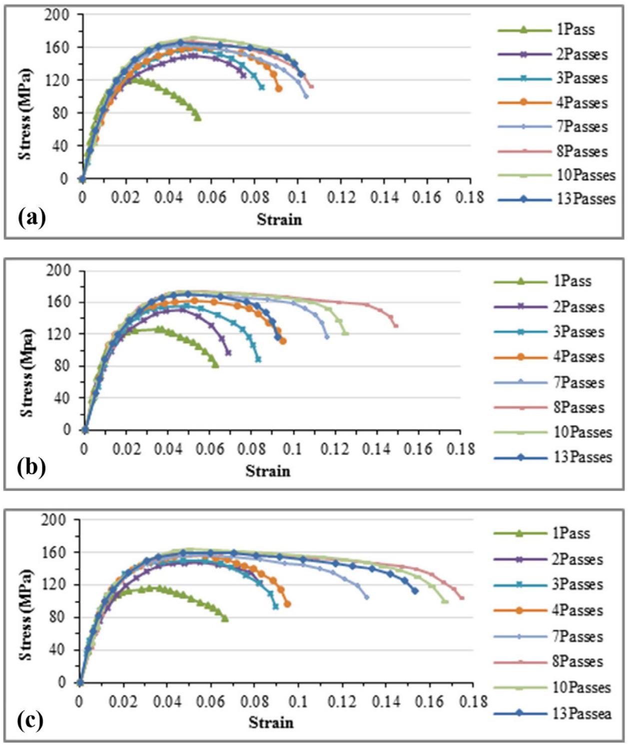

Figure 1. Engineering stress–strain curve of the ARBed sheet at different ARB passes in (a) RD, (b) TD and (c) angle of 45° toward RD

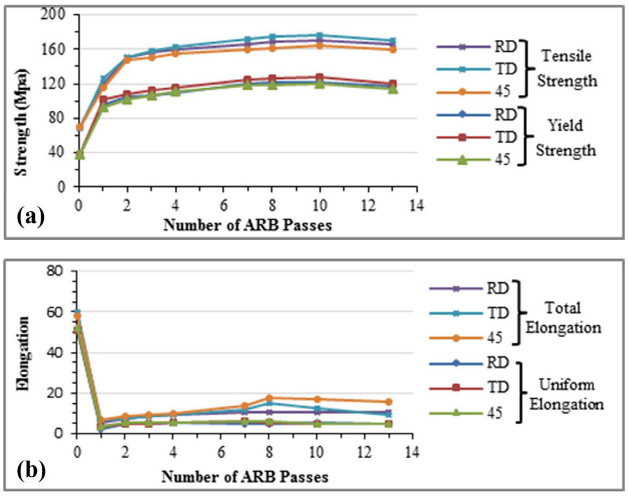

Figure 2. Variation of (a) strength and (b) elongation with respect to number of ARB passes

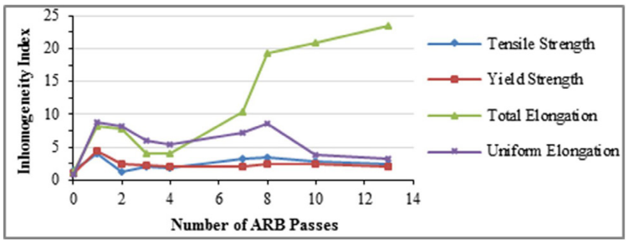

Figure 3. The inhomogeneity percent of mechanical properties in RD, TD and angle of 45o toward RD

4- Conclusions

1. In the Reversed ARB processed sheet, the grains are elongated along RD and the thickness of the grains gradually decreased. UFG in nanometer range could be successfully attained by the reversed ARB process.
2. The strength and micro-Vickers hardness greatly increased by early ARB passes, and then increased slightly with increasing strain; and subsequently decreased gradually. The elongation decreased quickly by one ARB pass; and then it increased slightly.
3. The variation of mechanical properties inhomogeneity in reversed ARB process is sinusoidal. The least and most optimal of inhomogeneity occurred in third, fourth and thirteenth passes of process.
4. The distribution of micro-Vickers hardness through the sheet thickness is uniform.

5- References

[1] M. Eizadjou, H. Danesh Manesh, K. Janghorban, 2009, "Microstructure and mechanical properties of ultra-fine grains (UFGs) aluminum strips produced by ARB process", *Journal of Alloys and Compounds,* 474, pp. 406-15.

[2] M. Dehghan, F. Qods, M. Gerdooei, 2012, "Investigation of Microstructure of the Commercial Pure Aluminium in the ARB Process", *Materials Science Forum,* 702-703, pp. 147-150.

[3] R. Nasiri Dehsorkhi, F. Qods, M. Tajally, 2011, "Investigation on microstructure and mechanical properties of Al–Zn composite during accumulative roll bonding (ARB) process", *Materials Science and Engineering A,* 530, pp. 63-72.

[4] K. Wu, H. Chang, E. Maawad, W.M. Gan, H.G. Brokmeier, M.Y. Zheng, 2010, "Microstructure and mechanical properties of the Mg/Al laminated composite fabricated by accumulative roll bonding (ARB)", *Materials Science and Engineering A,* 527, pp. 3073-78.

[5] M. Dehghan, F. Qods, M. Gerdooei, 2013, "Effect of Accumulative Roll Bonding Process with Inter-Cycle Heat Treatment on Microstructure and Microhardness of AA1050 Alloy", *Key Engineering Materials,* 531-532, pp. 623-26.