International Journal of Mechanical Engineering and Technology (IJMET)
Volume 9, Issue 8, August 2018, pp. 59–66, Article ID: IJMET_09_08_006
Available online at http://www.iaeme.com/ijmet/issues.asp?JType=IJMET&VType=9&IType=8
ISSN Print: 0976-6340 and ISSN Online: 0976-6359

 Scopus Indexed

STUDY THE EFFECT TIME FIXING OF SOLID STATE ALUMINUM ON THE MICRO-HARDNESS, IN THE SHAPE MEMORY ALLOY (CU,AL,NI)

Ahmed Abdulrasool Ahmed Alkhafaji
Asst. Professor in Mechanical Engineering Department,
College of Engineering - University of Baghdad

ABSTRACT

This research studied effect of time fixing aluminum in its solid state phase, on Micro-Hardness of a Memory Alloy (Cu,Al,Ni), the powder metallurgy method has been used to manufacture 3 samples for this alloy with(83%Cu,13%Al,4 %Ni) .

The samples were after the compression process, the process of sintering, different times for the first sintering stage at 500 ° C (0.5,1, and 1.5) hours.

Physical tests (Optical microscopy, XRD, and SEM) were carried out before and after sintering, to make sure of the generation phases (martensite, and austenite).

Vickers micro-hardness testing was conducted on three samples, using a digital micro-hardness tester, an applied load of 200 mg and a holding time of 20 seconds in order to investigate the effect of first stage sintering time on hardness values of smart alloys. The hardness value of the samples was (181.10, 148.33, and 109.20) respectively for the holding time. The difference in the type and quantity of the martensite generated by the holding time at the degree of 500 degrees Celsius, impact on the value of hardness.

Keywords: (Cu-Al-Ni) Smart Alloys, Powder Metallurgy, Micro-Hardness, XRD, SEM.

Cite this Article: Ahmed Abdulrasool Ahmed Alkhafaji, Study the Effect Time Fixing of Solid State Aluminum on the Micro-Hardness, in the Shape Memory Alloy (Cu,Al,Ni), International Journal of Mechanical Engineering and Technology, 9(8), 2018, pp. 59–66.
http://www.iaeme.com/IJMET/issues.asp?JType=IJMET&VType=9&IType=8

1. INTRODUCTION

A smart material is a term used to describe material that have an ability to adjust its properties and shape due to change in applied stress and or temperature. There is more than one application make smart materials or smart alloy very importance like actuators or piping fastener's or medical applications [1]. Cu-Al-Ni alloy get attention as smart alloy because its ability to work fine at high temperature about 200 [2]. The parent phase of Cu-Al-Ni smart alloy is austenite phase; to change it to Martensite must shear lattice distortion happen by quenching or super cooling. To return it to austenite phase a heating action must be done [3]. Fig. 1 shows this fact.

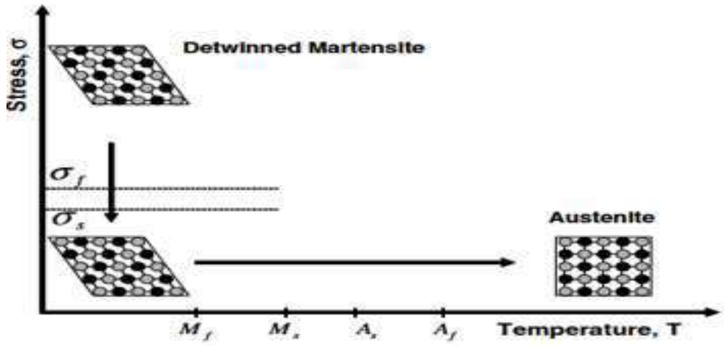


Figure 1 Phase Transformation [3].

Ahmed, and Sarah (2016) [4]: this paper presents the Taguchi approach for optimization of hardness for shape memory alloy (Cu-Al-Ni) . Nine experimental runs based on Taguchi's L9 orthogonal array were performed (OA),for two parameters was studied (Pressure and sintering temperature) for three different levels (300 ,500 and 700) MPa ,(700 ,800 and 900)oC respectively . After application the result of study showed the height hardness at a pressure and temperature at magnitude value 500MPa and 700 ºC. The best effective factor at ANOVA has pressure, 36.39%. The interaction given the best pressure 500 MPa and Temperature 800 ºC.

