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EFFECT OF TREATMENT SOLUTION ON THE MICRO-STRUCTURE AND MICROHARDNESS OF TERNARY Ni-Al-Nb ALLOY DOPED WITH TITANIUM

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ABSTRACT

EFFECT OF TREATMENT SOLUTION ON THE MICROSTRUCTURE AND MICROHARDNES OF TERNARY Ni-Al-Nb ALLOY DOPED WITH TITANIUM. Nickel-based superalloys have been widely used in various applications, which require high strength at high temperatures. Most types of these superalloys is age-hardenable because they have γ' particles' chemical composition $Ni_3(Al, Ti)$ in γ'-phase matrix. This research will be used alloy Ni-Al-Nb added alloying elements Ti. This research was conducted to study the mechanical properties, microstructure conditions in some alloys Ni-Al-Nb added distinction Titanium element (0,5% and 1% Ti) using the method of aging temperature variation performed at a temperature of 650 °C,700 °C and 750 °C with a holding time 4 hours and air cooling. Tests were conducted to determine the characterization of the specimen includes testing metallographic optical microscope, Rockwell hardness C and SEM- EDS,XRD. Results obtained from this research that addition of titanium element affecting the hardness values as well as the results of the cast, solution treatment and aging process results. The 1% Titanium content can affect the gamma prime coarsening and make the grain on the microstructure result smooth.

Keywords: Ni base supperalloy, Ni-Al-Nb, Aging, Effects of Titanium element

ABSTRAK

PENGARUH PERLAKUAN PELARUTAN PADA MIKROSTRUKTUR DAN MICROHARDNES PADUAN TERNER Ni-Al-Nb YANG DI DOPING DENGAN TITANIUM. Superalloy berbasis nikel telah banyak digunakan dalam berbagai aplikasi, dimana membutuhkan kekuatan tinggi pada suhu tinggi. Sebagian besar tipe dari superalloy ini adalah age-hardenable (mampu keras),karena mereka memiliki partikel γ' dengan komposisi kimia $Ni_3(Al, Ti)$ dalam matriks fasa γ'. Pada penelitian ini akan digunakan paduan Ni-Al- Nb yang ditambahkan unsur pemadu Ti. Penelitian ini dilakukan untuk mempelajari sifat mekanik, kondisi struktur mikro pada beberapa paduan Ni-Al-Nb yang ditambahkan perbedaan unsur Titanium (0,5% dan 1% Ti) menggunakan metode variasi temperatur aging yang dilakukan pada temperatur 650 °C,700 °C and 750 °C dengan holding time 4 jam serta media pendingin udara. Pengujian yang dilakukan untuk mengetahui karakterisasi spesimen meliputi pengujian metalografi menggunakan mikroskop optik, Rockwel hardness C, dan SEM-EDS, XRD. Hasil yang diperoleh dari penelitian ini yaitu Penambahan unsur Titanium mempengaruhi nilai kekerasan baik setelah hasil proses as cast, solution treatment maupun hasil proses aging. Kandungan Titanium 1% dapat mempengaruhi coarsening gamma prime dan membuat butir pada hasil struktur mikro menjadi halus.

Kata kunci: Ni base supperalloy, Aging, Pengaruh unsur Titanium

INTRODUCTION

Superalloys are heat-resistant alloys of nickel-based, iron-nickel, and cobalt-nickel which showed a good combination of mechanical strength and resistance to surface degradation. High temperature strength at all base superalloys matrix based on the principle of face-centered cubic (fcc) combined with precipitation strengthening and solid-solution hardening. [1].

In the nickel-base alloy, intermetallic γ' (Ni_3Al, Ti) generally has the properties to strengthen, while the alloy nickel, cobalt, and iron depend on strengthening on solid solution strengthening of the matrix fcc (γ). Iron-based superalloys and nickel-iron can also be grown in the presence of γ', the strengthening of the second phase of a γ' (Ni_3Nb) intermetallic and maybe η (Ni_3Ti). Cobalt-base superalloys can develop some boosters precipitation of carbides (Cr_7C_3, $M_{23}C_6$), but there is no strengthening of intermetallic phases of the same with the strengthening of the nickel-based alloys have been found in cobalt-base superalloys. [3]. Nickel-based superalloys have been widely used in various applications, which require high strength at high temperatures. Most types of these superalloys is age-hardenable because they have γ particles' chemical composition Ni_3 (Al, Ti) in γ-phase matrix. Superalloy properties depend on the size and distribution of precipitates γ' [1-3].

