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Manufacturing of bimetal 1060/5083 composites via accumulative press bonding

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Abstract: In this study using accumulative press bonding (APB) process, bimetal AA1060 and AA5083 have been fabricated. The aluminum bars were first press bonded and then this process continued up to five pressing steps. In the APB process, the composite samples were preheated at 320°C for 7 min before each pressing step. Mechanical-properties-of the-AA1060-AA5083 composites were appraised in appraisal to AA1060-AA1060 and AA15083-AA5083 accumulative press bonded single alloy MMCs, and this is done for the first time as its novelty. It was found that both aluminum alloys deform in the same way in the AA1060-AA5083 composites-up-two-APB steps and then AA5083 layers began to neck. Also, it was found that the average strength of the AA1060-AA5083 composites is more than that of these-two-single-alloy MMCs. Moreover, by using-scanning-electron-microscopy (SEM), the effect of APB steps on the fracture surfaces of bi alloy composites have been investigated.

Keywords: Bi alloy matrix-composites (MMCs); Fractography; Mechanical properties

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1. Introduction

There is a grwoing need for the use of bi metal or bi alloy composites due to their desirable properties. There is a chance to get several properties together y by combining several metals or alloys through the composite matrixes (Bokov et al., 2021; Kianfar et al., 2019a, 2019b). So, bi-alloy composites are predominant in use in important productions such as vessels, automobile and aerospace industries due to their appropriate advents such as light weight, low density, high corrosion resistant, high wear resistance and high mechanical strength (Korbel et al., 1981; Radhy & Jasim 2021; Saito et al., 1999). In producing "ultra fine grain (UFG)" structures, sever plastic deformation (SPD) methods are famous processes. Some of these methods are equal channel angular pressing (ECAP), powder metallurgy (PM), accumulative roll bonding (ARB), equal channel angular rolling (ECAR), multi axial forging (MAF), cyclic extrusion compression (CEC) and so on. During this technique, APB process which is a type of the solid phase welding method is a pressing process conducted on bars which have the particular. Usually and looks like many other SPD deformations, layers bond together during the pressing process and thickness reduction ratio for each step is 50% and. So, cutting, brushing, surface cleaning and stacking of bars together for the next step ate cutting, brushing, surface cleaning and stacking of bars together for the next step in the APB process (Farhadipour et al., 2017; Kok, 2005; Sedighi et al., 2016). It is stated that during the forming process of bi metal or bi alloy laminates and composites at low number of the process steps, both of soft and harder materials deform in a same style (Heydari Vini et al., 2017; 2018; Mostafapor & Mohammadinia 2016; Rajan et al., 2007;). But, by growing the plastic strain of the process, the harder material fractures which lead to the spreading of harder material in the soft material matrix. Hence, the strength of the composite progresses significantly, regardless of the breakage of the hard layers (Chaudhari & Acoff, 2009; Vini & Daneshmand, 2019a; 2019b). AA1060-AA5083 MMCs via APB process with higher toughness and strength have been fabricated in this study. Firstly, the material preparation and fabricating process has been clarified. Then, mechanical properties and the microstructure evolution of composite samples such as elongation, toughness, strength and fracture surfaces after the tensile test have been studied.

2. Materials and methods

2.1. Materials

In this study as raw materials for the APB process, two fully annealed aluminum alloys 5083 and 1060 were used. Tables 1 and 2 show the detailed chemical compositions of these alloys, respectively.

Table 1. The chemical-composition-of AA5083.

Element	Al	Mg	Cu	Ti	Zn	Mn	Fe	Si
Wt. %	balance	4.53	0.07	0.004	0.24	0.51	0.183	0.25

Table 2. The chemical-composition of AA1060.

Element	Al	Mg	Cu	Ti	Zn	Mn	Fe	Si
Wt. %	balance	0.04	0.06	0.003	0.06	0.031	0.032	0.252

2.2. APB processing

First of all, aluminum alloys 1060 and 5083 bars were fully annealed. Then, as the primary samples, Al bars of 190×16×6 mm were machined. Then to eliminate the oxide layer from their surfaces, they were decreased in acetone bath and scratch brushed. All the samples were preheated at 330Ċ for 8 minutes. While its wide is constant during the process, all the samples were pressed with a thickness reduction ratio of 50% in a pressing die, Fig. 1, and this process was repeated to five steps. The APB steps of the process are summarized in Table 3.