Ahmed and Hasan (2016) [5]: In this study a Cu-Al-Ni alloy was manufactured by powder metallurgy (PM) method by mixing powder of 83%Cu-13%Al-4%Ni for 6 hrs. after that compacted at 650 MPa and sintered at 850 C for (3,4,5,6,7) hrs. and heat treated to investigate the influence of(hardness and shape recovery) with multiple sintering time. To make sure that manufactured alloy is smart alloy XRD and SEM tests were done for 3 and 7 hrs .The result showed that Martensite layer was formed on the surface. The result of hardness and recovery tests showed a fluctuation of hardness and shape recovery with sintering time. The effect of sintering time on hardness is apposite on shape recovery.

Ahmed ,and Hasan (2017) [6]: For Producing shape memory alloy In this study the powder metallurgy method has been used to manufacture Cu-13%Al-4%Ni alloy by producing 5 samples every sample sintered in difference sintering time(3,4,5,6,7) hours. The samples also heat treated to stabilize Martensite phase. The result of shape recovery and porosity testing analyses by using artificial neural network predicting system to predict shape recovery and porosity behavior between three and seven sintering hours with smaller time step Due to there is no physical relationship between porosity and shape recovery

Ahmed and Bassam (2018) [7]: In this work study effect two elements (Cu, AL) of the alloy (Cu-Al- Ni) on the physical and mechanical properties which is considered one of the smart materials ,which manufactured by powder metallurgy technique with a constant weight percentage of element Ni in each the percentages. The compacting pressure and sintering temperature are constant in each the fabricated sample. The results of the sample test show the maximum values of shape recovery and micro hardness are 83%, 185HV respectively, which appeared in the weight percentage [82%Cu-14%Al-4%Ni].. IN this research the fuzzy logic model was used to investigate and the predicate of the mechanical properties between the weight percentages of the alloy by using parameters (Cu, Al).

Taher and Ahmed (2018) [8]: In this research, the newly achieved results determined the best ratio of (Cu-Ni) and (Al-Ni) in the smart (Cu-Al-Ni) alloys since these values achieved the best results in terms of, hardness and porosity. The (Cu-Al-Ni) smart alloys samples were produced using powder metallurgy technique with vacuum system. In this experimental setup, five weight percentages Cu-Ni & Al-Ni of ternary (Cu-Al-Ni) smart alloys were selected. Vickers micro-hardness and porosity properties of these alloys were studied using a digital Vickers micro-hardness tester, X-ray diffraction device (XRD), Optical microscopic device, Scanning Electron Microscope device (SEM) &Porosity testing in accordance to the ASTM B328-(1996) so as to show the effects of (Cu-Ni) & (Al-Ni) concentration ratios on hardness & porosity of (Cu-Al-Ni) smart alloys. The analysis results proved that when there is an increase in Al and Ni concentration in the alloy, lead, it will automatically increase the hardness and porosity, but the increase in Al ratio shows more effect than the increase in Ni ratio.

2. EXPERIMENTAL WORK

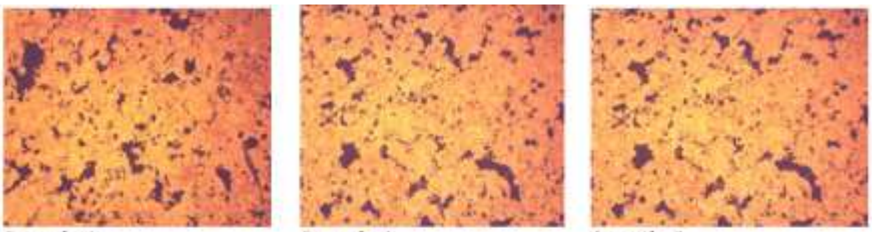
2.1. Manufacturing and heat treatment

The (Cu83%-Al13%-Ni4%) percentage was prepared by powder metallurgy method.

First step, was to mix the powder by horizontal drum mixing ,with 78 rpm speed for 6 hrs with 1% acetone (by volume) to prevent particle separateration due to different densities , also acetone decreases the friction between particles . The powder which has been used in this study was brought from (Skyspring Nanomaterials, USA) with a purity of 99% and an average particle size of 45 microns (-325 mesh).