The investigations of intermetallic alloys is generally concentrated on the system Fe-Al, Ti-Al and Ni-Al. In addition, Ni_3Al-based alloys have been given the attention for excellence in physical and mechanical properties, such as low density, high temperature strength and excellent corrosion resistance. Superalloy nickel involving elements in significant amounts, Characteristic of each of the elements alloying and its effect on phase stability depends on its position in the periodic table of elements such as Ni, Co, Fe, Cr, Ru, Mo, Rh and W tend to be partitioned in the austenite phase (γ) and stabilize this phase. [4]. Investigations on intermetallic alloys generally concentrated on the system Fe-Al, Ti-Al and Ni-Al. In addition, Ni_3Al- based alloys have been given the attention for excellence in physical and mechanical properties, such as low density, high temperature strength and excellent corrosion resistance [5-8]. These elements have a radius not much different from the Ni and elements such as Al, Ti, Nb and Ta which have a radius of atoms are larger and tend to form ordered as phase (γ') Ni_3(Al , Ti, Ta) as the main amplifier particles. While elements such as B, Zr and C is the third group of inclined elements segregated to the grain boundaries of matriknya phase (γ) [9]. Phases of existing fixed react and interact. Phases that can appear based on the binary phase diagram of Ni-Al is the matrix γ, precipitated γ' and carbides [10].

The addition of alloying elements (Al and Ti) resulting in coherent phase γ'[Ni (Al, Ti)] which can provide a strengthening effect. But the ã-phase and phase γ' has a different lattice parameter. This difference produces a coherent strain that can hinder the movement of dislocations resulting in hardening precipitates. Elements such as chromium and aluminum are added, aims to improve protection against hot corrosion and high temperature oxidation. [11].

The purpose of this study was to test the mechanical properties, of hardness and mikrostructure the ternary alloy Ni-Al-Nb when added with titanium at different concentrations under conditions of solution treatment and aging 1200 °C.

MATERIALS AND METHODS

Specimen Preparation

The chemical composition of the alloy used in this study is the system of Ni-Al-Nb, Ni-Al- Nb-X Ti (x = 0.5% and 1%) is made of square nickel, aluminum, niobium and titanium with a purity of 99 +%. The process of weighing each ingredient according to the material balance as shown in Table 1.

Aging Testing

Alloys are processed using single arc furnace melting furnace using hearth furnace copper crucible by flowing water as a coolant conducted in the atmosphere of argon gas with high purity and used as an electrode

Table 1. Chemical Composition (wt%)

specimens	% weight			
	Ni	Al	Nb	Ti
Alloy-1 (Ni-Al-Nb)	76.05	6.65	17.25	-
Alloy-2 (Ni-Al-Nb-0.5% Ti)	75.65	6.6	16.7	1
Alloy-3 (Ni-Al-Nb-1% Ti)	75.3	6.55	17.05	2

in which tungsten if the tungsten interact with the surface of the material will produce an electric arc (arc).

After aging testing the specimens were observed with an Olympus BX60M optical microscope for testing metallography using epoxy resin and then polished mechanically with grid sandpaper 80 to 2000 and etching using aqua regia solution of 20 ml of HCl and 60 mL HNO_3. Hardness measurement specimens was performed by Krisbow Rockwell Hardness Tester with C-Scale. Analysis of X-ray diffraction (XRD) is used for phase identification and characterization of the specimen after the aging process using PAN alytical / X'Pert PRO PW3040 / x0. The specimens were analyzed by SEM using a Hitachi SU3500 and EDS using Ametek Apollo XL.

RESULTS AND DISCUSSION

Microstructure alloys as solution treatment

In Figure 1 shows the results of the microstructure of the alloy after solution treatment of the specimen Ni-Al-Nb with and without doping by Ti. The solution treatment process is carried out to influence the formation of the microstructure morphology of the three alloys.

