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Effect of Sintering Time for Aluminum / Stainless Steel Composite on Mechanical Properties

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Abstract

The effect of sintering time on mechanical properties of two powder composition containing ٢٥ wt% and ١٢,٥ wt% ٣١٦L Austenitic Stainless Steel and the balance is Aluminum has been studied, at two sintering temperatures ٥٠٠ and ٥٣٠ C^{o} for sintering time (٣٠،٦٠،٩٠،١٢٠،١٨٠) minutes. Results of compression tests showed that compression strength and yield strength increase with sintering time, reaches a maximum value and then decreases gradually, for both compositions and sintering temperatures used. Hardness showed a similar relation with sintering time for both compositions and sintering temperatures, microstructure of the sintered parts showed a two phase structure, one phase was identified using XRD technique as FeAl٣, the other phase is Al matrix.

Keywords: *Sintering, Composite, Compression Strength, Compression yield Strength, micro-hardness, microstructure*.

تأثير زمن التلبيد لمركب الألمنيوم / الصلب اللامصديء على الخواص الميكانيكية

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الخلاصة

تم في هذا البحث دراسة تأثير زمن التلبيد على الخواص الميكانيكية لخليط مشكل بطريقة متالورجيا المساحيق ، يتكون من ٢٥% و ١٢,٥% وزنا صلب لامصديء نوع (٣١٦L) والباقي معدن الألمنيوم ، عند درجتي حرارة تحميص هي ٥٠٠ و ٥٣٠ ^{o}م لزمن تلبيد (١٨٠،١٢٠،٩٠،٦٠،٣٠) دقيقة. بينت نتائج اختبارات الضغط ان مقاومة الضغط ومقاومة الخضوع ازدادت مع زيادة زمن التلبيد ، حتى قيمة قصوى ثم تنخفض تدريجيا .لكل من الخليط المعدني ولدرجتي حرارة التلبيد المستخدمة. وقد اظهر اختبار الصلادة نفس التصرف وايضا لكل من تركيب الخليط المعدني ولدرجتي حرارة التلبيد.ان التركيب ألمجهري للعينات التي جرى لها تلبيد أظهرت وجود طورين ، حيث تم تحديد احد الطورين باستخدام حيود أشعة X وكان عبارة عن(FeAl٣) وكان الطور الأخر هو الأساس معدن الألمنيوم .

Introduction

An increased interest is observed in last years in metal-matrix composite, mostly light metal based, which have found their applications in many industry branches, among others in the aircraft industry, automotive, as well as electrical and electronics engineering [١،٢،٣،٤]. A large series of investigation have been done on metal-matrix composites concerning the production methods and properties of mixtures [٥،٦،٧].The powder metallurgy can be used to produce alloys that are unobtainable by other techniques[٨،٩].The prospect of strengthen metals, especially light weight metals having low yield strength, such as commercial aluminum alloys with other alloys has stimulated a great deal of experimental study and theoretical consideration[١٠]. A great interest has been focus on the production of aluminum P/M parts because of the combination of lightweight. Corrosion resistance, and acceptable mechanical strength [١١،١٢،١٣،١٤]. Sintered aluminum precision parts have now featured for some years in the delivery programmers of numerous producers of sintered products [١٥, ١٦, ١٧،١٨]. In present investigation aluminum /austenitic Stainless Steel cold pressing and the sintered have fabricated mixture. The choice of this system lies in the easy availability of matrix aluminum and expected good mechanical properties as well as unique corrosion resistance [٨،١٩].

