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Phase Transitions for Al-base Alloy on Themicro Structural Experimental Measurements

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ABSTRACT:The ternary Al-base alloys were re-melted and processed with a rapid extraction of thermal energy. In an effort to find the influences of the temperature on the solid transition, the materials were annealing at 500 °C during 48 hours. The effects of the rapid extraction of thermal energy plus the phase transition on the morphology were studied by SEM. Microstructural morphology has been related to mechanical properties thought-out the high cooling rate. In order to provide a means of determine their mechanical properties,the microhardness, and tensile tests have been characterized. The microstructure refinement of ternary Al-base alloy was observed due to melt undercooling associated with the cooling rate. The transition phase process from melt to solid by conventional methods of melting and casting has been approached by cooling rate parameter.A successful approach to finer microstructure is correlated with the grain size measured. Reduced grain size results depends on increased cooling rates because nucleation events become more frequent by establishing a positive temperature gradient in the melt ahead of the advancing solid-liquid interface. The purpose of the present study in this paper, is evaluatethe relationship between microstructure, rapid extraction of thermal energy, and the mechanical properties as hardness and tensile tests.The present investigation clearly compared the hardness measurements inthe Al-VIIB-VIB alloy processed at high cooling rateswith the less microhardness values from the annealed condition. Correlation between tensile tests results and fracture type indicate that a transgranular + intergranular mode depend on the solidification route compared with the microstructural changes associated with an increment on grain-size refinement.In both cases, in as-spun and annealed condition grain size was found to depend significant on the magnitude of the cooling rate parameter obtained by the wheel speed velocity.

KEYWORDS: Thermal energy, Phase transition, Morphological microphases, Structure, Mechanical performance.

I. INTRODUCTION

The past years has seen a dramatic surge of interest in the study of high-strength, high-performance, and cost-effective materials. That led to improvement of processing methods for the development of metallic alloys with attractive combination of microstructure and mechanical properties. The microstructural properties could be achieved by chemical alloying, stoichiometry control, liquid to solid quickly transformation, and thermal process [1,2]. In fact, based on metallurgical understanding a considerable improvement on mechanical properties can be achieved too. In actual practice, the primary emphasis is to improve the properties of alloys by rapid solidification process [3].
The extreme rates of heat removal on topological metallic surface and thermodynamically unstable melts can affect not only the formation of unique microstructure. The effect of rapid solidification process can be used toreduce embrittlement mechanism and improve the ductility. Indeed, the physical solidification phenomena permit large deviations from equilibrium, achievable through rapid extraction of thermal energy [4,5]. Traditional approaches use the summary of solid solubility limits, reduction in the size and number of segregated phases with potentially important development of nonequilibrium phases [6].The various processing techniques used to achieve rapid quenching with specific application to aluminum alloys were critically examined. A laboratory test system of chill block melt-spinning technique [7] outlines the methodology that makes an excellent method to relate the fast cooling rate on the

solidification process. Effective application of superheat and latent heat during the transition from the liquid state to solid material could be used with the casting design that allows the shortest possible lead times and permits to study the potential of rapid solidification on microstructure and mechanical properties. In more recent study [8,9], the mechanical behavior of Al-VIIB-VIB alloys manufactured by rapidly solidification technique had been mainly reported in terms of hardness and mode of failure after tensile tests. Furthermore, the Al-VIIB-VIB alloy has been barely studied in relationship with their ductility.Over the past decade, considerable research efforts have been directed at improving the alloys by extrusion with subsequent annealing [10, 11]. More recently, the Al-VIIB-VIB alloys were investigated to determine the effect of processing technique upon microstructure and mechanical properties. A study encompassed an Al-VIIB-VIB alloy with different composition [12, 13] tested under tension. The results of this study showedthe ductility measured by percent elongation. This ductility was attributed to a fine grain size. This grain size involving interactions with another microstructure reported for that alloy, the researchers found the presence of particles of Cr_2Al on fracture surfaces [14, 15]. These particles have been reported as the principal factor of an increment in yield strength with a simultaneous reduction of ductility [16, 17]. On the other hand, a previous work of Al-VIIB [18] was viewed as the results of a mixed mode of failure strongly depend on the conditions under cleavage plus intergranular fracture mode and a cleavage way to failure. Another potential source of improve the mechanical properties could be moved into the liquid to solid transition phase through the melting and solidification experiment under suitable conditions [19]. Concurrently, the relationship between the cooling rates and the refinement of microstructure were controlled by the tangential velocity of the spinning wheel. In an effort to find the relationship between processing, microstructure with chemical specie the addition of macro and micro alloying elements were evaluated [20,21]. Thus, it is evident that origin of a performance material allows updating the control,precise measurements, accurate data and inherent advances of technology. These topics provide a result to increase knowledge of tetragonal relationship associated with process, microstructure, properties and performance of materials in terms of the lattice parameter, grain size, solubility of solute chemical element and mechanical properties.

