The Iraqi Journal For Mechanical And Material Engineering, Vol.13, No.2, 2013

INFLUENCE OF SIC AND GRAPHITE ON TOOL LIFE USED IN DRILLING C63200 ALLOY PREPARED BY POWDER METALLURGY

Dr.Haydar Al-Ethari
Babylon University
College of Material's Engineering
Dept. of Engineering Metallurgy

Hussain Hamza
Babylon University
College of Engineering
Dept. of Material's Engineering

Nickel-Aluminum Bronze (NAB) alloys have properties meet many requirements in engineering applications. But many, especially the alloy C63200 suffer weakness in machining properties, so the current study aims at improvement the machineability of this alloy without loss their mechanical properties. A base alloy of (Cu-9%Al-5%Ni-4%Fe) composition was prepared by compacting mixed powders of the constituents under a pressure of 656MPa and sintering at 950℃ for 50min in special atmosphere, then heated to 900℃ for 45min and quenched in water and then aged at 500℃ for 25min. Under the same conditions other samples of the alloy with various percentage of graphite or/and SiC additions were prepared. The effects of these additives had been studied. Machineability was represented by a tool life of a 3mm-diameter high speed steel twist drill. A maximum width of flank wear of 450μm was considered as a criterion of tool life. Three cutting speed (0.95, 1.7, 3m/min) each with three feed rate (0.1, 0.25, and 0.4mm/rev) were considered as cutting conditions.

The study showed that (0.6%graphite) reduces the hardness by (11%) and the porosity by (30%), while (2%SiC) increases the hardness by (14.7%) and the porosity by (13%). Adding 0.6%graphite and 2%SiC together causes a decrease of (9.7%) in porosity and an increase of only (1.2%) in hardness. A maximum increase in tool life of (27%) was achieved with an addition of (0.6%graphite) while a maximum reduction of (29%) was recorded due to (2%SiC), but (0.6% graphite) with (2%SiC) caused an increase of tool life by (7%).

Key words: NAB- alloy, Graphite, SiC, PM, Tool life, Drilling

تأثير كاربيد السليكون والكرافيت على عمر عدة مستخدمة لتثقيب سبيكة (C63200) محضّرة بطريقة ميتالورجيا المساحيق

الخلاصة:

تمتلك سبائك برونزات الامنيوم–النيكل صفات تلاقي العديد من متطلبات التطبيقات الهندسية. الا ان الكثير وخاصة السبيكة (C63200) يعاني من ضعف في الصفات التشغيلية، لذا فان الدراسة الحالية تهدف الى تطوير قابلية تشغيل هذه السبيكة دون فقدان صفاتها الميكانيكية. حُضِّرت سبيكة أساس بتركيب كيميائي (Cu-9%Al-5%Ni-4%Fe) بكبس مكونات المساحيق المخلوطة باعتماد ضغط مقداره (656MPa) بعدها لُبدت عند درجة حرارة (950℃) لفترة (50min) في جو خاص بعدها سُخنت الى (900℃) لمدة (45min) وأُخمدت في الماء بعدها عُتِّقت عند (500℃) لمدة (25min). تحت نفس الظروف حُضرت نماذج أخرى مع اضافات بنسب مختلفة من كاربيد السليكون (SiC) أو/ و الكرافيت. دُرست تأثيرات هذه الاضافات. مُثلت قابلية التشغيل بعمر مثقب التوائي من فولاذ السرعات العالية بقطر (3mm). أقصى عرض بلى خلوص مقداره (450µm) قد تم اختياره كمعيار لعمر العدة. تم اعتماد ثلاث سرعات للقطع هي (0.95, 1.7, 3m/min) يقابلها ثلاث معدلات تغذية هي (0.1, 0.25, and 0.4mm/rev) كظروف تشغيل. بيّنت الدراسة بأن (0.6%graphite) تقلّل الصلادة بنسبة (11%) والمسامية بنسبة (30%)، بينما (2%SiC) تزيد الصلادة بنسبة (14.7%) والمسامية بنسبة (13%). ان اضافة (0.6%graphite) و (2%SiC) معا تتسبب بنقصان المسامية بنسبة (9.7%) وزيادة في الصلادة بنسبة (1.2%) فقط. بلغت أقصى زيادة في عمر العدة نسبة (27%) عند اضافة (0.6%graphite) بينما يلغ أقصى نقصان نسبة (29%) عند اضافة (2%SiC)، لكن اضافة (0.6%graphite) و (2%SiC) معا سببت زيادة في عمر العدة نسبتها (7%).