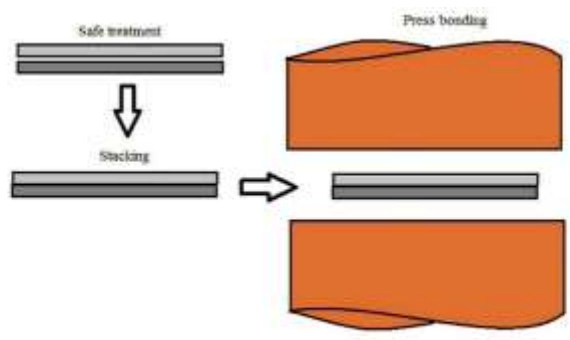

Fig. 1. The schematic illustration of the cumulative pressing process.

Table 3. the APB process steps for fabrication of AA1060/AA5083 bi-alloy composites.

No. of steps	Pressing temperature (°C)	No. of composite layers	Reduction in steps (%)	Composite layer thickness (μm)	Final reduction (%)	1. lastic strain
1	320	2	50	5000	50	0.8
2	320	4	50	2500	75	1.6
3	320	8	50	1250	87.5	2.4
4	320	16	50	625	93.75	3.2
5	320	32	50	312.5	96.87	4

To design the pressing process, a press machine with a capacity of 100 tones is used in this study. To perform the tensile test, the ASTM standards E8M has been used. Also, standard ASTM-E384 with a 500 grams' load during fifteen seconds were used as the Vickers hardness testing condition. To measure the hardness of samples, more than five point on the surface of each sample have been tested and the average value was reported.

3. Results and discussion

3.1. Tensile strength

Fig. 2 shows the bonding among AA1060-AA5083 layers. The strain hardening of aluminum alloy 5083 is more than alloy 1060 through the composite matrix due to the higher strength of aluminum alloy 5083. So, at steps one and two, thinning both alloys are the same and at the higher number of APB steps, the thickness of 5083 layers begins to change because of an inhomogeneous deformation, Fig. 2. After step #2, 5083 layer starts necking some zones with more deformation, Fig. 3. After necking and disruption of harder metal through the softer matrix, these particles can be considered as reinforcement phase.

Fig. 3 shows the difference of the tensile strength of bi alloy samples. According to Fig. 3, the strength of samples increases incessantly (maximum value 361MPa) by increasing the APB steps up to five steps. At lower number of steps, (I): grain boundary strengthening and (II): dislocation strengthening are the main factors affecting of the increasing of the tensile strength of composite samples (Soltani et al., 2017). So, (I): local strain hardening of aluminum alloys and (II): necking of 5083 layers and dispersal of them in the softer 1060 matrix are two other factors affecting of the increasing of strength.

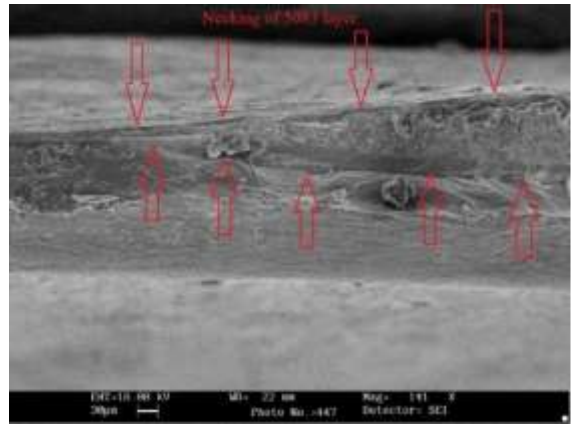

Fig. 2. The cross section of APB processed-materials-after three steps (SEM image).

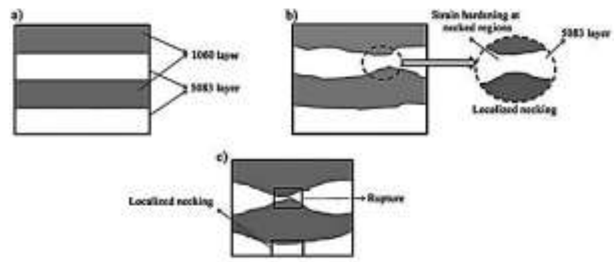

Fig. 3. Schematic micrographs of specimens after APB processing for (a) before step#1, (b) two and (c) five steps.

The elongation difference of samples vs the total of APB steps is shown in Fig. 4. According to Fig. 4, The elongation of samples increases from 1 2.51 for step #1 to 7.82 for step #5. which is due to (I): increasing the bond strength between alloys 1060 and 5083 before rapture of 5083 layers and growing the bond strength between Al layers and (II): dynamic recrystallization of both of aluminum alloys matrix.