Second step, using cylindrical die of 11 mm diameter, Fig. 2 shown that. In this research, three samples (1,2,and3) were manufactured, have (11 mm dia. x 5 mm length). Powder mixture was compacted at 650 MPa. After compacting finish the punch put on hold at 650 Mpa for 2minutes to prevent the spring back of the sample. The optical microscopy with 200x was then used to investigate the microstructure of the samples after compacting, to show the homogeneity of the samples, as shown in fig.3.The fig. 4 shown X-ray diffraction (XRD) tests were done on samples before sintering.

Figure 2 Die,Punch,and a Holder for Mold.



Sample 1 Sample 2 Sample 3

Figure 3 Microstructure of Samples after Compacting

Sample 1 Sample 2 Sample 3

Figure 4 XRD Tests before Sintering for Samples

Third step, fig. 5 shows the sintering diagram procedures of this alloy for heating the diagram is guaranteed in two phases. The first stage after heating the sample to 500 degrees centigrade, this is the stage of study for this research, to identify the effect of the holding of samples at different times (0.5,1, and1.5) hr. respectively, on the micro-hardness for this alloy. The purpose of this stage to keep aluminum (melting point is 660 oC) in solid state phase, before moving on to the second stage of sintering at 850 oC hold it 5 hr. All samples undergo the same procedures after the first stage. After heating procedures, then samples were left to cool in furnace to room temperature for the purpose of bonding particles of the sample in the solid state. The sintering process was done an electrical tube furnace with a vacuum atmosphere to prevent oxidization of the samples, fig.6 shows the furnace, and fig.7 shows the samples after sintering.

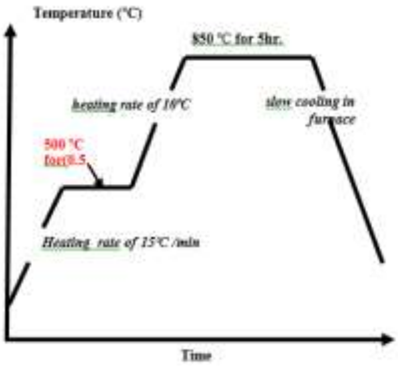


Figure 5 Diagram of Sintering Procedure.

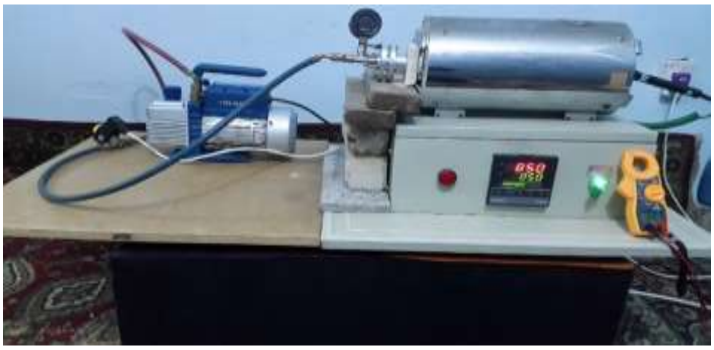


Figure 6 Electrical Furnace with a Vacuum System

Figure 7 Samples after Sintered.

Fourth step, heat treatment procedure, by the same system (electrical tube furnace with a vacuum atmosphere to prevent oxidization of the samples) was used for all samples (1,2,and 3) have different time (0.5,1,and1.5) of sintered in the first stage. To transform the Austenite samples after sintering to Martensite, two stages of heat treatment were employed. The first stage (aging the samples at 800 oC hold it at one hour, and after that rapidly quenched in iced water). And the second stage (heating the samples to 100 oC and hold it for two hours, and left it to cool in furnace).

2.2. Tests after manufacturing

After etching the samples so as to prepare them for microscopic inspection the following tests were performed. Two types of tests were applied in this research.

2.2.1. Physical tests

This type of testing is included:-

Optical microscopy: this test was done to show the homogeneity of the samples (1,2,and 3) after sintering, fig. 8 show the microstructure of samples after sintering.