II. MATERIALS AND METHODS

*II.A.Aluminum alloys melting experiments.*Undercooling a melt to produce the required grain refinement by applying the optimal cooling rate initiated with ingots from as-cast procedure. Some metallurgical as-cast conditions were obtained by high-frequency vacuum induction furnace. Thebinary Al-VIIB ingots have an elemental composition of 60at. % VIIIB element (balance) %Al and a third chemical element the VIB added with 5 at.The alloying addition has been associated with the importance of solute redistribution during the freezing, due to solute induced undercooling that is essential to the nucleation sites. Stoichiometric amounts of mixing pieces from Al, VIIB and VIBchemical element with a purity of 99.9 % were placed in a machined graphite crucible and induction heated. The alloys were subsequent chill casting in arectangular cooper mold dimensions of 20×50×90 mm. To further understand the effect of melt conditions,small cubic pieces ($1cm^3$) were obtained from cast ingots by cutting with a diamond blade which were used to metallographic analysis and rapid solidified samples.

*II.B. Processing for rapid solidification.*An attractive technique for rapidly solidifying the molten alloy it to cause it to fine drops formed by a small amount of cubic as-cast pieces of Al-VIIB-VIBalloy in an inert quartz tube nozzle with a 1mm diameter orifice under argon atmosphereinjected at 34.47 KPa from the top of the crucible. To achieving a rapid solidification, imposing a high cooling rate during solidification by spilled the liquid alloy into the rotating wheel at 12, 16 and 20 m/s tangential speeds.With the control of rotating wheel we achieve cooling rates of 0.715×10^6 K/s to 1.38×10^6 K/s. For these conditions ribbons of 20 to 90 μm thick and 2 to 3 mm width were produced. The ribbons were annealed at 500 °C during 48 h in order to induce vacancies removal.

*II.C.Metallographicdevelopment.*A basic method for evaluate the microstructure as well as microcracks in metallic surfaces has been used. The surfaces of as-cast and melt-spun conditions were prepared on the transversal area sections between roll-contact and not roll-contact. The metallographic preparation has been done by standard technique of grinding with SiC from 240 to 1500 grit paper and mechanical polished with 0.5 and 0.05μmalumina powder. The sample in as-cast condition was etched by swabbing in the following mixture with percent in volume, 50 % CH_3COOH plus 33 % $HNO_3$and more 17 % HCl.For investigations concerned with chemical variations and detailed comparisons

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of microstructural features the ribbons were etched in a Keller's reagent, which contained 5ml of HNO_3, 3ml of HCl, 2ml of HF and 190 ml of H_2O; the etching was done at room temperature for 10s.

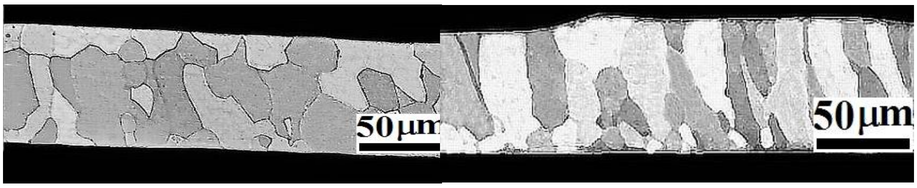
*II.D. Combined SEM/OM analysis.*The combination of scanning electron microscopy (SEM) with Optical Microscopy (OM) is a useful tool for a broad characterization. In order to reveal grain size, morphology surface quality, impurity levels and understanding of mechanisms underlying Al-alloy performance the combined microscopy analysis has been done. A scanning electron microscopy STEREOSCAN-440 was used to observe microstructure. An energy dispersive X-ray spectroscopy OXFORD Isis 300 from SEM equipped performs punctual chemical analyses. The samples were analyzed with X-ray powder diffraction (XRD) In order to determine crystal structure and phases identification, a Siemens D5000 X-ray diffractometer with a power of 40 kV accelerating voltage and 30mA current, using Cu tube of Kα line radiation: $\lambda = 0.15406$ nm, and a diffracting beam graphite monochrometer. The XRD data of the alloy samples were recorded on a computer-interfaced. The diffraction patterns were scanned in the 2θ range, step size of 0.02 deg., and time per step 0.6 s. TheDIFRACT/AC software was used to obtain information about the crystal structures.

*II.E. Microhardness.*The microhardness tests have been related with the mechanical properties of the alloys as well as the physical properties of materials. The harness number has been defined by the ratio between the indentation load and the area of the residual impression, associated with the indenter shape. The Vickers hardness values for microhardness indentations were carried out with a tester INSTRON model 210013 on the cross sections of the samples using a load of 490.3 mN applied for 10 s in air at room temperature and at least ten impressions were recorded of each sample. The tests were not performed in the big flat surfaces of ribbons. Instead of that, the Vickers tests were done along the ribbons longitudinal thickness face. The maximum and the minimum values of microindentations were excluding and the experimental error was estimated.