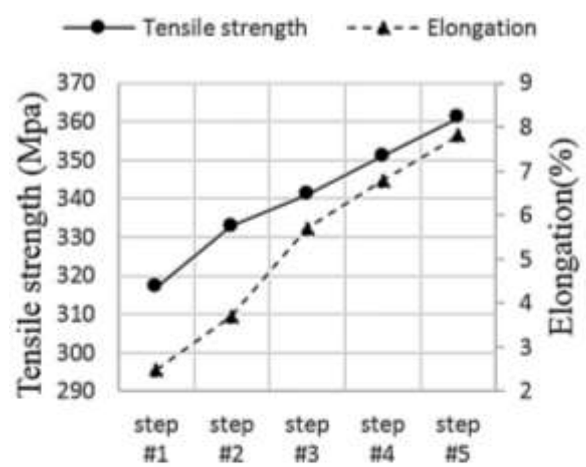

Fig. 4. Mechanical properties of the AA1060-AA5083 composites produced by the APB.

Fig. 5 shows toughness variation of 1060-5083 bi-alloy composites. Growing in the strain and strength amounts of the samples through the APB process makes upper toughness value of the manufactures 1060-5083 bi-alloy composites. So, the toughness improves up to step #2 (2.22 $j.m^{-3}\times 10^{4}$) first and this trend becomes faster to step #5 (5.62×10^{4} $j.m^{-3}$), Fig. 5.

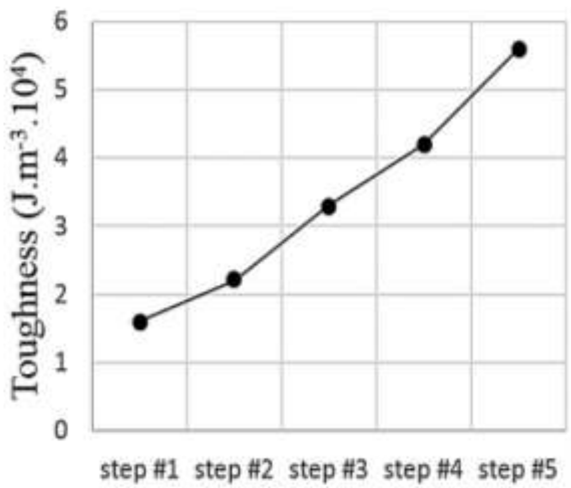

Fig. 5. Tensile toughness vs the APB steps.

The evaluations of their strength vs. the APB steps for three kinds of composites are illustrated in Fig. 6. Their strength increases vs the APB steps. Also, for each number of APB step, the strength of 1060-5083 samples is more than two others which is due to the scattering of fractured harder 5083 layers through the softer matrix (1060).

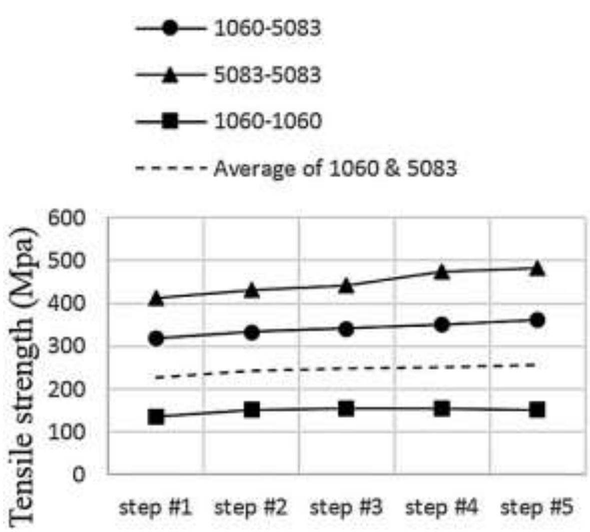

Fig. 6. The strength of bimetal composite vs the APB steps.

By growing the APB steps, the elongations of all three kinds of samples improves, Fig. 7. Finally, the elongation amplitude of 1060-5083 samples in each step is among the amounts of 1060-1060 and 5083-5083 samples, Fig. 7. Also, by increasing the strain, the porosities through the metallic matrix reduce and leads to increasing the density of composites.