After of the specimen Ni-Al-Nb with and without doping by Ti reheating at a temperature 1200 ºC for 2 hours, followed by rapid cooling using water media, it is shown that the microstructure morphology and grain size are different form microstructure. When the grain is enlarged, diffusion phenomena also occur which also arise due to temperature variables, where during the diffusion the atoms will tend to move to find equilibrium which is to look for areas with lower chemical potential, along with the heating time carried out during the solution process the treatment of the diffusion phenomenon continues, until after reaching 2 hours, rapid cooling is done with the water medium, the rapid cooling, affects several things, including, the unit cell that occurs will become more tightly the distance between cells which causes mechanical properties also increase, the emergence of carbides trapped in the phase growth that occurs. [12].

The alloys of the specimen Ni-Al-Nb with and without doping by Ti after the solution treatment process will form the phase γ' as in the arrow indicated. The Ni element will form Ni_3Al, Ni_3Nb and Ni_3Ti

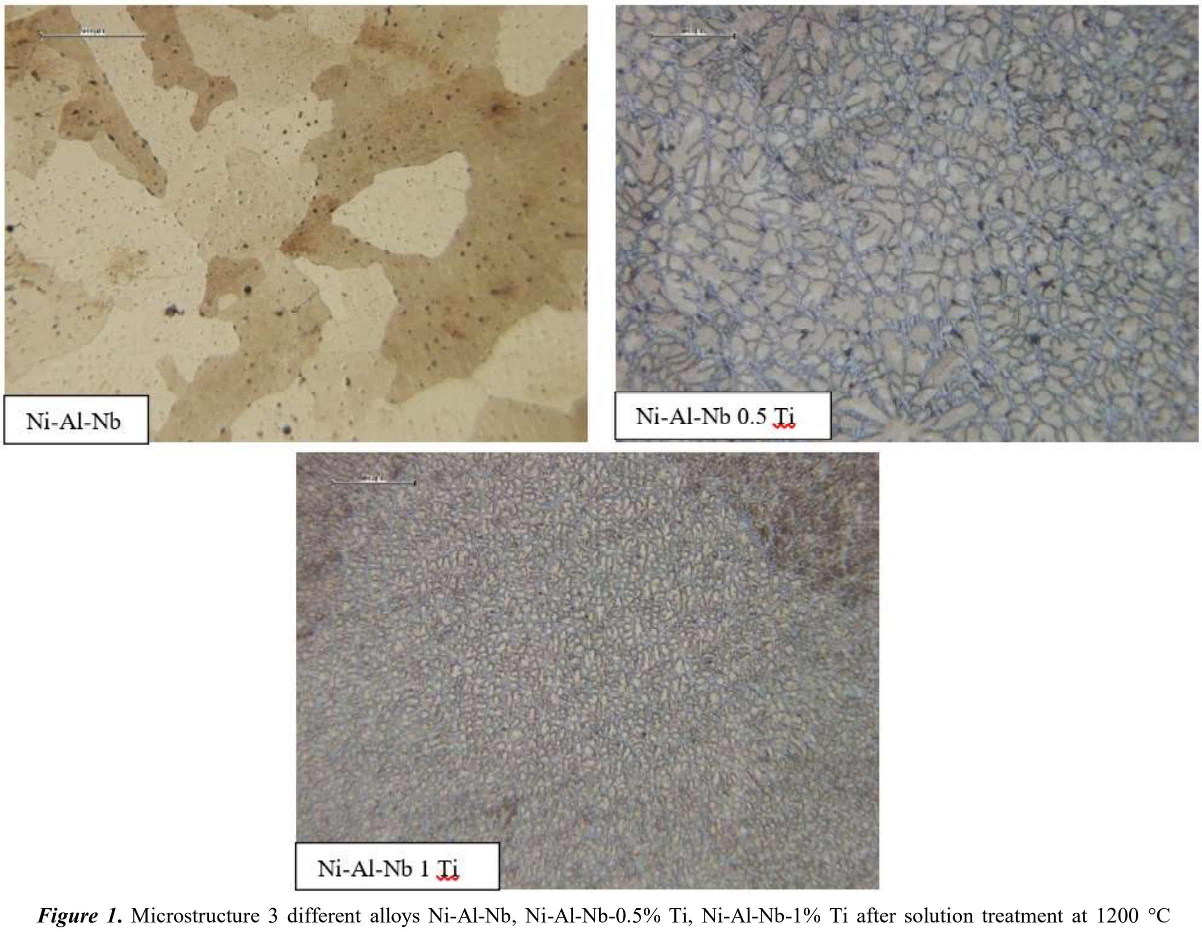


Figure 1. Microstructure 3 different alloys Ni-Al-Nb, Ni-Al-Nb-0.5% Ti, Ni-Al-Nb-1% Ti after solution treatment at 1200 °C for 2 hours 100x