1.INTRODUCTION:

Aluminum bronzes are one of the important groups of Cu-alloys that provides many properties which make them the only choice for some engineering applications. Aluminum is the basic alloying element in this group giving it the high strength and excellent wear resistance. Alloys with (8-11% Al) and some additives of Fe & Ni consist of two phases "α+β". Fe & Ni are added to enhance the properties of the alloy. Fe increases the alloy strength, while Ni increases the corrosion resistance and the yield stress. Fe & Ni have very important effects on (Cu-Al) system as they move the equilibrium diagram up to the right and result in some precipitates . Phase "K" precipitates from α and β and these precipitates take spherical or lamellar configuration according to the precipitation method which depends on precipitation temperature and composition [1]. Precipitates resulted due to Fe are fine, regular through the structure and do not concentrated on the unit cell boundary [2,3] and this impede the grain's growth. Precipitates resulted due to Ni are clustering with lamellar shape and they occur at a lower temperature. The final micro structure of Nickel- Aluminum Bronzes (NAB) depends on the cooling rate and Al- contain, so the micro – structure produced by slow cooling must be treated by quenching and aging to precipitate very fine "K" to enhance the alloy strength.

Many papers related to NAB alloy were published. They were focused on the effect of Al-percentage in the alloy [4] or the effect of some other alloying element and cooling rates [5,6] or on the corrosion behavior of the alloy [7] or on the wear behavior of such alloy prepared by powder metallurgy (PM) technique, but alloys of this group prepared by PM specially (C63200) alloy suffer a weakness in their machining properties. So the present study will be focused on the improvement of the machining properties of this alloy without loss in its mechanical properties.

Using of PM technique to produce parts or components from NAB lead to new applications for this alloy. Characteristics of PM technique with the specifications of NAB – alloy make it suitable for components that required high strength as gears, impeller's , connecting rods in internal combustion engines and others [8]. One of the more important characteristics of PM technique is its ability to produce alloys from undissolved materials in each other or have limited solubility. So in present study PM technique was used to prepare the alloy samples. Components with complex configuration (as cross holes, undercut , threads , blind holes,…etc) cannot be produced completely by PM technique, so there in a need for machining operation. Drilling of short holes represents 30% of the machining operations for the sintered products [9]. So machineability will be studied considering a drilling process.

2.EXPERIMENTAL PART:

Samples of a base NAB alloy with a chemical composition of (Cu-9% Al- 5% Ni - 4%Fe) according to ASTM was prepared by using PM technique. Other samples of this alloy were prepared with different percentages of SiC or/ and graphite. The prepared samples are coded as demonstrated in table 1. Chemical analyses tests using atomic absorption spectrophotometer shows the purity of the used powders as indicated in table 2. Powders with grain size of no more than 38μm were used to prepare the samples. Wet mixing with acetone (2 wt%) for 6hrs in electric mixture was used.

The samples were compacted at ambient temperature on an electric hydraulic press type (Soil test, Inc. – USA) using double action dies specially designed to produce cylindrical samples with a diameter of 16.9 mm and a height of 10mm. The samples were used for hardness, porosity, microstructure, and machineability tests.

Many attempts for compacting had been carried out for a maximum green density of the samples to be achieved, so as shown in fig.1 compacting pressure of 656MPa was used. All samples were compacted with a loading rate of (1.7 ton/ min) and a period of 1 min for the maximum pressure. All samples were sintered in electric furnace type (SRJX 5.1, ±5°C accuracy, 1600°C maximum temperature, China). Many attempts had been carried out to achieve best results. During sintering the samples were coated with a 1-cm-thick layer of cook (preheated to 700^0C) and impeded in pure alumina powder in uncovered prismatic steel container . The container was heated to 650°C and then up to 950°C for 45 min and cooled in still air. The sintered samples were heated to 900°C for 50 min and quenched in water. A temperature of 500°C for a period of 25 min was considered for aging treatment of the samples.