*II.F. Tensile test.*A potentially valuable use of ternary Al-VIIB-VIB alloy for automotive applications and structural uses, has been conducted to evaluate the essential requirement of the rapid solidification stage with the mechanical property behavior thought-out the tensile ductility or elongation values.The tensile specimens of the Al-alloys ribbons were deformed at room temperature (20 ºC) in air using a screw-driven universal testing machine operating with a constant grip velocity at an initial strain rate of $1 \times 10^{-3}\ s^{-1}$. Fractographic analysis was performed to report their failure mode and the transgranular range percent was determined in each fracture surface by digital image analyses.

III. EXPERIMENTAL RESULTS AND DISCUSSION

It is interesting to note that the microstructure of the as-solidifiedas-cast metals exhibit a recognized refinement of the grain structures by the presence of soluble solutes and by heterogeneous nucleation of grains [22]. Furthermore, comparison of the microstructures from rapid solidification during melt-spinning shows that imposing a high cooling rate during solidification promotes the formation of microstructural refinement with the formation, in some alloys, ofamorphous structures or quasicrystalline phases. Particularly in the microstructural examinations ofAl-VIIB-VIB alloyassociated with manufacturing at 12, 16 and 20 m/sof tangential wheel speeds shows a drastic reduction in grain size. When the Al-VIIB-VIB alloy has been manufactured by rapid solidification the combination of three kinds of grains has been observed. The grain morphology of Al-VIIB-VIB was chill, equiaxial, and columnar has shown in the Figure 1. The grain morphology is associated with the wheel speed of the alloy produced. For the alloys in figure (a) and (b) the wheel speed was 12 and 16 m/s while the alloy drop onto the cupper wheel. A grain with predominant columnar morphology was observed for the ribbons at 16 m/s, while the ribbon fabricated at 20 m/s shows equiaxial and columnar grains.A successful approach to produce the required grain refinement by applying the optimal cooling rate depends on process parameters and small fluctuations in melt composition. In this work the process parameter controlled was the wheel speed. The size of the equiaxial grains of the melt-spun Al-VIIB-VIB alloy, exhibited a reduction from 24.7 µm to 6.61 µm when increases the wheel speed from 12 to 20 ms^{-1}. The columnar grain decreases in width from 30.4 to 6.4 µm at the same value of wheel speed.The relationship among the tangential wheel speed (V, m/s) with the ribbon thickness (t, µm) is available according to the mathematical expression: $t \propto V^{-0.6}$. More recent work on these kind of alloy has employed a $t = 390V^{-0.61}$by a ribbon which was expelled from a crucible with a diameter of 1.9 mm, however when the crucible diameter was 1.6 mm the relation was $t = 270V^{-0.59}$ for Fe15Cr10Ni and Fe13Cr11Ni alloys.Therefore, the dependence of ribbon thickness with the lineal speed of substrate varies slightly with production parameters and alloy system. This is a particularly interesting observation since the ribbon thickness (t, µm) and the tangential wheel speed (V, m/s) was found to be a factor contributing to the observed morphological differences in grain structure [21].The final microstructure and distribution of phases results in significant undercooling of the melt, microstructural effects include refinement of features such as the dendrite arm spacing, and the sizes of constituent particles, dispersoids and precipitates. Segregation of phases or phases in the alloy usually adopts one of several regular packing structures, thus the Al-VIIB-VIB alloy solidified in as-cast, in as-spun ribbons and annealed conditions exhibit a cubic structure confirmed by XRD analyses. The effect of wheel speed can be related with the grain size, and the lattice parameter throughout the Table 1.



(a) (b)

(c)

Fig. 1.The grain size from as-cast solidification samples has been improved when extreme rates of heat removal have subsequently exposed on Al-VIIB-VIB alloy, figure 1 (a), (b) and (c). The figure 1, shows the internal structures by an optical micrograph from the melt-spun Al-base ribbons solidified at (a) 12, (b) 16and,(c) 20 m/s.