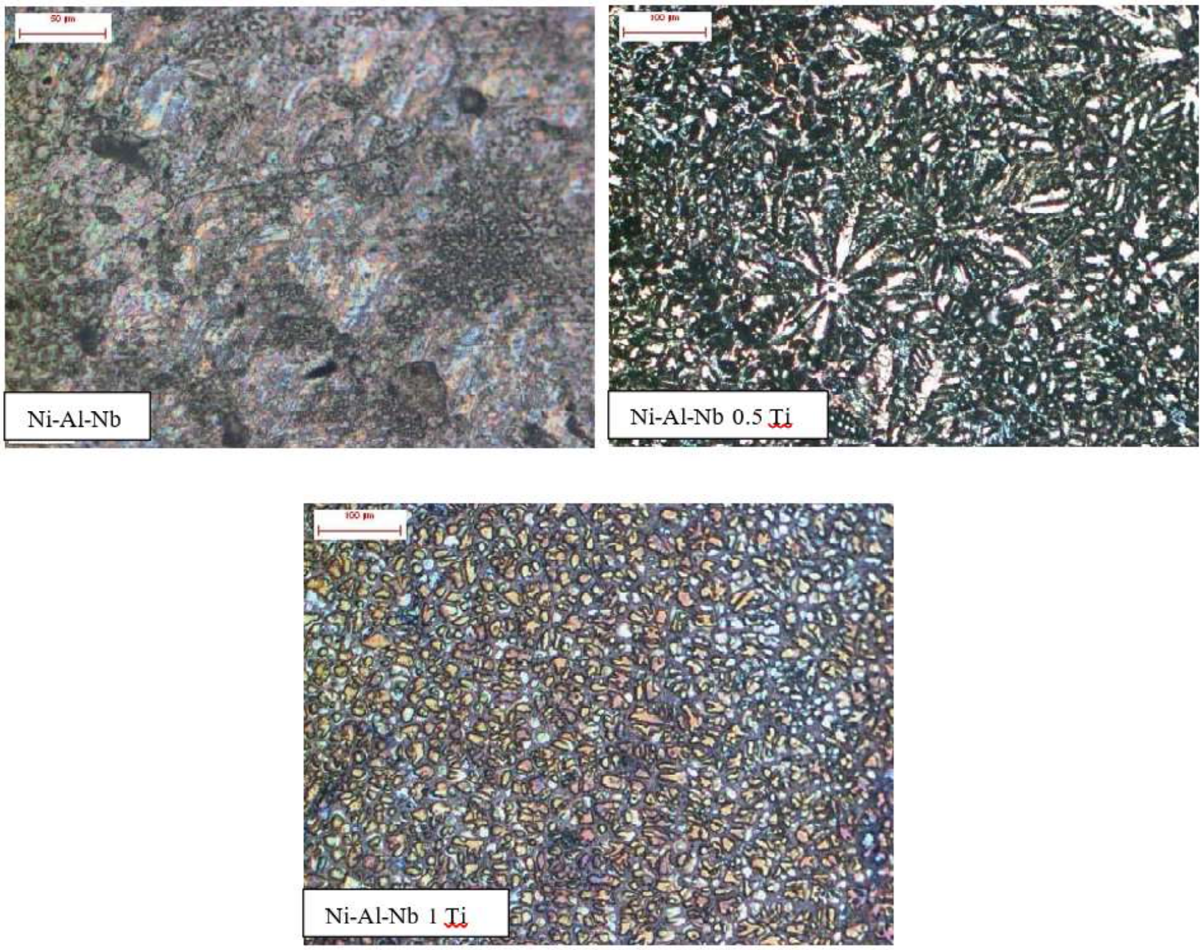


Figure 2. Microstructure 3 different alloys Ni-Al-Nb, Ni-Al-Nb-0.5% Ti, Ni-Al-Nb-1% Ti after aging at 750 °C for 4 hours 100x

precipitates after the solution treatment process which will affect the mechanical properties of the alloy. The addition of Ti to the alloy will cause the nucleating agent mechanism to refine the grain as can be seen in Figure 1.

Microstructure as aging 750 ^{o}C

In Figure 2 shows the microstructure of aging as alloy at 750 ^{o}C temperature for 4 hours with air cooling media. Formed mechanism that forms the sludge precipitates gamma prime phase Ni_3Al, Ni_3Nb and Ni_3Ti on the alloy.The presence of intermetallic phase serves as the main amplifier on a Ni- base superalloys, especially on the resistance to high temperatures. There is precipitated phase γ '$Ni_3(Al, Ti)$ that has been distributed into the matrix is capable of inhibiting movement of dislocations, which is responsible for increasing the yield strength. [3].

