MICROSTRUCTURE AND MECHANICAL PROPERTIES OF A HEAT -TREATABLE AL-SB AND AL-SB-IN ALLOYS BY MELT-SPUN TECHNIQUE

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ABSTRACT

The aluminum alloy Al₈₀-Sb₂₀ and Al₇₀-Sb₂₀-In₁₀ microstructure and mechanical properties are studied in Melt Spun condition after heat treatment. The elevated temperatures strength properties improved as compared to the AlSb base alloy with a reduction in stiffness. The maximum strength properties are obtained with heat treatment time rates 60 and 90 min; an additional rate causes a decrease in strength due to increased volume of coarse needle AlSb IMC precipitates. The resultant structural variations increase the creep rate (ϵ). Elastic modulus reduction might be due to high elastic lattice distortions after the thermal process, while the stress exponent refers to the dislocation climb mechanism of deformation after heat treatment.

KEYWORDS: Aluminum Alloys, Heat Treatment Solidification, Structural Stability, Mechanical Properties

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1 INTRODUCTION

Aluminum alloys reinforced by precipitation micro-alloyed with Sc and Zr have been developed as an auspicious family of lightweight alloys for use at 400 °C, with aerospace and vehicle structural elements applications [1–9]. More recently, Indium and Silico's elements were added to Al-Sb alloys to study their effects on anatomy, nucleation, growth rate, coarsening resistance, and reinforcement at average and elevated temperatures have been studied. Current, Aluminum alloys with aging hardness cannot be used at high temperatures for extended times since the precipitate roughen rapidly above ~230 °C, thus flagging the fusion [10,11]. The Al-Sb binary phase diagram indicates a minimal solid solubility of Sb in aluminum (< 0.02 at% at 627 °C), with AlSb as the only line-composition intermetallic [12–14]. The Sb atoms accelerate the attractive binding, the free energy of precipitation, and the peak intensity during thermal aging strengthens the nucleation of Al atoms and vacancies [15]. The synthesized Al₈₀-Sb₂₀ and Al₇₀-Sb₂₀-In₁₀ samples used the melt-spinning technique and fabricated with different heat treatment time rates at ~ 400°C for 30,60,90 and 120 min, which this treatment has been applied to additional advance the mechanical properties. Al-Sb was designated as a heat-treatable matrix, and Indium addition was elected as the strengthening. The present data is concerned with structural stability, in which the attention has been paid to the role of fabricated heat treatment, which affects mechanical properties to evaluate the compressive load and creep behavior.

2 EXPERIMENTAL PROCEDURES

the melt-quenched ribbons of binary Al₈₀-Sb₂₀ and tertiary Al₇₀-Sb₂₀-In₁₀ alloys were papered from pure commercial aluminum with the addition of 99.99 wt.% pure Sb and In. The samples were loaded into a graphite crucible and were heated in an electric resistance furnace. They were heat-treated to 400 °C and held for periods, and the samples were annealed [16]. The density of the composite was measured with the standard Archimedes method in distilled water. The Metallographic melt specimens were prepared through mechanical polishing by a SiC abrasive paper and cleaned for 10 – 20 sec by a solution containing 50 ml ethanol and 50 ml distilled water. The grain size was measured with the method of linear intercept (ASTM E112-210). The phases of the alloys were analyzed by X-ray Diffractometer (XRD, PANalyticalX'Pert Pro) with a monochromatic Cu K α radiation. Scanning electron microscope (SEM, (JEOL JSM-6510LV, Japan) operates at 30 kV with high resolution 3 nm was employed to study the precipitates' microstructure. The mechanical properties were examined in an air atmosphere with a dynamic resonance method [17,18]. The produced samples were tested in a Vickers microhardness tester machine at room temperature, where a diamond pyramid indenter with a square base is used. The Vickers hardness Micro-creep indentation measurements, as described by El-Ashram et al. [19] using load 0.245 N at room temperatures for dwell time up to 80 s.