The Al-VIIB-VIB alloysystem studied by the X-ray diffraction in Table 1 summarizes the crystals structure and allows us to determine the lattice parameter. Specifically, with the three fundamental diffraction peaks and the three super lattice diffraction we can deduce that the cubic lattice exhibited a decrement related with the grain size. In addition the B2 ordered structure is not modified by the Cr stoichiometry, and also were not detected additional peaks pertaining to second phases neither in as-spun or annealed ribbons. An important microstructural characteristic frequently associated with the high wheel velocity and high cooling rate is the extension of solid solubility, for that reason could be suggested that Cr enters in solid solution in the intermetallic B2 matrix. This is according with a previous study of Al40Fe alloys [11, 19] added with Cr. One of the primary concerns with this type of XRD analysis that the lattice constants of annealed Al-VIIB-VIB alloys exhibited a slight decrement in relationship with ribbons in as-spun condition, as is listed in Table 1. The comparison of the diffraction pattern for the physical alloys provides an illustration of the distinction between an as-spun structure and annealed lattice structure.In previous work, the Cr generates a diminution of vacancy concentration and also a hardness decrease. In our case the reduction of lattice constant after annealing, showed in Table 1, could be due to a combination of a vacancy reduction plus an ordering mechanism, both of them induced by the chromium addition. The conventional viewpoint it that because the different atoms in the solid solution possess atomic form factors or the local symmetry effects. A useful comparison, that everybody known, is an attractive demonstration between two different metals mixed up. Due to the relative sizes of the atoms may be created two types of alloys determined by either single-phase or two-phase. This data, together with heat flow during the solidification process, permitted an estimate of the microstructure relationship between the casting processes with the nature and chemical stoichiometry of the alloy. We have been showed theoretically that the increase in the cooling rate from casting processes to melt-spinning shows a drastic reduction in grain size.More application-oriented work on this theme shows that the cooling rate during solidification has the single most important influence on the microstructural refinement. One of the advantages of the microstructural refinement has been associated with the toughness improvement. There are, however, a number of additional properties in achieving good performance with respect to these properties. For example, the formability, fatigue crack growth resistance, fracture toughness, and

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corrosion resistance. In all this studies it has been considered that the microstructure was dominated by heterogeneous nucleation mechanisms. A mechanism for homogeneous nucleation plays a dominant role during the solidification at low cooling rate under well controlled experimental conditions, which is contrary to the case in this actual work. However, when is compared the microstructure of grain size with different candidate alloy development at extreme rates of heat removal during rapid solidification processing, exhibit superior combinations of strength, toughness and stress corrosion resistance has been observed. It is an important consideration and also an attractive alternative since high-strength alloys are candidate aircraft structural materials.

Wheel speed V (ms^{-1})	Grain Size (µm)		Lattice parameter (́)	
As-spun and annealed	As-spun	annealed	As-spun	annealed
12	30.42	21.59	2.8898	2.8874
16	22.58	13.27	2.8963	2.8881
20	6.48	6.39	2.8933	2.8900

Table 1 Relationship of wheel cupper speed with de variations of lattice parameter for each crystalline structure associated with the grain size of theAl-VIIB-VIB alloy. Considering that the grain size decreases when the wheel speed increases. In addition, the lattice parameter determined by XRD analyses, shows variations related linearly with the grain size.

At the same time, the property of materials occurs predominantly by the microstructure formation during the manufacturing process, as the melt spinning rapid solidification one.According to this statement, has been sponsored many efforts to produce high strengthening alloys. These structural materials combined the high strength with axial fatigue strength and restricting grain growth that could replace more dense Ti- alloys. In order to establish the influence of speed velocity on grain size and the mechanical properties of the Al-VIIB-VIB alloy this investigation contributed with the results of the elongation value, ductility and tensile strength.These results have been evident compared in two conditions, one of them was the annealing way and the second one was in as-spun condition. It is generally recognized that the annealing process has a behavior analogous to a recrystallization process after deformation [9]. The literature contains many papers dedicated to the study of the annealing behavior with partially grain refinement. Either or both of these annealing or recrystallization process can be explained due to a great quantity of defects that could be originated, in annealing operatesafter the rapid solidification process. For the investigation of annealing when solidification was complete, the influence of dislocations has been considered as possible parameter. This is almost certainly due to the dislocations that can be grouped in tangles, and subsequently new cells or subgrains bounded by dislocations walls should be formed during annealing. The present results are for Al-VIIB-VIB alloys that indicate the important role in determining themechanical properties related to conventional high-strength alloys. In summary, the results highlighted the outstanding combinations of structure and properties with specific features like the effect of grain size. These microstructural grain refinements presumably demonstrate the concomitant effects of high rates of solidification with outstanding new generation of materials with solid solubility extensions of alloying elements, plus a metastable crystalline phase formation with some amorphous structures as well as quasicrystals. In our present work, the grain sizecould have contributed effect for the ductility improvement in as-spun Al-VIIB-VIB alloys. It is well known that the reduction of grain size has been a consequence of the rapid solidification processing. This is one of the various intrinsic features usually observed in rapidly solidified alloys. The main cause of mechanical behavior it has been associated with the refinement of grain size, as can been seen in the table 2. An improved Al-VIIB-VIBalloy system can be observed from table 2. The alloy can be hardened in as-spun condition; however the elongation to fracture was improved after annealing.This behavior was characteristic for the case of ribbons produced at 16 m/s, where the elongation value increased from 0.94 to 1.16 %, while for the ribbons fabricated at 12 m/s the elongation values increased from 2.3 to 2.97 %. The increment in ductility is due to the softening that have been induced by vacancies removal after annealing. A similar effect has been also noticed in the after annealing hardness values. The induced ductility improvement by the reduction of punctual defects has been reported before in binary AlFe-B2 alloys [8]. For the Al-Fe added with Cr alloy, their ribbons showed a decrement of failure by tensile strength after annealing.This performance could be due to softening probably by the reduction of vacancy after annealing. In addition, previous

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reports showed that the yield strength decreases approximately in a monotonic way, such as the vacancy content also decrease [13, 14].Previous studies it has been carried out on tensile tests in air at room temperature in double extruded Al-Fe-Cr alloys [15]. Their results show a 2% elongation to failure in one specimen deformed at a deformation rate of 1 x 10^{-6} s^{-1}. These values are slightly minor with respect to the observed in the annealed Al-Fe-Cr ribbons produced at 12 m/s in the present work.