Experimental procedure

Commercially pure aluminum powder and ٣١٦L Stainless Steel were used (table ١ & ٢ shows their chemical composition and sieving analysis).They are mixed thoroughly then compacted uniaxially using universal testing machine for a total pressure of ٥٩٥ MPa in a high strength steel die to form a cylindrical shape specimens (diameter ٢٢,٣ mm , height ٢٠-٢٣ mm). Two kinds of powder mixtures have been prepared, powder containing ١٢,٥٪ and ٢٥٪ Stainless Steel (St.St.) / balance Aluminum (Al). Sintering has been carried out using a tube furnace (with argon atmosphere) at temperatures ٥٠٠ and ٥٣٠ C˚ for ٣٠, ٦٠, ٩٠, ١٢٠ and ١٨٠ minutes. Microstructure of all specimens using optical microscope have been studied, mechanical properties such as micro vicker hardness and Compression strength have been studied for the sintered specimens using Instron universal testing machine, the strain rate was ١mm/min. with load up to ١٥ tons. X-ray diffraction have been used also to determine the phases present after sintering (table ٣ shows the XRD analysis of the Al/ St.St. composite).

Table (١) the chemical composition of Stainless steel and Aluminum.

Stainless Steel	C ٠,٠٩٦	Si ٠,٤٦	Mn ١,٦٥	Cr ١٧,٩	Ni ١٤	Al ٠,٠٥	Cu ٠,٢٨٥	Mo ٢,٠	Fe Rem.
Aluminum	Cu ٠,٠٠٥	Mn ٠,٠٠٥	Fe ٠,١٩٩	Mg ٠,٠٠١٩	Zn ٠,٠٠٥٧	Al Rem.			

Table (٢) the sieve analysis of Stainless steel and Aluminum

Stainless Steel	- ٥٠٠ ------	- ٣٥٥ ------	- ١٥٠ ٣٣,٤٪	- ١٠٥ ٤٣,٦٪	- ٥٣ ٢٢,٩٪	Micron Wt.%
Aluminum	- ٥٠٠ ٩,١٪	- ٣٥٥ ٥٨,٥٪	- ١٥٠ ١٧,٧٪	- ١٠٥ ١٢,٣٪	- ٥٣ ٢,٢٪	Micron Wt.%

Table (٣) the X-Ray Diffraction (XRD) analysis of Al / St. St. composite.

d	I / I_o	Phase	hkl
٢,٣٣	VS	Al	١١١
٢,٠٨	M	$FeAl_٣$	٦٦٢
٢,٠٢٩	S	Al	٢٠٠
١,٨	W	Al	٢٢٠
١,٤٣	M	$FeAl_٣$	٢،٢،٣٠
١,٢٧	W	$FeAl_٣$	٣،٩،١١

$FeAl_٣$ is OPTHORHOMBIC Lattice.

It's lattice parameter are a = ٤٧,٤٣ A°, b =١٥,٤٥ A°, c = ٨,٠٧ A°.

VS = very strong, S = strong, M = medium, W = weak.

Results

I) Compression test

Fig.(١) shows the relation between compression strength and yield strength with sintering time at ٥٣٠°C sintering temperature. The diagram shows that compression strength (Su) and yield strength (Sy) increases to a maximum up to sintering time of about ٦٠ min., at ٥٣٠C° then gradually decreases and reaches a steady state after ٢hrs.sintering time.

Fig.(٢) shows the relation between Compression strength and yield strength with sintering time for specimens sintered at ٥٠٠°C, it can be seen that the Compression strength and yield strength reaches a max. after ٩٠ min. of sintering time at ٥٠٠C˚ .From both figs.(١&٢) it can be seen that sintering temp. of ٥٠٠C˚ gives higher compressive and yield strength than that sintered at ٥٣٠C˚

Figs. (٣) and (٤) shows the relation between strain of ٠,٢٪ (yield strain) and ٢٠٪ strain with sintering time at ٥٣٠ and ٥٠٠ C˚ sintering temp. respectively. It can be seen that Max. strain obtained also after ٩٠ min. of sintering time for ٥٠٠C˚ sintering temp. ,while at ٥٣٠C˚ sintering temp. Max. strain was obtained also after ٩٠ min. accept for the ٢٥٪ St.St. specimen with ٢٠٪ strain which shows a different behavior.