Porosity of the final (heat-treated) alloy samples was determined according to the following equation [10,11]:

$$Porosity(Apparent)\% = \frac{W_w - W_d}{W_{sat} - W_s} \times 100$$

When: W_d – Dry weight of the samples; W_w- wet weight of the sample (the sample was weighted after immersing it for 24 hours in distilled water); W_{sat} – Saturated weight (the sample was weighted after immersing it for 5hrs. in pure water at 80°C); W_s – suspended weight (weighting the suspended sample in distilled water).

Microstructure test were carried out on a photo-microscope type (KLNS320, USA) with the help of a digital camera type (Canon). Samples to be tested were prepared according to (ASTME407-99, 1999).

Machineablility was assessed basing on a tool life of a high speed steel (HSS) 3mm diameter twist drill. A maximum width of 450 μm for the flank wear was regarded as a criterion for the tool life [12]. Dry blind drilling operations had been carried out on drilling machine type (AJAX, 56-1000rpm, 0.1-0.5mm/ rev, Great Britain). Three cutting speed (0.95, 1.7 , and 3 m/ min) were used with three feed rate (0.1, 0.25, and 0.4 mm/ rev.). The width of the crater wear was measured every 60sec of drilling. Optical microscope type **(1280XEQ-MM300TUSB)** integrated with CCD camera was used to capture the image of worn tools and to measure the flank wear.

3. RESULTS & DISCUSSION:

3.1. Results of physical and mechanical tests:

Results are demonstrated in table 3. The results show noticeable increase in hardness of the samples after treating them by quenching and aging. This indicates that new phases had been created after these treatment. The recorded hardness numbers of the base alloy are close to those recorded by other researcher [13]. Fig.2 demonstrates the effect of the additives and their percentage on the hardness of the heat –treated alloy-samples. It can be noticed that a low percentage of graphite led to a little increase in hardness but a negative effect appeared with a higher percentage This is due to the lubricating behavior of graphite. SiC led to increase the hardness due to its nature as a hard reinforcing phase.

Tab.3 and fig.3 show the porosity of the prepared alloy samples. It is clear that SiC increases the porosity, while graphite reduces it. Maximum increase of 12.9% was recorded in alloy sample A4 and maximum reduction of 29.1% was recorded in alloy sample B3.

Fig.4 illustrates the structure of the only sintered alloy samples BA, A4 and B3. It seems that the major phase of these structure is the "α" phase, while no k-phases appeared as such phases can be resulted from slow cooling rate only [14]. However, K_4-phase in the standard microstructure of NAB alloy can be seen if and only if (%Fe>5%). SiC and graphite particles can be noticed clearly from fig. (4, b&d). Fig.5 shows the resulted microstructure of the alloy samples AB, A2, B2, and C2 after quenching in water. Martensite can be noticed as fine black lines (nodular martensite) created due to the change of β as a result of high cooling rate the white spaces in the microstructure shown represent α-phase. Creation of compounds between Al&Cu represents the change in microstructure due to aging treatment. Such compounds cannot be seen by usual microscoping, but increase in hardness indicates their creation.

3.2. Results of machineability tests:

Fig.6 shows alloy samples before and after drilling operation and table 4 demonstrates the tool life of the used drill according to the regarded machining conditions. The following can be concluded from the results :

- For all alloy samples cutting speed or/ and feed rate have a negative effect on tool life. This is typical effects related to the fact that more heat is generated with a higher cutting conditions so more wear at the flank surface of the tool. In addition an increase in feed rate causes a higher thrust force so a higher effect on the drill.
- Tool life is affected negatively with the percentage of SiC at all cutting conditions due to its abrasive effect and as it increases the hardness of the alloy samples. This may lead to a higher cutting force and more heat may be generated.
- SiC led to increase the porosity of the alloy sample, which affects the continuity of the cutting process. This means that the tool is affected by vibrating load and is subjected to thermo-mechanical fatigue.