Wheel speed V (ms^{-1})	Grain size (µm)		Strain (%)		Failure strength (MPa)		Microvickers Hardness (Hv)	
	As-spun	annealed	As-spun	annealed	As-spun	annealed	As-spun	annealed
12	30.42	21.59	2.301	3.22	245.05	151	393.8	300
16	22.58	13.27	0.944	1.46	139.75	120	352.9	282
20	6.48	6.39	0.830	0.942	105.31	118	379.2	328

Table 2Tangential wheel speedand grain size values of the Al-VIIB-VIB alloyin relationship with microvickershardness (Hv), plus the strain/Stretch & Elongation (%). In order to associate the stress at which the Al-VIIB-VIB alloyfractures, it has been tabulated the values of failure strength (FS). The values have been compared between the two conditions, as-spun and annealed alloys.

Nevertheless, for the work [15] have been observed particles of Cr_2Al in the fracture surfaces. These Cr_2Al particles have been related with an increment in fracture strength with a combined reduction of elongation to fracture.With this consideration, it has been related that the higher elongation and also the minor failure strength with the absence of precipitated particles. For the ribbon produced at 12 m/s the absence of Cr_2Al avoid the obstacles to dislocations motion. Finally, another factor that could have contributed for the ductility improvement of ribbons is the grain size. Therefore as showed for these alloys, their grain refinement could be a potent method for enhance ductility or originate a ductile-fragile transition too [16]. Furthermore there was not any significant microstructural change such as precipitation after annealing that could have contributed to their ductile behavior.
A substantial research effort has been directed towards the development of alloys by rapid solidification process with higher mechanical properties like higher strength, better ductility, and high yield stresses as compared to crystalline materials. A potentially valuable use of alloys rapidly solidified as the Al-VIIB-VIBalloy has been associated with applications at high temperature. In spite of the fact that the cost effectiveness of melt spinning technique could cost one-third as much as conventionally processed as-cast alloys.These economical parameters could be limited usefulness for the high rate forming processes and some rapid solidification technology compromises many opportunities.The major concern is the development of new and improved materials for practical applications. Most of the need is form the consolidation of rapidly solidified alloys with improved mechanical alloys, like mechanical strength, reasonable ductility,and increase in hardness, high impact strengths and shear strengths for brazed joins as one example. In general, the formation of structural materials, preferentially results in practical consequences with strong effect on mechanical strength, as tensile, yield, and fracture stress.
For this reason, further research shows a previously results that relates the ductility increases at high rate in a narrow range of grain size from 5 to 25 µm. Meanwhile, by conventional methods such as melting, casting or extrusion, the change in ductility as grain size function was very small within a large range of bigger grain sizes. A great deal of additional research also exhibits a ductility enhancement as the grain size becomes smaller.Nevertheless it is necessary to emphasize that the smallest grain sizes in the works reported has been obtained by using rapid solidification and powder metallurgy techniques [13, 17, 18].The increase in ductility and hardening associated with the grain size reduction is another evidence of the powerful effect of microstructural refinement on the delay of cracking.Microstructural refinement has been closely linked with evolution and dissipation of thermal energy during the high cooling usually observed in rapidly solidified alloys. From our results have been observed that the ribbons produced at 12 m/s are thicker (76µm) than those produced at 16 m/s (53µm). The difference of grain sizes between them is not as marked as their thickness difference, the former possess a bigger grain boundary area than those at 16 m/s. Therefore, is expected a more notorious effect on the grain boundary in ribbons produced at 12 m/s, as it is illustrated in table 2. The area of grain boundary, such as the number of grainsin the ribbons is higher for those produced at 12 m/s. This behavior could be explained in terms of a grain boundary strengthening mechanism.There will