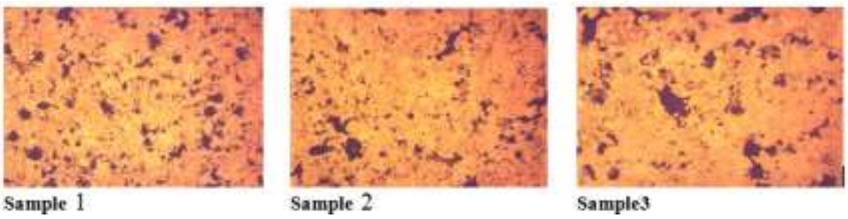


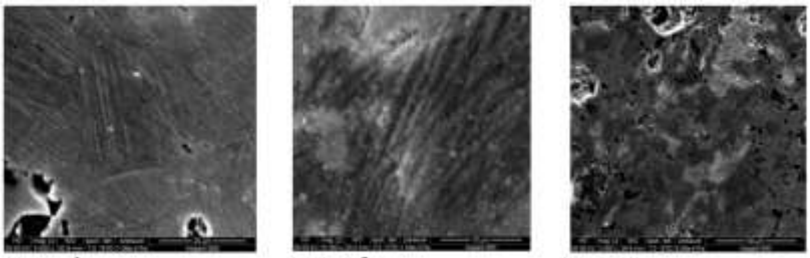
Figure 8 Microstructure of Samples after Sintering

XRD: X-ray diffraction tests were done on samples (1, 2,and 3) after sintering too, to cover the range of changes in first stage sintering time. The purpose of mentioned test was for investigating the effect of sintering time on Martensite transformation because the martensite transformation is the most important step to ensure that the sample is a smart alloy. Fig.9 shows the results of these tests.

Sample 1 Sample 2 Sample3

Figure 9 XRD Tests after Sintering for Samples

SEM: scanning electron microscope was used to obtain clear observation on microstructure to see the Martensite phase as shown in 10.



Sample 1 Sample 2 Sample3

Figure10 SEM after Sintering for Samples

2.2.2. Vickers micro-hardness test

Vickers micro-hardness testing was conducted on samples(1,2,and 3), using a digital micro-hardness tester as shown in fig. 11 an applied load of 200 mg and a holding time of 20 seconds in order to investigate the effect of first stage sintering time on hardness values of smart alloys. Micro-hardness measurement was used because most of the applications in which these smart alloys operate are small in size and are subjected to low loads such as coil wires. Table (1) shows the results of Vickers micro-hardness test of samples.

Figure 11 Digital Vickers Micro-Hardness Tester.

Table 1 Vickers Micro-Hardness Results of Samples.

Sample No.	Sintering time (hrs.) of first stage	HV_1	HV_2	HV_3	HV Average
1	0.5	179.1	169.3	194.9	181.10
2	1	112	160	173	148.33
3	1.5	128.1	106.1	93.40	109.20

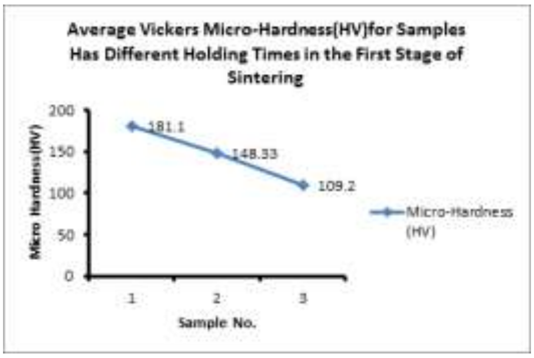


Figure 12 Average Vickers Micro-Hardness (HV) for Samples.

3. RESULTS AND DISCUSSION

1. 1. Fig.3. Optical microscopy, shown Microstructure of samples after compacting, before sintering and heat treatment. Note the homogeneity of the distribution of the components. This test has shown too pores and austenite layers, indicating that the mixing process of the components is almost good
2. Fig.4. XRD tests before sintering and heat treatment for samples. The results of this test showed the presence of the austenite phase, which has the effect of transformation after the process of sintering. This test is important to ensure that the sample has the ability to transform to the martensite phase after sintering.
3. Fig.8. Optical Microscopic examination of samples after sintering and heat treatment. He explained a difference before sintering for the microstructure. As well as the effect of time to hold in the first stage between the three samples. As well as the shrinking size of pores and expanding areas of the Martensites
4. Fig.9. XRD tests, the generation the martensite phase after the process of sintering and heat treatment. Figure (1) shows the behavior of the austenite and the martensite of the alloys in the shape of the transformation.
5. Fig.10. SEM after sintering and heat treatment for samples. This test clearly demonstrated the Martensite phase in the three samples, with twinned-martensitic layers (V-shape or Zig-Zag shape), which are caused by heat treatment.
6. The search goal here shows, after confirming the tests in the previous steps on the samples within the reminder format. Table (1) vickers micro-hardness results of samples, Three points of the micro-hardness were measured on the diameter of the samples, note the difference between values for one sample. Due to the probability of measurement occurring on areas containing porosity, or its occurrence on the area of the Martensite or his relative Martensite area. The average was taken as a basis for evaluation.