- Graphite alone has positive effects on tool life as it behave as a lubricant which may reduce the amount of heat generated. In addition graphite reduces the porosity of the alloy samples.
- There is a compensation between the negative effect of SiC on tool life and the positive effect due to the addition of graphite. This is clear with an addition of 0.6% graphite together with 2% SiC specially at higher cutting speed and feed rate as shown in fig.7. Fig.8 shows the tool life of the alloy samples as a percentage of that of the base alloy.

4.CONCLUSIONS:

The following can be concluded:

1- Samples of C63200 alloy can be prepared by sintering the compacted constituting powders at 950°C for 45 min and quenching in water after heating to 900°C for 50 min and aging at 500°C for a period of 25 min.

2- (0.6%graphite) reduces the hardness by (11%) and the porosity by (30%), while (2%SiC) increases the hardness by (14.7%) and the porosity by (13%).

3- Adding (0.6%graphite) and (2%SiC) together causes a decrease of (9.7%) in porosity and an increase of only (1.2%) in hardness.

4- A maximum increase in tool life of (27%) was achieved by an addition of (0.6%graphite) while a maximum reduction of (29%) was recorded due to (2%SiC), but (0.6% graphite) with (2%SiC) caused an increase of tool life of a 3mm-diameter high speed steel twist drill by (7%) at high cutting conditions (cutting speed of 3 mm/min and feed rate of 0.4 mm/rev) .

Table 1. Codes of the prepared alloy- samples.

Alloy code	Weight percentage of the element (%)		Alloy code	Weight percentage of the element (%)	
	SiC	Graphite		SiC	Graphite
AB (Base alloy)	----	----	B1	----	0.1

A1	0.5	----	B2	----	0.3
A2	1.0	----	B3	----	0.6
A3	1.5	----	C1	2.0	0.1
A4	2.0	----	C1	2.0	0.3
			C3	2.0	0.6

Table 2. Purity of the used powders.

Powders Type	Purity (%)	Powders Type	Purity (%)
Cu	99.93	Ni	97.93
Al	97.89	Fe	98.06

Table 3. Results of physical and mechanical tests.

Alloy Code	Hardness HRB (Before Aging)	Hardness HRB (After Aging)	Final Porosity (After sintering)	Alloy Code	Hardness HRB (Before Aging)	Hardness HRB (After Aging)	Final Porosity (After sintering)
BA	70	82	10.31	B_1	72	83	9.45
A_1	75	86	10.62	B_2	66	75	8.02
A_2	86	89	10.82	B_3	61	73	7.31
A_3	89	91	11.21	C_1	90	92	10.20
A_4	94	94	11.64	C2	85	88	9.72
				C_3	77	83	9.31

Table 4. Tool life (in sec.) according to the regarded machining conditions.

Alloy code	Cutting Speed (mm/min)								
	0.95			1.7			3		
	Feed (mm/rev)			Feed (mm/rev)			Feed (mm/rev)		
	0.1	0.25	0.4	0.1	0.25	0.4	0.1	0.25	0.4
BA	656	646	621	480	462	418	302	234	184
A_1	653	637	605	473	438	412	294	201	176
A_2	636	642	591	452	426	397	254	186	165
A_3	628	603	573	428	409	375	242	184	159
A_4	591	584	551	406	386	365	226	165	143
B_1	667	655	639	484	454	429	307	226	168
B_2	667	661	635	506	476	463	319	242	201

B_3	687	675	657	547	503	486	357	298	240
C_1	601	587	678	400	395	371	232	173	154
C2	618	601	583	417	413	397	253	231	185
C_3	630	640	620	482	468	427	312	248	197