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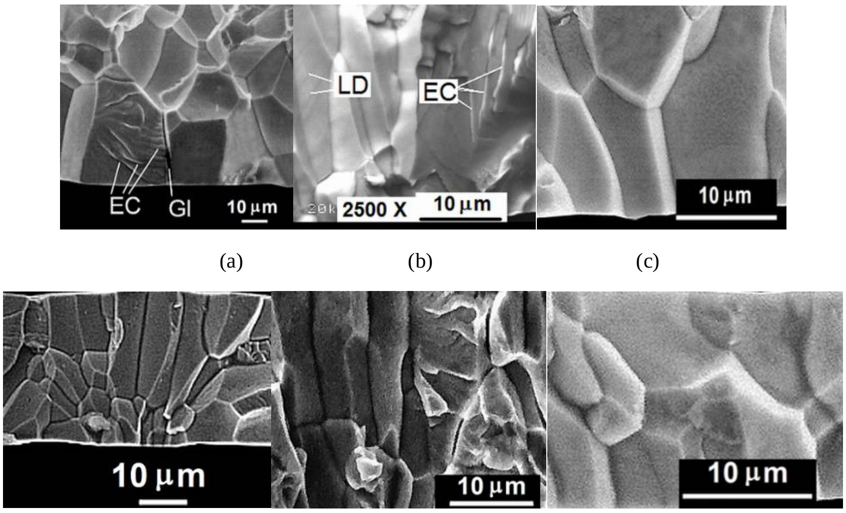
be a major probability that a bigger quantity of grains will be oriented in a favorable way in order to promote the dislocation slip process during deformation, inducing thus a major capability of deformation. There appears to have been a complete comprehensive study of the properties of some alloys with very fine structures.



(a) (b) (c)

(d) (e) (f)

Fig 2Microstructures obtained from Al-VIIB-VIB alloy at different cooling rate. These scanning electron microscopy images shows the morphology, where is always known that the susceptibility to intergranular fracture can be increased by changing the grain boundary, for this case, by the wheel speed velocity (m/s). Fractographic examination showed (a)12 m/s, (b) 16 m/s, (c) 20 m/s surface fractures of melt spun condition and (d) 12 m/s, (e) 16 m/s, (f) 20 m/s as annealed condition.

On the other hand, it has been reported that the Al-45Fe-5Cr (% at.) alloy reports [20] a ductility of 2.2 % with a grain size of ~ 30 µm. For this case, the Cr contained in the Al-45Fe-5Cr alloy occupies a 75 % of the places that pertain to Al sublattice, originating in this way an effective concentration of ~ Al 48 %at. The results of that study showed the microstructure of their alloys consisted of relatively equiaxed grains. However, it has been reported that ductility of AlFe-B2 binary alloys diminishes as the Aluminum content increases from 36% at. to 50% at. Al. This circumstance tends to decrease the ductility to lower values, as compared with the higher ductility values observed in some of the annealed ribbons.Supplementary strengthening in these alloys could be provided by dispersions of insoluble intermetallic phases as well as the introduction of controlled amounts of strain. It is evident, the fundamental influence of microstructure on mechanical properties. That is the case for microhardness of Al-VIIB-VIB alloy system reported in table 2. This shows that microhardness decreased after annealing. It was remarkable to see that the ternary Al-VIIB-VIB alloy in as-spun condition were softer than binary as-spun Al-40Fe (% at.) such as was reported previously [5]. This behavior could be related to the vacancy site occupation by Cr that induces softening in the material. In addition, there is an extra softening originated by an additional vacancy removal that is induced by annealing. It has been reported previously [22] that the microhardness of the Al-Fe-Cr ribbons rapidly solidified did not exhibit a significant difference with the alloys produced by conventional casting. Another work [20] observed that ternary $Al_{50}Fe_{49}X_1$ alloys (where X represents a transition metal for the first file) exhibited very similar hardness values to those measured in binary stoichiometricAlFe alloys. Therefore, these alloying elements did not seem to reduce the anomalous retention of vacancies after thermal treatments at high temperatures. In addition, this behavior is related to the vacancies substituted by Cr. The quantity of these punctual defects is also generated by rapid cooling, as well as the production method utilized. In addition, it has been observed [22] microhardness values from 300 to 325 Hv in Al-Fe-Cr (% at.) ribbons produced by melt-spinning technique at a wheel speed of $24ms^{-1}$. These values were similar to microhardness values reported in the present work. The analogous results were attributed to the similar cooling rates used in both cases.From previous discussion on solidification, it is apparent that in Al-Fe-10%Cr it has been observed a softening from 290 to