Differences solutioan treatment and aging process that is on the grain size distribution, where the addition of Ti relatively smaller grain size and grain coarsening inhibiting gamma prime. This affects the mechanical properties, the greater the temperature of aging the resulting mechanical properties will affect the hardness value. Influence the addition of Ti the specimen causes the sediment grains grow evenly in all areas and dissolve in the alloy.

Hardness of alloy

In Figure 3 shows that the addition of Ti will increase alloy hardness in the process of solution treatment. Niobium and Titanium strengthening precipitate γ' to replace Al in Ni_3Al with precipitation hardening mechanism. Precipitation hardening occurs because through the process of heating and exceeds the solubility limit of Al, Nb and Ti in nickel and produces a phase Ni_3Al (γ'), Ni_3Nb (γ' ') and phase Ni_3Ti.

Interest aging process carried out to obtain an effective arrangement or uneven reinforcement in order to obtain maximum hardness or strength and form a substrate of microstructure or fine grain.At 750 ^{o}C aging

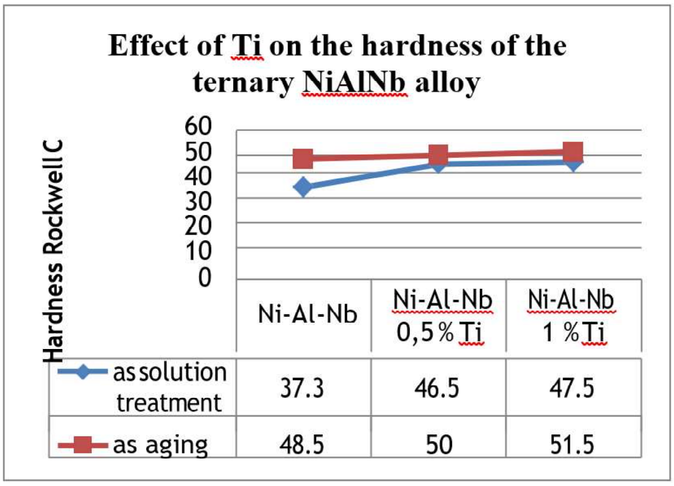


Figure 3. Alloy hardness Ni-Al-Nb, Ni-Al-Nb-0.5% Ti, Ni-Al-Nb-1% Ti after the solution treatment and the aging process.