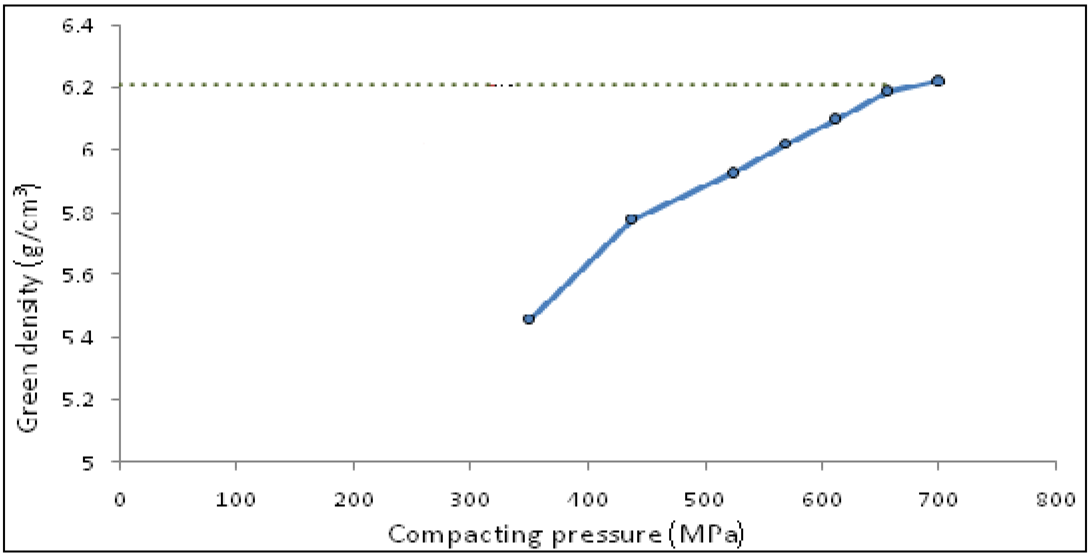

Fig.1. Variation of green density with the compacting pressure.

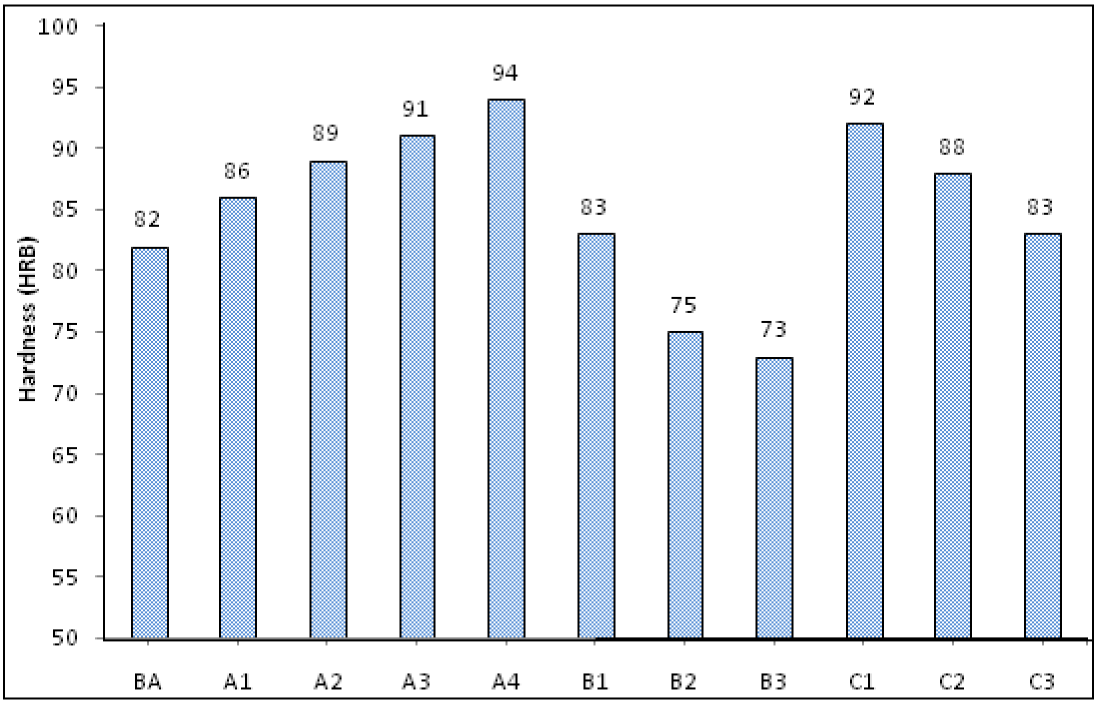

Fig.2. Hardness of the heat treated alloy samples.

