Accumulative roll bonding of the Mg-Al alloy

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Abstract – The aim of this work is to investigate whether accumulative roll bonding (ARB) is an effective grain refinement technique for the Mg based Al-Zn alloy. Thus, a number of ARB routes at 280^{0}C and 380^{0}C, using thickness reductions per pass of 30%, 50%, 70%, and 90%, were performed. It has establish that the ultimate nano grain size (100 nm < d < 500 nm) achieved as well as the degree of bonding, depend on the rolling temperature and on the thickness reduction per pass. Higher temperatures and higher reductions promote a larger degree of bonding. Increasing strain also favors the formation of a more homogeneous microstructure. The smallest grain sizes have obtained at the lowest rolling temperature.

Keywords: Nano grained microstructure, ultrafine-grained (UFG) materials, Accumulative roll bonding, Severe plastic deformation.

I. Introduction

Over the last decade, nanostructure and ultrafine-grained (UFG) materials with an average grain size of less than 1 μm have produced significant attention due to their mechanical characteristic in terms of strength, ductility related to conventionally grained (CG) materials [1]. They have a stout possible for future engineering uses as structural, high durability modules in automobile, aerospace and medical engineering. The ultrafine-grained sheet materials can be successfully produced by a comparatively new method named Accumulative Roll Bonding (ARB). This process belongs to the group of Severe Plastic Deformation (SPD) techniques, and it was firstly established and primarily presented by Japanese scholars Saito et al [2]. The ARB process was primarily achieved on commercial purity aluminum. It involves repeated stacking and rolling of the usually grained metal sheets in order to improve an ultrafine-grained structure. In addition the ARB process[1], there are many additional approaches all go to the severe plastic deformation (SPD) techniques, which can be used to achieve an nanostructure or UFG microstructure and hence attain an improvement in material strength and ductility; these consist of: Equal Channel Angular Pressing (ECAP) originally known to by Segal in the start of 80s [3] and earlier commercialized by Valiev and co-workers [4], High Pressure Torsion (HPT) [5], Folding and Rolling (F&R) [6], etc. Though, the major existing restriction of most SPD techniques like ECAP and HPT is the up scaling of the process to bulk production for viable uses. Instead of, the ARB process is an acceptable technique for real applications subsequently it can be certainly scaled up and modified to a conventional rolling process to produce bulk UFG metal sheets [10].

II. EXPERIMENTAL PROCEDURE

In the ARB process, the faces of two aluminum sheets are wire brushed, arranged on top of each other and rolled together to a 50 % thickness reduction. The two aluminum sheets bond in the course of rolling and can then be halved and roll bonded again. The process is typically repeated up to 7 to 8 times. Cumulatively the integer of ARB cycles indicates to an increase in yield strength, tensile strength one or both ductility. Hence, nanostructure aluminum and aluminum alloy sheets with extraordinary strength are of scientific importance and have established significant attention as likely applicants for new lightweight and high durability manufacture materials in the automotive engineering. ARB process manufacture high strength nanostructured metal sheets, comprehensive research on nanostructure development, mechanical properties, sheet metal forming prospective and join ability must be find out. The sheet forming ability of the ARB processed materials is very vital for a successful use of these recent elements of materials in mechanical uses. Distinctive examinations which can be used to assess the sheet metal forming ability are hydraulic bulge test [7] and cup drawing tests. On the other hand, only limited amount of data are obtainable in the literature on the sheet forming ability of the nanostructured sheet materials, which is typically due to limited ARB sample size [8]. Thus, fine-grained Mg alloys would be susceptible to be formed into complex parts in one single operation by super plastic forming. In this paper, the efficiency of ARB[9] to produce a fine-grained microstructure in the Mg based Al(6%), Zn (2%)alloy is investigated.

III. RESULTS AND DISCUSSION

Fig. 1 shows the grain growth of the AZ62 alloy upon accumulative roll bonding at 280 ^{0}C. After the first two passes of, in that order, 30% and 50% reduction (ARB0)(Fig. 1a and b), a bimodal microstructure appears, which is created by regions inhabited by large grains as well as a comparatively large volume fraction of small, recrystallized sub grains, that are not resolvable via optical microscopy. The later are primarily grouped forming bands at 45^0 with the rolling direction. In a earlier paper [11], on large strain hot rolling of this AZ62 alloy, it was accomplished that this mixed microstructure is a effect of the operation of several dynamic recrystallization mechanisms. Given the initial strong basal texture, most of the grains are not satisfactorily oriented for slip. Therefore, during the first pass with 30% reduction, relatively large stresses accumulate in the areas close to grain boundaries. This gives increase to a localized motion of dislocations, consequently in the rotation of the "mantle" regions to orientations that are more prone to slip under the rolling conditions imposed. This process is termed rotational recrystallization (RRX) [12].