3 RESULTS AND DISCUSSIONS

3.1 Structural Analysis Phase Identification

The X-ray diffraction patterns were achieved from the melt-spun Al₈₀-Sb₂₀ and Al₇₀-Sb₂₀-In₁₀ alloys by heat treatment (HT) during the time (t = 0,30,60,90 and 120 min) are shown in Figure 1. The 2 θ has been measured from 20 ° to 100 ° at 0.02 ° step and time interval 0.5 s step. Al₈₀-Sb₂₀ Contains only phase Al (Figure 1); however, AlSb intermetallic compound (IMC), as indicated in the Scanning Electron Microscope (SEM), is finely scattered in the aluminum matrix. The number of peaks of the AlSb IMC decreased with heat treatment time increasing, as shown in Table 1 and Figure 1. For Al₇₀-Sb₂₀-In₁₀ alloys shown in Figure 1, the alloy component (In) phase appears in addition to Al, AlSb IMC, and InSb IMC phases. With the HT process, InSb IMC phases have disappeared and become Indium phase separately embeddability in the Aluminum matrix; this may indicate to complete union of Sb atoms with Al-matrix and due to the very slow solid-state diffusion. The details of the XRD analysis are shown in Tables 1, 2. The results show that the value of Al and AlSb IMC crystallite size (**Error! Reference source not found.**) in samples increases after HT; this is maybe due to the cycle of recrystallization resulting from increased thermal energy, except Al₈₀-Sb₂₀ (30 min) due to the lowest duration of heat-treated exposure and except Al₇₀-Sb₂₀-In₁₀ due to its structural stability after HT process, where, Scherrer's formula used to observe a trend of crystallite size. The lattice distortions (ϵ) have been decreased after HT due to the balanced rearrangement progression of crystal particles. The number of atoms per unit cell (N) fluctuation may be due to quantitative IMCs formation. the micro strains were determined according to via Williamson- hall method defined by the following equation [20,21]:

$$\beta \frac{\cos \theta}{\lambda} = \frac{K}{d_{XRD}} + 4\epsilon \frac{\sin \theta}{\lambda} \quad (1)$$

Where K is shape factor (~ 0.94), (θ) the Bragg angle, and β is integral breadth. The micro-strain (ϵ) and the density of dislocation (ρ_D) studied using Eq [1] [22,23]. The strain distribution over the lattice (η) calculated by considering the Crystallite size and strain persuaded broadening according to Cauchy and Gaussian function [24] and Dislocation density (P) [25].

Table 1: Lattice parameters (a Å), Cell volume, number of atoms per unit cell (N), and Atomic Packing Factor (APF) for Al Phase in Al-Sb based system

The system in wt. %	a (Å)	Cell volume (Å) ³	N	APF
Al ₈₀ -Sb ₂₀ (0 min)	4.054	66.600	3.835	0.709
Al ₈₀ -Sb ₂₀ (30 min)	4.054	66.701	3.837	0.710
Al ₈₀ -Sb ₂₀ (60 min)	4.054	66.669	3.835	0.710
Al ₈₀ -Sb ₂₀ (90 min)	4.056	66.727	3.838	0.710
Al ₈₀ -Sb ₂₀ (120 min)	4.056	66.727	3.838	0.710
Al ₇₀ -Sb ₂₀ -In ₁₀ (0 min)	4.071	67.459	3.770	0.678
Al ₇₀ -Sb ₂₀ -In ₁₀ (30 min)	4.056	66.751	3.731	0.690
Al ₇₀ -Sb ₂₀ -In ₁₀ (60 min)	4.057	66.809	3.734	0.691
Al ₇₀ -Sb ₂₀ -In ₁₀ (90 min)	4.056	66.728	3.729	0.690
Al ₇₀ -Sb ₂₀ -In ₁₀ (120 min)	4.055	66.701	3.728	0.690

Figure 1: X-ray diffraction patterns of melt-spun Al₈₀-Sb₂₀ and Al₈₀-Sb₂₀-In₁₀ heat-treated alloys

Figure 2: Crystallite size with the heat treatment rate

Table 2: No. of Phase, Crystallite size (nm), lattice distortion (ε), Strain distribution (η), and Dislocation density (P) for Al-Sb based system.