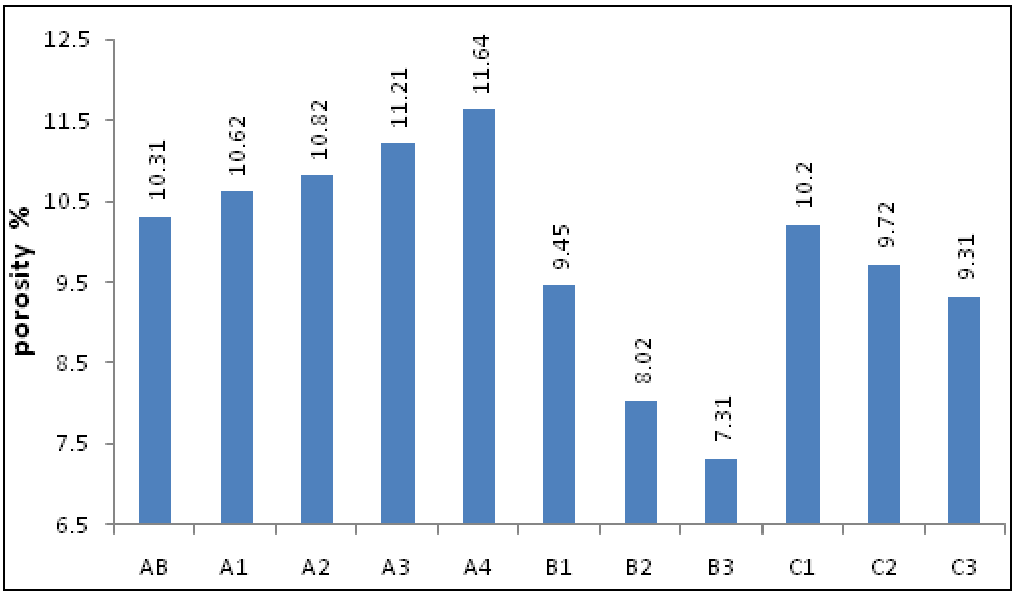

Fig.3. Porosity of the heat treated alloy samples.

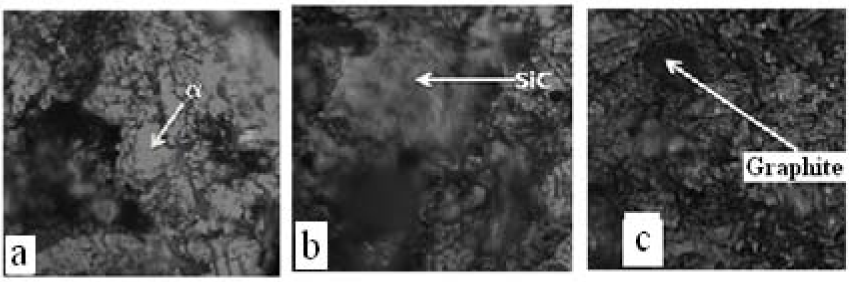

Fig.4. Microstructure of the sintered alloy samples(x800)
a) BA; b) A4; c) B3

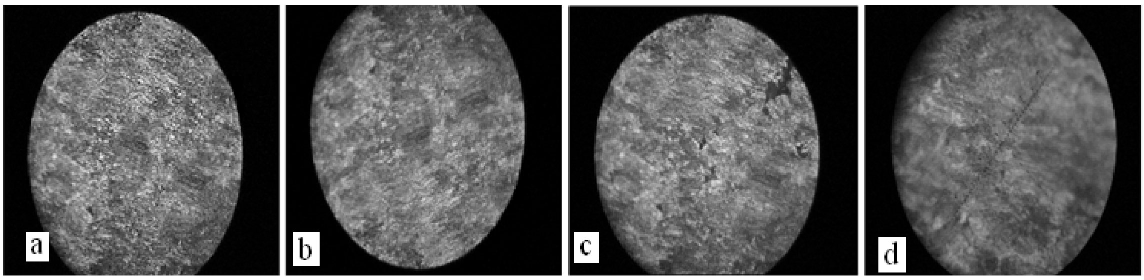

Fig.5. Microstructure of the final (heat treated) alloy samples(x800)
a) BA; b) A2; c) B2; d) C2.