II) Hardness test

Fig.(٥) shows the relation between VHN and sintering time at ٥٠٠ and ٥٣٠C˚ temperature. It is show that hardness increases and reaches a maximum value after ٦٠ min. sintering time then decreases gradually. Maximum hardness obtained was with specimens contains ٢٥٪St.St. sintered for ٦٠ min. at ٥٠٠ C˚ (٦٣,٥VHN).

III) The Microstructure

Fig.(٦) shown the microstructure of a sintered specimens. It's clear that we have two phase structures attempt has been made to identify the phases using XRD and the results are shown in table(٢). Where the second phase is identified as ($FeAl_٣$) in Al phase matrix. The micro-hardness of ($FeAl_٣$) phase was measured and found to be equal to (٧٣٠ $Kg/mm^٢$).

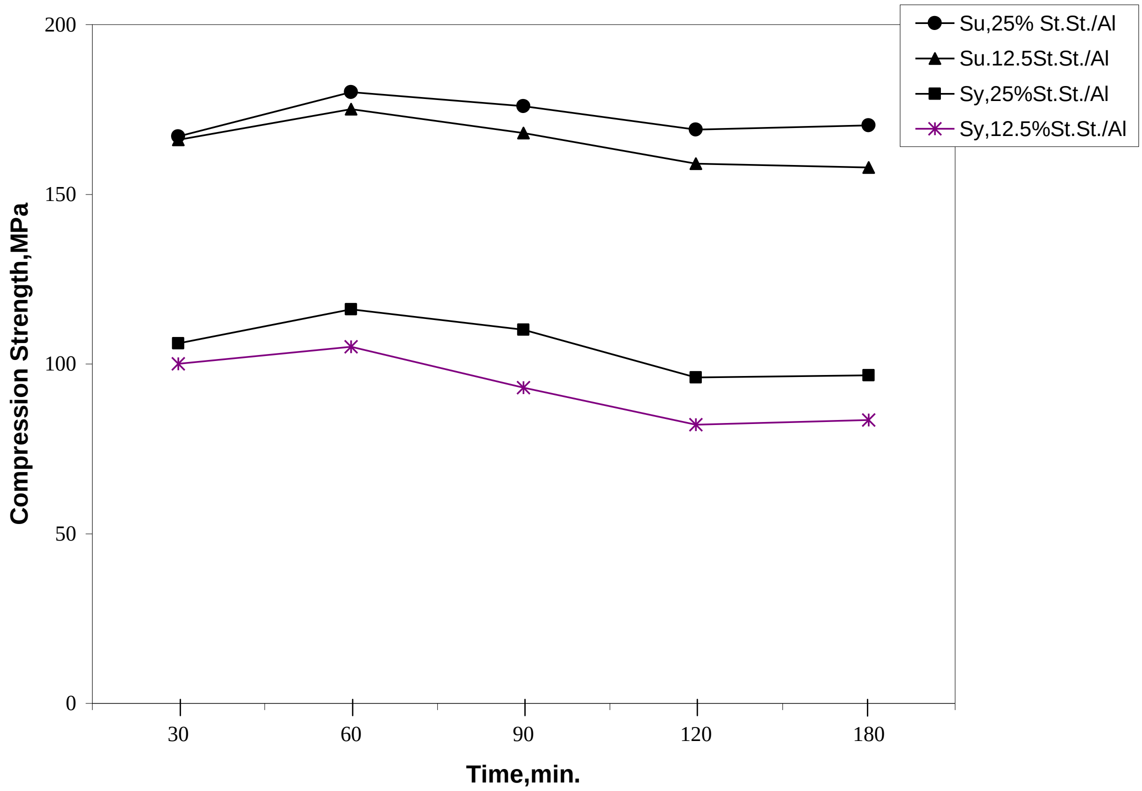

Fig. (١) Compression strength (Su) and yield strength (Sy) Vssintering time, sintered at ٥٣٠ C^o.