Alloy	Phases	No. of Phase	The crystallite size (nm)	($\varepsilon \times 10^{-4}$)	($\eta \times 10^{-3}$)	($P \times 10^{-4}$) (nm^{-2})
Al ₈₀ -Sb ₂₀ (0 min)	Al	5	38.74	12.05	8.87	6.94
	AlSb	11	24.16	23.51	14.24	7.52
Al ₈₀ -Sb ₂₀ (30 min)	Al	6	38.16	10.47	9.32	7.40
	AlSb	8	21.98	22.13	18.95	15.96
Al ₈₀ -Sb ₂₀ (60 min)	Al	6	40.02	9.93	7.06	5.34
	AlSb	9	26.29	18.44	14.91	11.33
Al ₈₀ -Sb ₂₀ (90 min)	Al	6	40.28	9.73	7.17	5.39
	AlSb	8	28.48	19.63	16.54	11.61
Al ₈₀ -Sb ₂₀ (120 min)	Al	6	40.48	11.02	7.91	5.93
	AlSb	5	30.29	29.43	26.60	17.55
Al ₇₀ -Sb ₂₀ -In ₁₀ (0 min)	Al	5	39.15	11.54	2.16	6.70
	AlSb	2	30.80	27.07	7.11	18.45
	InSb	8	30.96	15.13	2.80	6.83
	In	2	28.18	16.88	3.76	10.89
Al ₇₀ -Sb ₂₀ -In ₁₀ (30 min)	Al	6	43.00	10.40	7.44	5.24
	AlSb	6	33.05	17.35	15.33	9.28
	In	9	33.00	13.48	10.86	12.44
Al ₇₀ -Sb ₂₀ -In ₁₀ (60 min)	Al	6	37.05	12.96	9.37	7.66
	AlSb	4	29.38	18.38	17.50	11.90
	In	7	27.37	16.91	14.01	19.36
Al ₇₀ -Sb ₂₀ -In ₁₀ (90 min)	Al	6	39.23	13.04	8.26	6.38
	AlSb	4	30.72	16.48	15.52	10.09
	In	7	28.19	14.69	12.14	16.28
Al ₇₀ -Sb ₂₀ -In ₁₀ (120 min)	Al	6	41.80	12.05	7.76	5.62
	AlSb	5	44.39	13.92	10.66	4.80
	In	10	30.57	14.64	10.97	13.56

3.2 Microstructural Morphology

Figure 3,4 show the microstructure and morphology of samples before and after the HT process. It was detected that the grooves have vanished, and the grain boundaries are dendritic at eutectic AlSb and InSb. The In-phase demonstrating aspect of diffused semi-bright regions also delaminates in the interstitial distances with IMC bright regions AlSb which became nondendritic. The HT process prompts a coarsening IMCs crystal reshaped to be more circular and more perimeter, which may induce stress concentrations within the samples and reduce the adhesive strength, which influenced the creep indentation [8,26].

The SEM correlation parameters of heat treatment rate as a function of phases content were analyzed using NIH ImageJ's program as an open source based on Fiji "*Is Just ImageJ—Batteries included*" [27,28] according to the particle analysis protocol.

Table 3 shows the range of particle size Al phase of the heat treatment time where at 60 min, 90 min more refined and may lead to the transition of dendrite arms' precipitate-free districts.

Figure 3: SEM microstructures of $\text{Al}_{80}\text{Sb}_{20}$ (a) 0 min, (b) 30 min, (c) 60 min, (d) 90 min and (e) 120 min alloys.

Figure 4: SEM microstructures of $\text{Al}_{70}\text{-Sb}_{20}\text{-In}_{10}$ (f) 0 min, (g) 30 min, (h) 60 min, (i) 90 min and (j) 120 min alloys.

Table 3: The Microstructural parameters Via using an NIH ImageJ for data visualization and analysis tool