The results for the measurement of the Vickers micro-hardness, showed a decrease with an increase in holding time for the first stage of sintering at temperatures of 500 degrees centigrade , to fixing of solid state aluminum,

The average value of the hardness is at half an hour (181.10 HV) It is the highest value. While it decreased by (18 %) at the one hour, as the average value (148.33 HV) for the second sample. The third sample, declined from the first sample by a percentage of (39.7 %), and about the second sample (26.38 %), as the average value (109.20 HV),fig (12) shown that too.

4. CONCLUSION

When studying this type of alloy (the shape memory alloy), it is necessary to ascertain the phases generated by this characteristic (memory shape), the phases of the Austenite before the process of sintering and Martensite after the process of sintering and heat treatment to stabilize this phase. Through the physical tests(Optical microscopy, XRD, and SEM) exhibit by this research.

Keeping the aluminum in the solid state at (500 ° C) is important in the process of manufacturing of this type of alloy. And the hold time has an effect on the properties generated by the alloy, Manufacture of powder metallurgy. The results of the Vickers micro-hardness.The higher the hardness, when the hold time is less, the value of the hardness was (181.1HV) at half an hour, This type of martensite is brittle and causes heavy hardness that lead it to lose its ability to recover its original shape and confines to only limited applications at high temperatures .

Hold sample at one hour time in the first stage of sintering, decreased by 18%. While the decline reached 39% at the time of holding an hour and a half. Although the time varies by a fixed amount, the ratio of the drop to the hardness is variable, but it is approaching stability.

But when the hardness is lower than the required limit, it affects the ability to recover the alloy for original shape. The desired application that determines the value of hardness compared with the recovery original shape.

REFERENCES

[1] T.W. Duerig, “Present and Future Applications of Shape Memory and Superelastic Materials”, Nitinol Devices and Components, Fremont, CA, 94539 USA,(1995).

[2] N. Suresh and U. Ramamurty, “Effect of aging on mechanical behavior of single crystal Cu–Al–Ni shape memory alloys”, Department of Materials Engineering, Indian Institute of Science, Bangalore 560012, India (2006).

[3] P. K. Kumar and D. C. Lagoudas,”Introduction to Shape Memory Alloys”, Sipringer (2008).

[4] Ahmed Abdulrusool and Sarah Jalal Mosa"The Effective of Pressure and Sintering Temperature for Hardness Characteristics of Shape Memory Alloy by Using Taguchi Technique" Journal of Engineering, Number 1 Volume 22 January 2016.

[5] Ahmed Abdulrasool, Hasan Abdulsahib Mezaal"Investigating the Influence of Hardness and Shape Recovery with Sintering Time of Cu-Al-Ni Smart Alloy"International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-5, Issue-3, February 2016.

[6] Ahmed Abdulrasool ,and Hasan Abdulsahib" Investigation on Relationship between Shape Memory Effect and Interconnection Porosity under Multiple Sintering Time of Smart Alloy Cu-Al-Ni" Association of Arab Universities Journal of Engineering Sciences ,NO. 3 Volume. 24 Year. 2017.

[7] Ahmed Abdulrasool Alkhafaji, and Bassam Salman Darweesh" Effect of Cu-Al Proportions in Smart (Cu-Al-Ni) Alloy for Best Mechanical properties by Using Artificial Intelligent" Association of Arab Universities Journal of Engineering Sciences ,NO. 1 Volume. 25 Year. 2018.

[8] Taher Mnajid Ammar, and Ahmed A. R. Al-khafaji" Effect of (Al-Ni) & (Cu-Ni) Concentrations Ratios on the Hardness and Porosity of Ternary (Cu- Al-Ni) Smart Alloys" Australian Journal of Basic and Applied Sciences 2018 February; 12(2): pages 36-48 DOI: 10.22587/ajbas.2018.12.2.7.