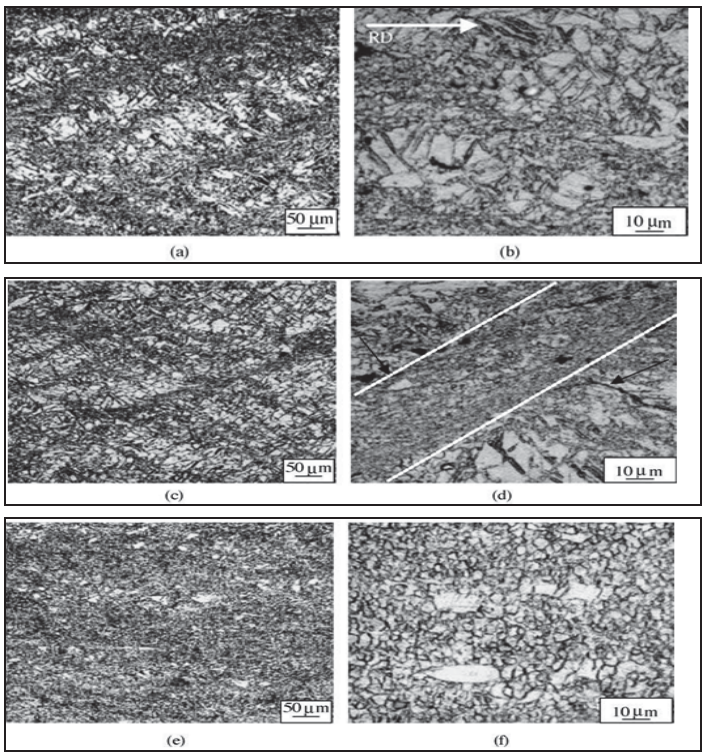

Figure. 1. Micro structural evolution of the AZ62 alloy after accumulative roll bonding at 380 ^{0}C. (a and b) ARB0: 1 pass with 30% reduction and a second pass with 50% reduction; (c and d) ARB1: a third pass with 70% thickness reduction; (e and f) a third pass with 90% reduction. The rolling direction is the horizontal

The microstructure would then be prepared to put up additional rolling reductions second pass with 50% reduction), with deformation taking place mostly in the "yielding zones" or regions produced by bands of small grains rotated away from the original grains with basal orientations. The bigger grains would be the remains of the original grains. subsequent to further ARB pass (ARB1) with 70% thickness reduction (Fig. 1c and d), a alike microstructure form, even though with a slighter portion of outsized grains formed Again, this could be restructured, by considering that continuing RRX would add to raise the fraction of small grains at the expense of the large ones. Deformation take place at 45^0 angles with respect to the rolling direction are here also evidently observable. Fig. 1d illustrates the border line between two slabs after ARB with a thickness reduction of 70%. It can be observed that bonding of metals takes place generally on the areas covered by the shear plane, where the interface becomes more or less invisible. This yet again reflects the actuality most of the deformation is accommodated in these areas. Finally reduction of 90% is applied during ARB process (Fig. 1e and f), the grain growth becomes relatively homogeneous. The cause may be attributed to the dispersion of the RRX mechanism. The final grain growth size achieved, about 2 µm, is greater than that obtained within the deformation bands apparent with smaller ARB reductions. The larger amount of strain energy accumulated on the material as a significance of the higher thickness reduction per pass might represent a operating force for grain growth.

Figure.2 shows the development of the grain growth after ARB at 280^0C. In common terms, the same patterns can be experience as those described above for the samples ARB processed at 280^0C.