Alloy	Phases	Average Grain size (μm)	Percentage Area %	Average Perimeter	Average Circularity	Average Solidity
Al ₈₀ -Sb ₂₀ (0 min)	Al	10.44 $\pm$ 0.5	62.42	10.41 $\pm$ 0.12	0.70	0.84
	AlSb	5.467 $\pm$ 0.4	37.87	7.362 $\pm$ 0.05	0.77	0.86
Al ₈₀ -Sb ₂₀ (30 min)	Al	18.01 $\pm$ 0.8	67.04	13.51 $\pm$ 0.11	0.67	0.87
	AlSb	1.31 $\pm$ 0.02	2.371	3.08 $\pm$ 0.05	0.60	0.58
Al ₈₀ -Sb ₂₀ (60 min)	Al	12.50 $\pm$ 0.9	70.61	11.49 $\pm$ 0.11	0.72	0.88
	AlSb	1.05 $\pm$ 0.12	7.606	2.932 $\pm$ 0.52	0.79	0.84
Al ₈₀ -Sb ₂₀ (90 min)	Al	30.54 $\pm$ 0.4	67.62	18.87 $\pm$ 0.12	0.72	0.90
	AlSb	1.65 $\pm$ 0.2	13.98	3.68 $\pm$ 0.08	0.81	0.86
Al ₈₀ -Sb ₂₀ (120 min)	Al	43.63 $\pm$ 0.82	74.01	24.97 $\pm$ 0.25	0.66	0.91
	AlSb	1.189 $\pm$ 0.4	3.15	3.54 $\pm$ 0.04	0.78	0.85
Al ₇₀ -Sb ₂₀ -In ₁₀ (0 min)	Al	2.377 $\pm$ 0.05	26.08	5.851 $\pm$ 0.53	0.72	0.83
	AlSb	1.079 $\pm$ 0.02	14.615	3.707 $\pm$ 0.02	0.78	0.84
	InSb	1.171 $\pm$ 0.04	54.34	4.19 $\pm$ 0.05	0.75	0.85
Al ₇₀ -Sb ₂₀ -In ₁₀ (30 min)	Al	6.27 $\pm$ 0.06	61.26	8.70 $\pm$ 0.04	0.71	0.86
	AlSb	1.29 $\pm$ 0.02	19.12	4.05 $\pm$ 0.02	0.75	0.83
	In	1.95 $\pm$ 0.04	24.77	4.52 $\pm$ 0.04	0.79	0.86
Al ₇₀ -Sb ₂₀ -In ₁₀ (60 min)	Al	8.15 $\pm$ 0.06	74.47	10.69 $\pm$ 0.06	0.70	0.88
	AlSb	0.8 $\pm$ 0.04	3.5	2.98 $\pm$ 0.02	0.86	0.87
	In	0.733 $\pm$ 0.04	17.14	3.07 $\pm$ 0.01	0.80	0.85
Al ₇₀ -Sb ₂₀ -In ₁₀ (90 min)	Al	3.69 $\pm$ 0.03	68.63	5.71 $\pm$ 0.03	0.72	0.86
	AlSb	0.939 $\pm$ 0.03	9.05	2.14 $\pm$ 0.02	0.81	0.88
	In	0.204 $\pm$ 0.02	18.39	1.61 $\pm$ 0.01	0.79	0.86
Al ₇₀ -Sb ₂₀ -In ₁₀ (120 min)	Al	8.09 $\pm$ 0.03	70.15	10.64 $\pm$ 0.03	0.70	0.87
	AlSb	1.33 $\pm$ 0.03	6.29	2.73 $\pm$ 0.02	0.86	0.86
	In	1.51 $\pm$ 0.04	14.15	4.46 $\pm$ 0.03	0.73	0.83

3.3 Mechanical behavior

The mechanical study is divided into two essential parts:

Elastic moduli and internal fraction by dynamic and static techniques

The mechanical properties will be studied at the level of molecules and atoms by Dynamic Resonance Technique and Hardness indentation micro-creep behavior to complement the correlation of results and implications for heat treatment exposure. Table 4 comprises the dependence on heat treatment duration mechanical parameters before and after heat treatment (HT). Polycrystalline alloys' elasticity E modulus is considered somewhat susceptible to microstructural alteration. Portray of mechanical energy by the Q^{-1} values. The mechanical behavior of the alloys' investigation was based on a modified dynamic resonance technique, which determined using the following equations [29–31]:

$$\left(\frac{E}{\rho}\right)^{1/2} = \frac{2\pi L^2 f_0}{Kz^2} \quad (2)$$

where (ρ , K , L) are the density, radius of gyration, and length of the vibrated section, respectively, resonance vibrating frequency f_0 the constant z is equal to 1.875, and it depends on the vibration type of the samples under test. Plotting the vibration s' frequency about the resonance f_0 against representing the resonance graph where Δf is the half breadth of the resonance and $[Q^{-1}]$ is internal friction, for alloys [32]:

$$Q^{-1} = 0.577 \frac{\Delta f}{f_0} \quad (3)$$

It is found that there is a significant decrease in the E values after HT, which may be due to standard crystal arrangements free energy for these alloys except Al₈₀-Sb₂₀ (60 min) alloy (Figure 5) that is attributed to the cluster and segregation of nano-AlSb particles to become accumulated over each other, so these results are in agreement with Altin, E. et al [33]. On the Al₇₀-Sb₂₀-In₁₀ alloys, it is observed that the decrease in internal friction (Q^{-1}) with increasing Young's modulus (E). A significant decrease is also observed in (Q^{-1}) with a substantial increase in (E), which may involve increasing dislocation density of intermetallic compounds that sliding over the Al-matrix. Young's modulus (E) behavior can elucidate the modification in the Al matrix's unit cell, so with Unit cell growth, the alloy weakens. It is due to increasing In phase whose inclusions in Al-matrix resist the deformations.