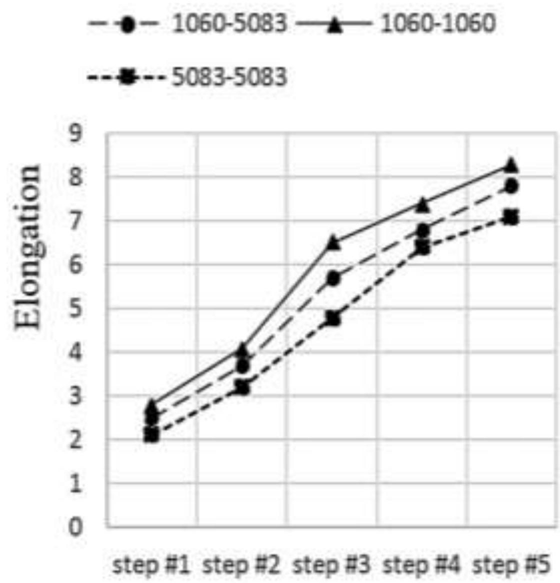

Fig. 7. The elongation of samples vs APB steps.

3.2. Fractography

Figs. 8 and 9 show the rupture mechanism of samples after one and five steps. According to Fig. 8(a), ductile fracture containing deep dimples are shown in zones of aluminum alloy 1060 with one step whereas the fracture surface of aluminum 5083 in the same steps involves of shear zones, Fig. 8(b). This change is due to the lower strength of AA1060 in comparison with AA5083. Figs. 9(a, b) show the fracture surfaces with one and five steps comprised of dimples and shear zones. By increasing the forming strain, the deepness of dimples losses and they are not as lengthened and deep as formerly. So, shear stresses lead to combination of micro voids in the structure.

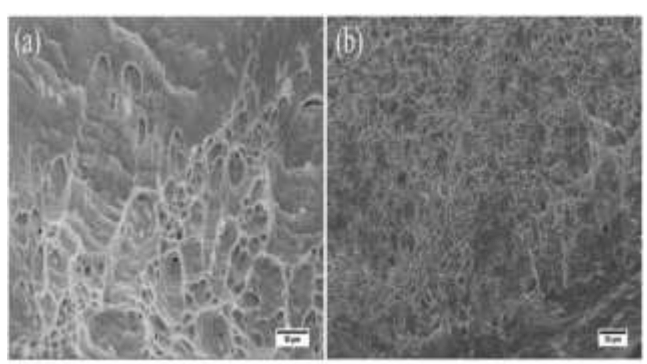

Fig. 8. The fracture-surfaces-of (a) zone of AA1060 and (b) zone of AA5083 with 1 step.

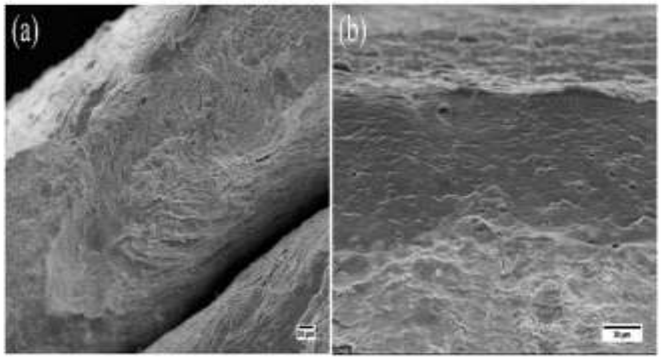

Fig. 9. The fracture surfaces -with- (a) -
one-and (b) five step.

Conclusions

In this paper, AA1060 and AA5083 are collective to produce bi alloy1060-5083 MMCs. On the base of experimental study, the followings are comprised:

1. The strength of samples extends to a maximum value of 362 MPa (step #5) which is about 1.17 times more than step#1. The strength of the bimetal composite was more than the average
2. of both primary metals and monolithic multilayered samples.
3. The maximum elongation of sample after step#1 is 2.51 % and advances 7.8 % after step#5. The APB process has an improving effect on the elongation of samples due to the dynamic recrystallization during the process.
4. By enduring the APB process, the tensile toughness amplitude earns the value of 5.6 jm^{-3} which is 2.54 time more than that of step#1 (2.2 jm^{-3}) due to the enhancement of strength and strain of composite samples fabricated at higher number of APB steps.
5. Before two APB steps, both of AA1060 and AA5083 layers deform in a close manner. Then, the necking of 5083 layers and its distribution in 1060 matrix advances the strength of the final MMCs by growing the steps in reverence to 1060-1060 and 5083-5083 MMCs.

Conflict of interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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