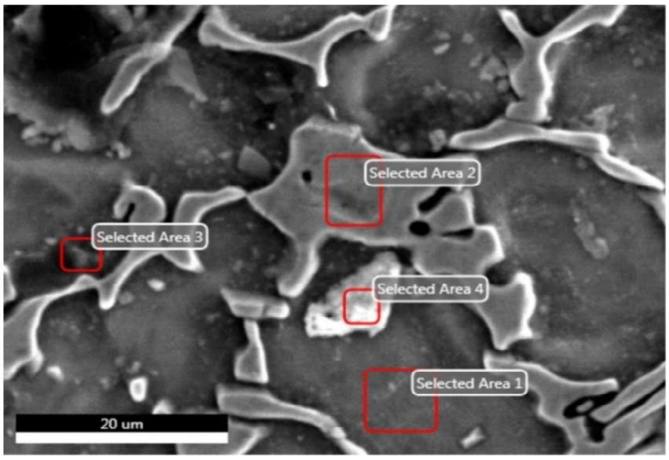


Figure 4. SEM alloys Ni-Al-Nb-Ti 1% after Aging 750 °C SEM

get an increase in hardness, because at a temperature of about 750 °C and 800 °C is the temperature stability gamma + gamma prime temperature equilibrium which makes its constancy increase as the number of gamma prime particles is formed until its peak strength is reached [1-3].

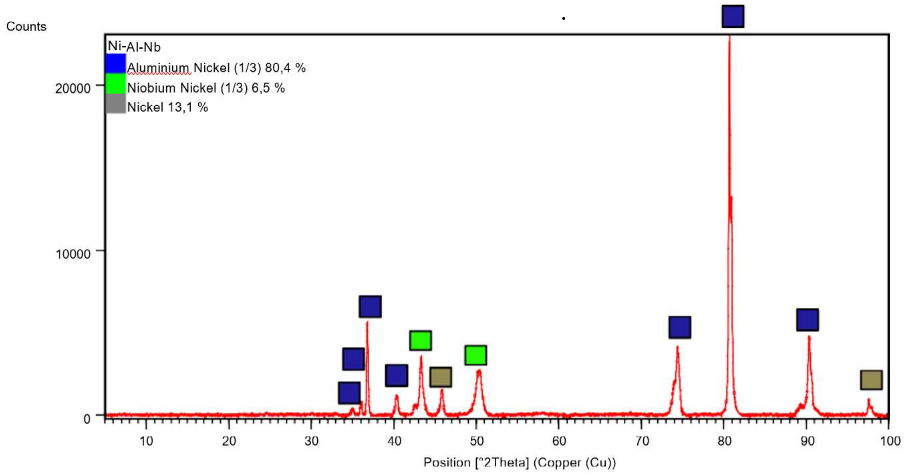
SEM alloy Ni-Al-Nb-Ti 1%

In Figure 4 the samples were tested for SEM and EDS, are Ni-Al-Nb 1% Ti aging 750 °C with a holding time of 4 hours.The results of SEM testing can be seen in Figure 4 which for the dark areas on the samples Ni-Al-Nb 1% Ti formed Ni_3Al phase γ‘and the protruding area formed Ni_3Nb phase γ’‘ as well as the light formed Ni γ phase and phase distribution Ni_3Ti γ’ that dissolve completely in the samples of Ni-Al. Type of reinforcement at each compound is for Ni based solid solution matrix, as aging compounds that occur are strengthening precipitation hardening.

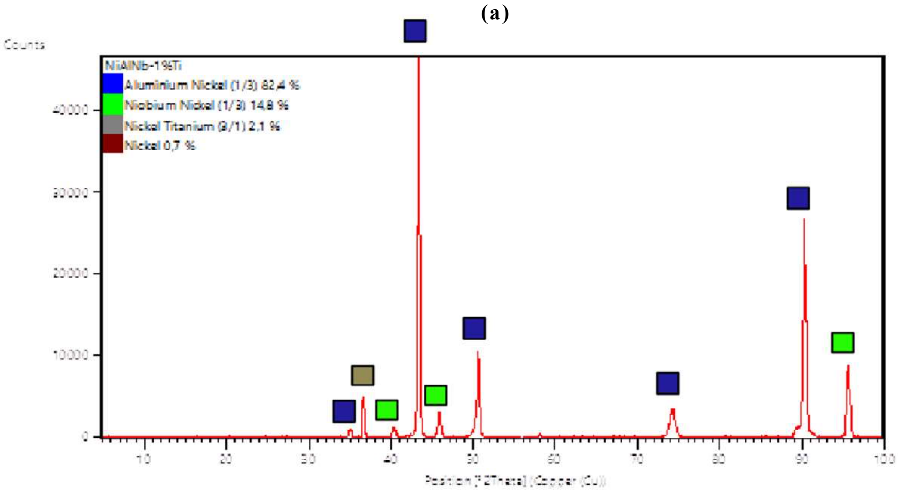
Table 2. Chemical composition of alloys Ni-Al-Nb 1% Ti aging 750 °C (wt%)