Figure 5: Resonance curves for melt-spun Al₈₀-Sb₂₀ and Al₇₀-Sb₂₀-In₁₀ heat-treated samples.

Table 4: Young's modulus (E), internal friction (Q^{-1}), Bulk modulus (B), Shear modulus (G), and Thermal diffusivity for heat-treated alloys.

A system in wt. %	E (GPa)	$Q^{-1} \times 10^{-2}$	B (GPa)	G (GPa)	Thermal diffusivity (m^2/s) $\times 10^{-7}$
Al ₈₀ -Sb ₂₀ (0 min)	66.68	2.31	72.31	24.82	3.93
Al ₈₀ -Sb ₂₀ (30 min)	22.96	3.53	24.85	8.53	6.89
Al ₈₀ -Sb ₂₀ (60 min)	16.96	1.59	18.35	6.30	5.92
Al ₈₀ -Sb ₂₀ (90 min)	22.96	7.01	24.85	8.53	3.87
Al ₈₀ -Sb ₂₀ (120 min)	20.48	7.17	22.16	7.61	3.66
Al ₇₀ -Sb ₂₀ -In ₁₀ (0 min)	56.12	2.40	64.95	20.69	4.63
Al ₇₀ -Sb ₂₀ -In ₁₀ (30 min)	20.93	1.24	24.22	7.72	4.41
Al ₇₀ -Sb ₂₀ -In ₁₀ (60 min)	5.84	8.20	6.76	2.15	7.70
Al ₇₀ -Sb ₂₀ -In ₁₀ (90 min)	9.47	5.40	10.96	3.49	4.48
Al ₇₀ -Sb ₂₀ -In ₁₀ (120 min)	20.04	4.53	23.20	7.39	6.52

Micro creep and Microhardness

Due to the benefits of fast, simple, and nondestructive methods, the micro-creep indentation test was considered one of the best techniques, particularly in thin ribbons. Figure 6 shows the creep curves for Al₈₀-Sb₂₀ and Al₇₀-Sb₂₀-In₁₀ samples after

heat treatment (HT) at load 0.245 N at room temperatures. The indentation tension increases with the time of loading. From these creep indentations, curves manifest two regions; at the end of the first stage, the creep rate is variable. The second stage is called the steady-state region, and the creep rate is relatively stable. The tertiary stage does not happen to owe to low loads and loading times, and the fracture does not occur. The steady-state slope is equal to the creep rate; The high resistance to shrinking distortion from other alloys more conducive to structural and mechanical study. The creep resistance ascends at 60 min of heat treatment. It may be because of IMC AlSb impact of the interaction between dispersions and an α -Al matrix, which acts as a gap and interstitial defect inhaler, where at 120 min of HT, the thermal process prompts a roughening of the AlSb particles, that can cause stress levels within the Al₇₀-Sb₂₀-In₁₀ sample and therefore reduces the strength. The stress exponent is used to classify deformation processes in which the process type from the stress exponent value is found. A straight line would be obtained from plotted $\ln d$ against HV on a double logarithmic scale, whose slope gives the stress exponent [34] (as shown in Figure 7)). This is different in

Table 5; there are a decrease in the stress exponent (n) values after HT for 30 min. The relationship between hardness and indentation time or dwell time was explained by Ashby –Sargent [35].

$$n = \left[\frac{\partial \ln d}{\partial \ln H_v} \right]_d \quad (4)$$

It implies to the grain border fatigue, where the grain border of precipitates that serve as an obstacle has been attributed to this activity motion for dislocation was tired, and stress exponents were reduced (n) led to creeping rate-raising [36,37]. However, due to grain boundary size after HT, this definition is not valid [38]. The dominant form of creeping in the samples measured is grain boundary sliding-type where is less than six except Al₈₀-Sb₂₀ ($t=30$ and 120) and Al₇₀-Sb₂₀-In₁₀ ($t=0$ and 30 min) because of a swing in creep type to becomes a more substantial rate (dislocation climb form) [39–41]. The ability to resist plastic deformation increased with heat treatment rate; the stress exponent (n) altered has indicated the deformation of creep behavior from dislocation climb grains to diffusional or grain boundary sliding, which has an increasing impact on creep resistance.