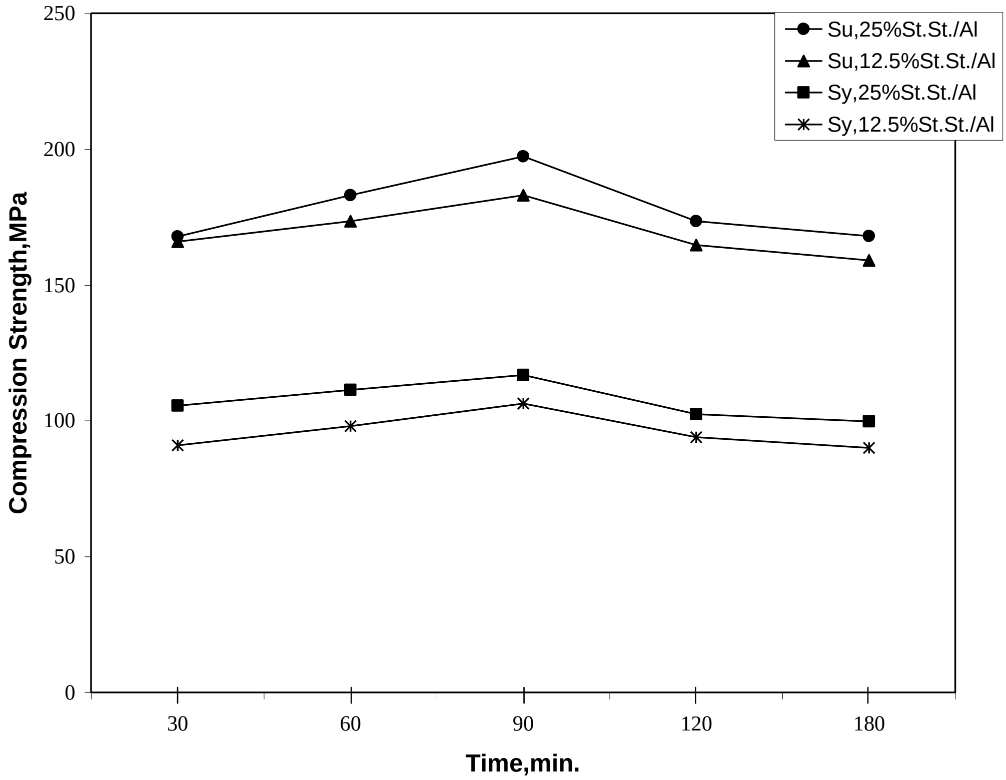

Fig. (٢) Compression strength (Su) and yield strength (Sy) Vs sintering time, sintered at ٥٠٠ C^o.