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280 HV after thermal treatment. The insignificant softening reported could be attributed to the limited reduction of vacancies induced under the annealing condition as compared with the softening observed in the present work.In addition, the hardness of $Fe_{49}Al_{50}X_1$ (X = Cu, Ni, Co) cooled in air from 950 ºC with a subsequent annealing at 400ºC @ 120hrs reports [21] that annealed samples with Mn, Co, Cu and Cr alloying additions did not exhibited a significant difference of microhardness among each other and with the binary almost stoichiometric alloy AlFe. Thus, these alloying additions do not seem to alter in a significant way the equilibrium hardness achieved after annealing. This study set the course for emphasis on prospects for the development of useful alloying additions with improved mechanical properties for potential applications. Recently it has been considered that the proportion offracture regions could be correlated with the interaction between impurities and alloying elements. Previous study [22] on the fracture behavior of rapidly solidified for Al35Fe and Al40Fe with 5 and 10 % at. Cr additions shows a mixed way of failure (cleavage + intergranular) also reports a cleavage failure mode for 15 % at Cr. This work showed the fracture surface observation by SEM in Figure 2, which shows the cleavage steps and river patterns clearly observed in ribbons produced at 12 m/s in Figure 2 (a, d) and 16 m/s in Figure 2 (b, e). In contrast, a reduced percent of transgranular cleavage was observed in ribbons produced at 20 m/s showed in Figure 2 (c, f). It is worth emphasizing that the proportion of zones affected by transgranular cleavage decreases with increasing the wheel speed velocity. In this particular work, has not been observed a precipitates on the microstructural surface. This is consequence of the interdifussion of the alloying elements due to the extension of solid solubility, which is a characteristic of the rapid solidification process obtained by the melt spinning technique in the case ofAl-VIIB-VIB alloy system.In recent years, the microstructural features has been showed that the in as-cast conditions, the fracture behavior was attributed to smaller constituent particle sizes in the matrix, was also responsible for an improvement in crack initiation resistance. The general aspect of the microstructural features of the specimens fractured can be observed in a detailed fractography analysis showed in table 3. The results tabulated showed that the percent of transgranular area (% A_t) decreased almost linearly as the wheel speed or when cooling rate increased. In addition, the fraction of transgranular area was increased after annealing with a parallel increment in elongation to failure.

Wheel speed V (ms^{-1})	Transgranular area A_t(%)	
	As-spun	annealed
12	10.73	14.6
16	5.28	7.80
20	2.50	4.00

Table 3.Al-VIIB-VIB alloy developed and processed by melt spinning technique that showed thepercent oftransgranular area (% A_t) as a function of wheel speed in Al-Fe-Cr alloys in as-spun and annealed conditions. As is well knownthe fracture follows the pattern of the grain, as a characteristic of a transgranular fracture. The key pathway is the grain boundaries in polycrystalline materials that are stronger when the number of grains increases.

The fracture surfaces obtained suggest that the crack path could occur along a weakened grain boundary indicating that follows the crystal lattice of individual grains. In addition, rapid solidification processes provide a greater number of arbitrarily aligned grains with reduced grain-size. The grain-size refinement provides an increment of grain boundary regions, with weakening or embrittlement preference due to are likewise a region with many faults, dislocations, and voids. The decrement in (% A_t) is congruent with a parallel decrement of elongation to failure, as can be seen from Table 2 and Table 3. This behavior can be explained in terms of the quantity of retained vacancies formed after the rapid cooling. When, the cooling rate increases also the retained vacancy concentration increases. In the same way, when the vacancy content increases a parallel increment of resistance inside the grains is induced. With this process it has been promoted a proportional increment of the intergranular mode of failure.Likewise, a tension test in Al-35Fe-5Cr (at. %) alloy at room temperature at a deformation rate of 1.4 x 10^{-2} s^{-1} produced by arc melting in argon atmosphere and subsequently homogenized at 1000 °C during 24 hrs, hot rolled in the temperature range of 1050 – 950 °C [22] observed a predominantly intergranular failure trajectory with a low percentage of transgranular cleavage in the Al-35Fe-5Cr tension tested specimen. Therefore, production and processing methods does not alter the predominant way of failure of these Al-VIIB-VIBternary alloys.

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V. CONCLUSION

According to the effects of alloying addition on the microstructure and mechanical properties of an Al-VIIB modified with VIB alloying element, the following conclusions are obtained:

The relationship between of ribbon thickness with the lineal speed of substrate depends upon production conditions and alloy system.

The elongation to fracture was improved and the ultimate tensile strength decreases after the long low temperature annealing due to the softening induced by the vacancies removal.

Some of the ribbons exhibited a higher elongation to failure with respect to Al-VIIB-VIBternary alloy produced by extrusion, mainly by the absence of precipitates in as-spun and annealed ribbons.

Fracture surfaces exhibited a mixed mode of fracture (transgranular + intergranular) with increases the intergranular failure mode when the wheel speed or cooling rate increases with a reduction of elongation to failure.

REFERENCES

[1] Donghong Ding, Zengxi Pan, Stephen van Duin, Huijun Li and Chen Shen, “Fabricating Superior NiAl Bronze Componentsthrough Wire Arc Additive Manufacturing”. Materials vol. 652, pp. 6-12, 2016.

[2] M. M. Belde, H. Springer,D. Raabe, “Vessel microstructure design: A new approach for site-specific core-shell micromechanical tailoring of TRIP-assisted ultra-high strength steels”, ActaMaterialia, vol. 113, pp. 19-31, 2016.

[3] Shouxun Ji, Wenchao Yang, Feng Gao, Douglas Watson, Zhongyun Fan. “Effect of iron on the microstructure and mechanical property of Al–Mg–Si–Mn and Al–Mg–Si diecast alloys”,Materials Science and Engineering: A,Vol. 564, no. 1, pp. 130–139, 2013.