Figure 6: Strain variation versus loading time of Al₈₀-Sb₂₀ and Al₇₀-Sb₂₀-In₁₀ heat-treated samples at 0.245 N.

Table 5: Creep rate (ε), Vickers Hardness, Maximum shear stress, Compressive yield strain ($\sigma_{c,y}$), and Creep stress exponent (n)

A system in wt. %	$\varepsilon \times 10^{-4}$ at 25 gf	H_v (MPa)	Maximum shear stress	compressive yield strain $\sigma_{c,y} \times 10^{-3}$	creep stress exponent (n)
Al ₈₀ -Sb ₂₀ (0 min)	5.15	521	174.68	2.60	3.90
Al ₈₀ -Sb ₂₀ (30 min)	6.59	377	126.23	5.47	19.32
Al ₈₀ -Sb ₂₀ (60 min)	6.01	400	133.93	7.86	4.32
Al ₈₀ -Sb ₂₀ (90 min)	13.00	592	198.22	8.59	3.28
Al ₈₀ -Sb ₂₀ (120 min)	14.60	376	125.89	6.12	10.06
Al ₇₀ -Sb ₂₀ -In ₁₀ (0 min)	5.97	416	135.70	2.12	8.92
Al ₇₀ -Sb ₂₀ -In ₁₀ (30 min)	4.62	375	122.10	5.97	19.32
Al ₇₀ -Sb ₂₀ -In ₁₀ (60 min)	3.66	467	152.05	26.64	4.70
Al ₇₀ -Sb ₂₀ -In ₁₀ (90 min)	7.99	423	137.72	14.88	4.41
Al ₇₀ -Sb ₂₀ -In ₁₀ (120 min)	7.77	406	132.19	6.75	3.94

Figure 7: Plot rate of $\ln(d)$ as a function of $\ln(H_v)$ number for the $Al_{80}Sb_{20}$ and $Al_{70}Sb_{20}In_{10}$ samples.

4 CONCLUSIONS

- The effect of heat treatment at 0.60 of T_m on structural and the physical behavior of $Al_{80}Sb_{20}$ and $Al_{70}Sb_{20}In_{10}$ annealed ribbons from melt showed desirable properties. The thermal Procedure for obtaining more softer materials have several mechanical advantages for making wires and ribbons.
- The x-ray diffraction analysis for $Al_{80}Sb_{20}$ and $Al_{70}Sb_{20}In_{10}$ heat-treated samples at different time rates ($t=30,60,90$ and 120 min) show a face-centered Cubic in the following phases: Aluminum phase ($\alpha-Al$), aluminum antimonide ($AlSb$), body-centered tetragonal In phase, and disappeared of Antimony Indium ($InSb$).
- The scanning electron microscope images of $Al_{80}Sb_{20}$ and $Al_{70}Sb_{20}In_{10}$ alloys showed decreasing in the dendritic arms, and the dark areas of $\alpha-Al$ grains decreased with reshaped to be more circular and more perimeter. The delaminating mechanism of $AlSb$ and In is produced as of disappearing the $InSb$ phase and vary the partial size.
- The sample's mechanical properties showed that the hardness value strongly depends on heat treatment temperature; there is an effective technic in elastic modulus' result, which decreases by increasing the time rate of heat treatment ($400^\circ C$) for one hour.
- The internal friction of samples had discrete values the $Al_{80}Sb_{20}$ unheated treated sample equal 2.31×10^{-4} . While the lowest value corresponding with a one-hour heat treatment time rate, and for the $Al_{70}Sb_{20}In_{10}$ sample, it increased from $(2.40 \text{ to } 8.20) \times 10^{-4}$ may be due to an increase in the dislocation density, which corresponding also to the one-hour time rate.
- The stress exponent values of $Al_{80}Sb_{20}$ and $Al_{70}Sb_{20}In_{10}$ alloys range from 3.28 to 19.32 and 3.94 to 19.32, respectively. It agrees with the previous structural behavior results, so the state of the dominant creep mechanism is dislocation climb.
- The average hardness, H_v , the value of $Al_{80}Sb_{20}$ heat-treated alloys increased significantly with increasing the time rate with the highest value at 90 min. It decreased suddenly, maybe due to varying structural parameters like dislocation density and distortion occurring in the system, while $Al_{70}Sb_{20}In_{10}$ alloys it increases to be the highest value at one hour of heat treatment (467 Mpa).

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