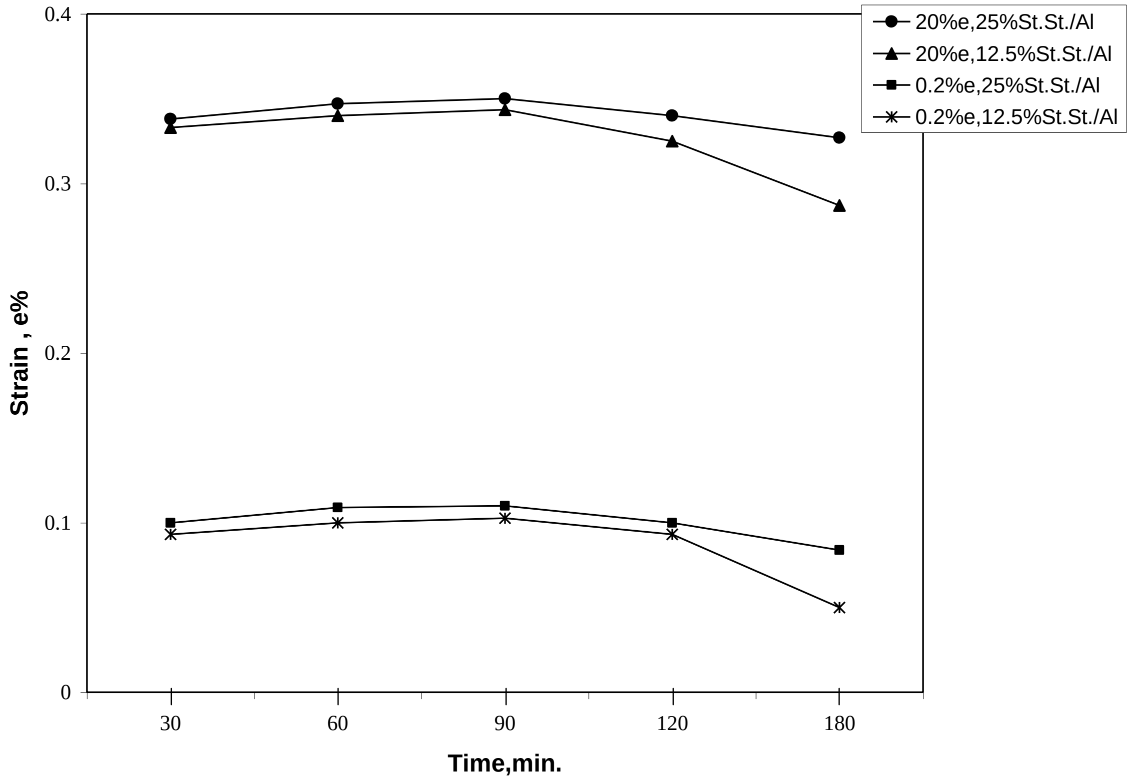

Fig. (٣) Strain (work hardening) Vs sintering time, sintered at ٥٣٠ C^o.