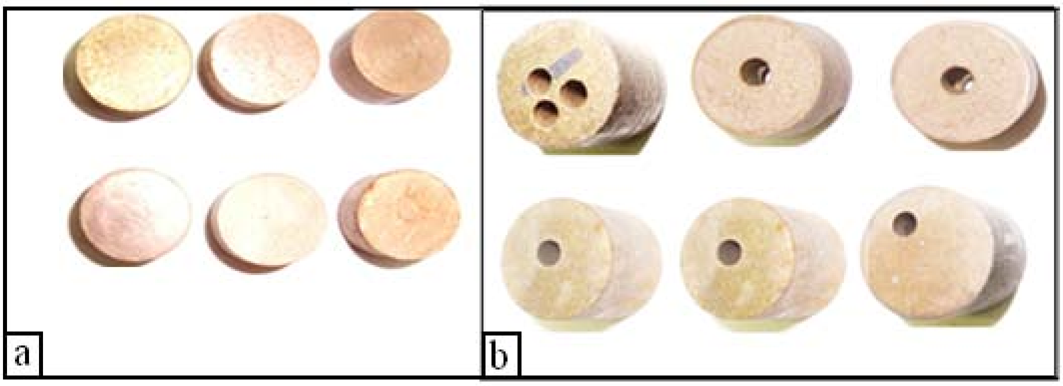

Fig.6. Alloy samples a) before drilling; b) after drilling

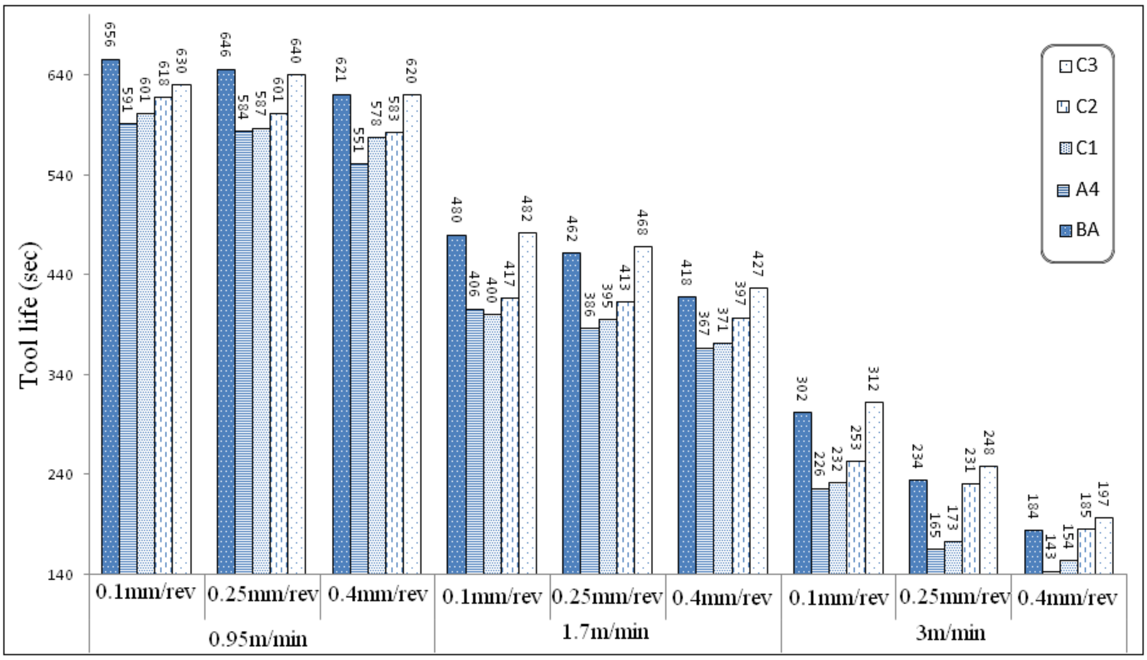

Fig.7. Effect of 2%SiC and graphite on tool life.