[4] Guowei Zhang, YefengBao, Yongfeng Jiang, and Hong Zhu, “Microstructure and Mechanical Properties of 6063 Aluminum Alloy Brazed Joints with Al-Si-Cu-Ni-RE Filler Metal”, Journal of Materials Engineering and Performance. Vol. 20, no. 8, pp. 1450-1456, 2011.

[5] Laurens Katgerman, Fred Domb, “Rapidly solidified aluminium alloys by meltspinning”, Materials Science and Engineering A. Vol. 375–377, pp. 1212–1216, 2004.

[6] ErcanKaraköse , Mustafa Keskin, “Structural investigations of mechanical properties of Al based rapidly solidified alloys”, Materials and Design, vol. 32, pp. 4970–4979, 2011.

[7] DavorPavuna, “Production of metallic glass ribbons by the chill-block melt-spinning technique in stabilized laboratory conditions”. Journal Of Materials Science, vol. 16, pp. 2419-2433, 1981.

[8] Dongdong Zhu, Duo Dong, Chenyuan Ni, Defeng Zhang, Zhaozhong Zhou , Hongwei Wang , Zunjie Wei, “Effect of wheel speed on the microstructure and nanohardness of rapidly solidified Ti–48Al–2Cr alloy”, Materials Characterization, vol. 99, pp. 243–247, 2015.

[9] LongchaoZhuo, Shujie Pang, Hui Wang, Tao Zhang, “Effect of cooling rate on microstructure and mechanical properties of rapidly solidified Al-based bulk alloys”. Journal of Alloys and Compounds, vol. 504S, pp. S117–S122, 2010.

[10] G. He, W. Looser, J. Eckert, “In situ formed Ti–Cu–Ni–Sn–Ta nanostructure-dendrite composite with large plasticity”, ActaMaterialia, vol. 51, pp. 5223–5234, 2003.

[11] R. Khorshidi , A. Hassani, A. HonarbakhshRauof, M. Emamy, “Selection of an optimal refinement condition to achieve maximum tensile properties of Al–15%Mg2Si composite based on TOPSIS method” Materials and Design, vol. 46, pp. 442–450, 2013.

[12] F. Audebert, M. Galano, C. Triveño Rios, H. Kasama, M. Peres, C. Kiminami, W.J. Botta, C. Bolfarini, “Nanoquasicrystalline Al–Fe–Cr–Nb alloys produced by poder Metallurgy”, Journal of Alloys and Compounds, vol. 577, pp. 650–657, 2013.

[13] Musa Gögebakan, OrhanUzun, TuncayKaraaslan, Mustafa Keskin, “Rapidly solidified Al–6.5 wt.% Ni alloy”, Journal of Materials Processing Technology, vol. 142, pp. 87–92, 2003.

[14] O. Uzun, T. Karaaslan, M. Gogebakan, M. Keskin, “Hardness and microstructural characteristics of rapidly solidified Al–8–16 wt.%Si alloys”, Journal of Alloys and Compounds, vol. 376, pp. 149–157, 2004.

[15] OrhanUzun ,TuncayKaraaslan , Mustafa Keskin, “Hardness evaluation of Al–12Si–0.5Sb melt–spun ribbons”, Journal of Alloys and Compounds, vol. 358, pp. 104–111, 2003.

[16] C. Örnek, D.L. Engelberg, “Towards understanding the effect of deformation mode on stress corrosion cracking susceptibility of grade 2205 duplex stainless steel” Materials Science & Engineering A, vol. 666, pp. 269–279, 2016.

[17] O. Uzun, F. Yılmaz, U. Kölemen, N. Basman, “Sb effect on micro structural and mechanical properties of rapidly solidified Al–12Si alloy” Journal of Alloys and Compounds, vol. 509, pp. 21–26, 2011.

[18] LongchaoZhuo, Shujie Pang, Hui Wang, Tao Zhang, “Effect of cooling rate on microstructure and mechanical properties of rapidly solidified Al-based bulk alloys” Journal of Alloys and Compounds, vol. 504S, pp. S117–S122, 2010.

[19] Yang Cai, Xiaosong Wang, Shijian Yuan, “Analysis of surface roughening behavior of 6063 aluminum alloy by tensile testing of a trapezoidal uniaxial specimen” Materials Science & Engineering A, vol. 672, pp. 184–193, 2016.

[20] L.A. Dobrzanski, R. Maniara, J. Sokołowski, W. Kasprzak, “Effect of cooling rate on the solidification behavior of AC AlSi7Cu2 alloy”, Journal of Materials Processing Technology, vol. 191, pp. 317–320, 2007.

[21] A. Lekatou, A.K. Sfikas, A.E. Karantzalis, D. Sioulas, “Microstructure and corrosion performance of Al-32%Co alloys”, Corrosion Science, vol. 63, pp. 193–209, 2012.

[22] M. A. Easton, and D. H. Stjohn, “A Model Of Grain Refinement Incorporating Alloy Constitution And Potency Of Heterogeneous Nucleant Particles”, ActaMaterialia, vol, 49, pp. 1867–1878, 2001.