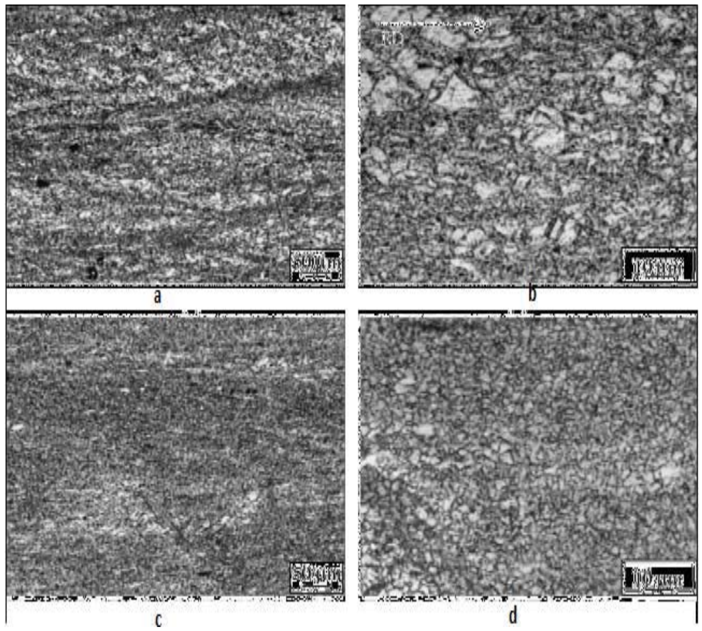

Figure 2. Micro structural evolution of the AZ62 alloy after accumulative roll bonding at 280 ^{0}C. (a and b) ARB1: a third pass with 70% thickness reduction; (c and d) a third pass with 90% reduction. The rolling direction is the horizontal.

ARB pass with 70% reduction (Fig. 2a and b) have a grain size distribution is still there. It has to be distinguished that the recrystallized grains growth is now smaller than those obtained at lower temperatures. This is due to the slowest rate of diffusion at this lower temperature. Upon higher reductions (Fig. 2c and d),homogeneous microstructure of grains develops another time with a smaller grain size (about 1–2 μm) at its 380^0C. In order to examine the degree of bonding, the ARB processed samples were afterward annealed at 380^0C for 45 min. Fig. 3 shows the interfaces related to the samples that were roll bonded at 380^0C with 70% thickness reduction (Fig. 3a), at 380 ^{0}C with 90% reduction (Fig. 3b), and at 280^0C with 90% reduction (Fig. 3c).

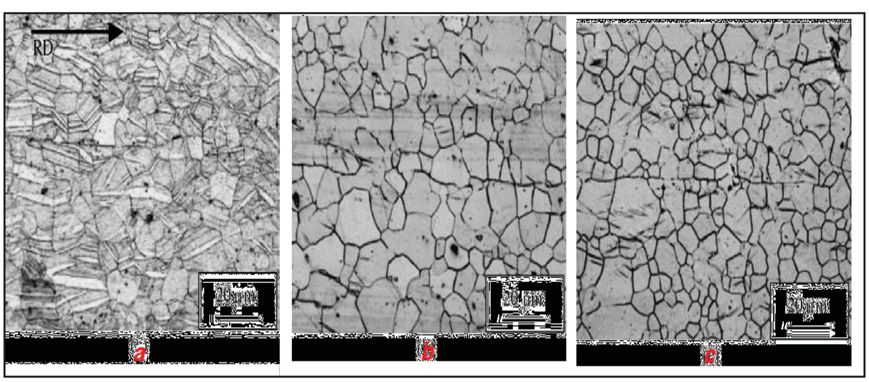

Figure. 3. Optical micrographs showing the interface between two adjacent layers, after accumulative roll bonding under different conditions. (a) 380 ^{0}C with 70% thickness reduction; (b) 280 ^{0}C with 90% reduction; (c) 280 ^{0}C with 90% reduction. The rolling direction is the horizontal.

It observed that bonding has taken place successfully at a definite region when the interface becomes invisible. The successful bonding. It is also observed that degree of bonding is better at higher temperatures and with larger rolling reductions. In particular, in the samples of metal piece that were rolled at 380^0C using an ARB reduction of 90%, the fraction of bonded interface is approximately 50%. Therefore, the present results specify that, despite the fact that a remarkable microstructure grain size refinement can be obtained in the Mg based Al-Zn alloy via ARB process. The degree of bonding achieved is not very superior. On the other hand, current investigations on diffusion bonding of a Mg AZ31 alloy have shown that bonding degrees of about 50% are sufficient to avoid deterioration of the mechanical properties [13]. Further work is currently being performed in order to investigate the mechanical properties of the ARB processed metals work pieces samples.

IV. SUMMARY

The feasibility of accumulative roll bonding is to produced very fine microstructures grain size,of AZ62 Mg–Al alloy was investigated. The subsequent conclusions can be drawn from this study:

a). ARB process does produced a spectacular grain size refinement. The grain sizes on the submicron range can be obtained after only 1 ARB pass with 70% thickness reductions. Lower temperatures support the appearance of smaller grain sizes. Larger reductions per pass result in increasingly homogeneous microstructures.

b). The degree of bonding achieved between the different roll bonded layers only amounted to about 50% under the most approving processing conditions.

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