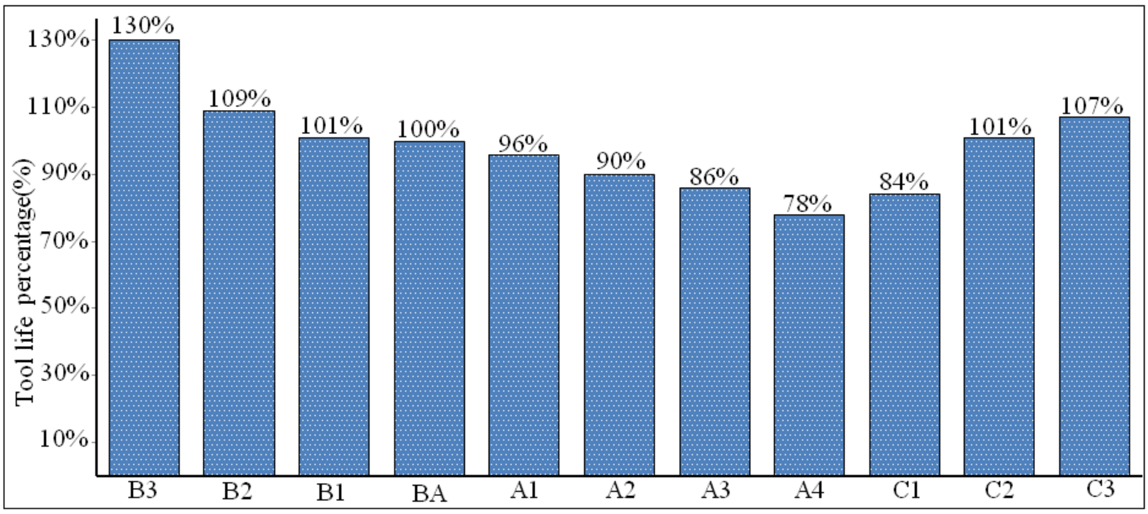

Fig.8. Tool life of the alloy samples compared with that of the base alloy

(Cutting speed= 3m/min ; Feed rate = 0.4mm/rev.)

REFERENCES:

- Abdul –Raheem Kadhim Abid-Ali, 2007, Investigation of Certain Shape Memory Alloys in Space Systems, Doctoral thesis, Babylon University.

- Alden kendall L., 2005, Tool Wear and Tool Life, ASM handbook**,** Vol-16, ASM International.

- ASTM International designation, 2003: B 328 – 96, Density, Oil Content, and Interconnected Porosity of Sintered Metal Structural Parts and Oil-Impregnated Bearings, ASTM International, United States.

- Calvin v.hyatt,1997, Review of Literature Related to Microstructure Development during Laser Surface Engineering of Nickel Aluminum Bronze, Defense research establishment Atlantic, Canada.

- Chen Rui-ping, Liang Ze-qin, 2007, Effect of Heat Treatment on Microstructure and Properties of Hot-Extruded Nickel-Aluminum-Bronze, Trans. Nonferrous met. Soc. China 17, p(1254-1258).

- Copper Development Association, Aluminum Bronze for Industry, CDA Publication No.83, March 1986.

- Copper Development Association, 2010, Characteristics and Properties of Copper and Copper Alloy P/M Materials. On website: www.copper.com.

- Dursun Özyürek, Tansel Tunçay , Cihan Degrmenc, 2009, Wear Behaviour Of Nickel-Aluminum Bronzes Produced With Mechanical Alloying, Uluslararası _leri Teknolojiler Sempozyumu (IATS'09). Karabuk, Turkiye.

- Gorecki T., korl S., Tokarski M., 1988, Effect of The Rate of Continuous Cooling From The Beta Phase Region On The Composition Structure And Properties of Cu-10Al-3Fe-2Mg. Novoch. Politech. Inst., Novocherkask, Russia.

- Hiyroyasa Mitani, Masaru Yokota, 1973, Sintering in Mixed Powder Compacts of Multicomponent System for Aluminum- Bronze.J.Japan Soc. of powder and powder metallurgy.

- Lenard D. R., Bayley C. J. and Noren B. A., 2009, Detection of Selective Phase Corrosion of Nickel Aluminum Bronze In Seawater by Electrochemical Frequency Modulation, DOD corrosion conference, Canada.

- Ronald N.Caron, James T.staley, 1997, Effects of Composition, Processing, And Structure on Properties of Nonferrous Alloys, ASM handbook,Vol-20,ASM Handbook Committee,.

- Šalak A., Selecká M. and Danninger H., 2005, Machinability of Powder Metallurgy Steels, Cambridge International Science Publishing.