Elements (Wt%)	1	2	3	4
Al	7.85	0.00	9.41	1.13
Nb	13.20	26.97	16.91	3.37
Ni	78.95	73.03	73.69	95.50
Ti	0.91	0.91	0.91	0.91

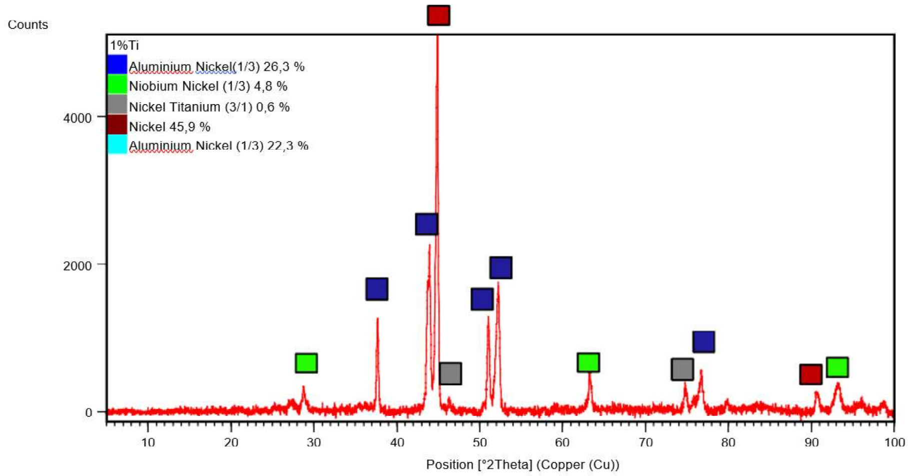
Because during the aging process elements of Al, Nb and Ti will seek stability or purity so as to form a bond precipitates. EDS testing result can be seen in table 2 with a few selected area and can be calculated and plotted on a ternary diagram to determine the phase contained in the selected areas.



(a)



(b)



(c)

Figure 5. Results of XRD Patterns Alloys Ni-Al-Nb (a) and Ni-Al-Nb 1% Ti (b) before aging and After aging750 °C Ni-Al-Nb 1% Ti (C)

X-Ray Diffraction

Figure 5 shows the X-ray diffraction pattern for a Ni-Al-Nb and Ni-Al-Nb 1% Ti before aging (a) and (b) and Ni-Al-Nb 1% Ti after aging at 750 °C (c). In Figure 5a, it can be seen that the diffraction pattern indicate the presence of γ-Ni phase, Ni_3Al (γ‘) and Ni_3Nb (γ’ ‘) and in Figure 5b are Ni_3Ti phase (δ) before aging. After aging, in Figure 5c where the result as aging phase highest in Ni γ and phase Ni_3Ti increases, the addition of Ti in Ni-Al-Nb will make the inhibition of grain γ‘ proved on the microstructure, the higher the temperature of aging the distribution of grain will the closer and the shape will be uniform.

CONCLUSION

Effect of solution treatment and aging tests on the alloy Ni-Al-Nb with Ti doping on aging 750 ^oC. alloy mechanical properties, especially hardness will increase with the addition of doping Ti and Ti content. Violence aging will increase compared to violent treatment solution due to temperature aging process will make the grain will be uneven and Titanium content of 1% can affect the gamma prime coarsening and make the grain on the results of micro structure becomes smoother and increase the value of violence. Phase alloy is formed on Ni_3Al phase γ ‘, Ni_3Nb γ’ ‘phase Ni γ and Ni_3Ti δ.

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