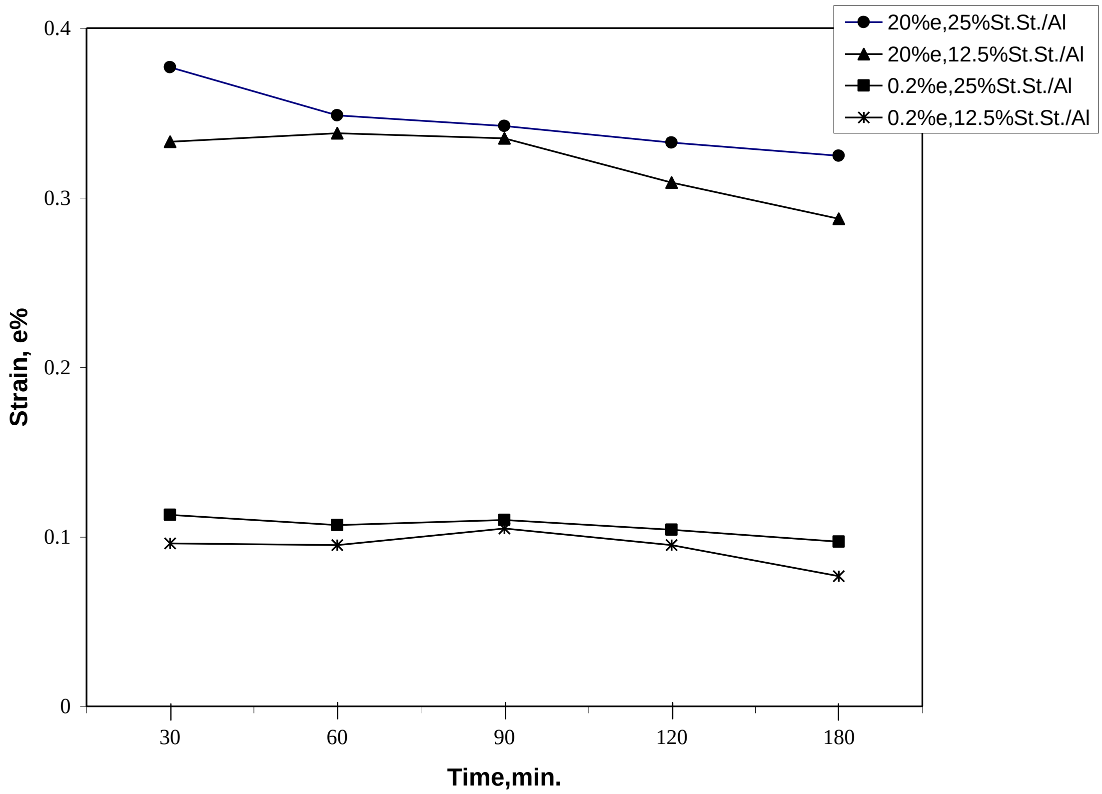

Fig. (٤) Strain (work hardening) Vs sintering time, sintered at ٥٠٠ C^o.

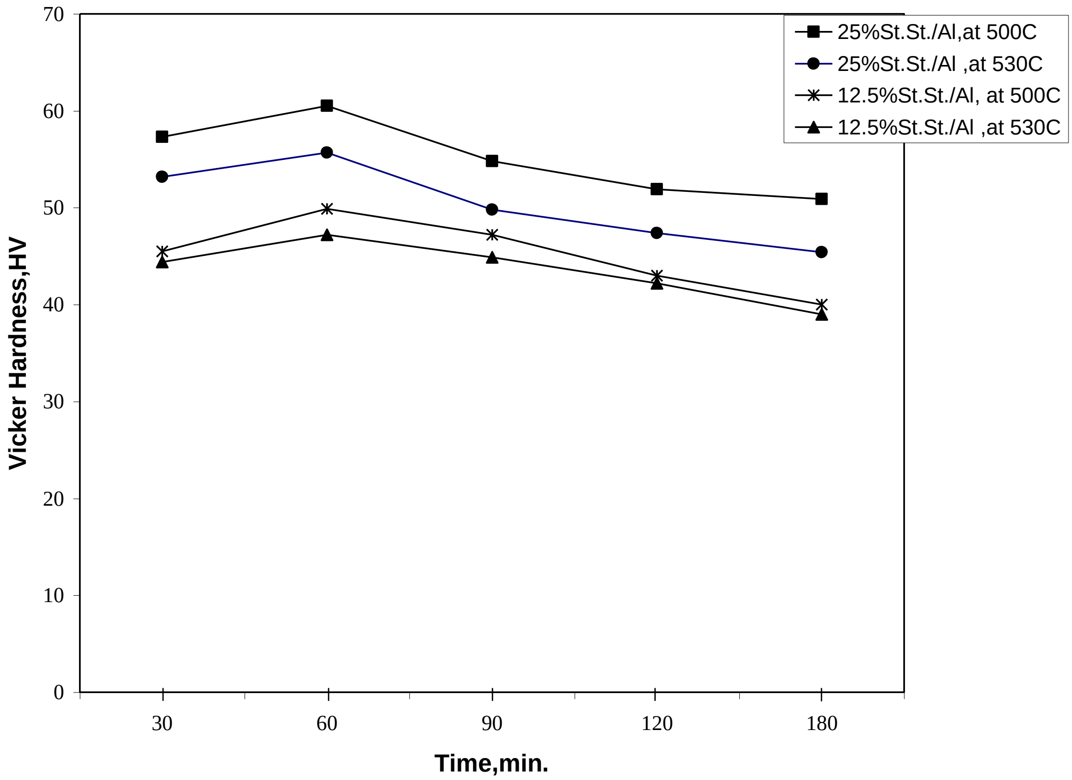

Fig. (٥) Vicker Hardness Vs sintering time, sintered at ٥٣٠ and ٥٠٠ C^o.

Fig.(٦) The microstructure of the sintered specimen. The dark boundary islands are FeAl٣.

Discussion

The results shows in Figs.(١ & ٢) can attributed to the formation of the new phase which is responsible for the increased compression strength it is well known that (FeAl٣) is a hard phase[٢٠]. It's presence with aluminum matrix acts as a strengthening phase [٤،١٤،٢١]. Decrease of strength with sintering time can be attributed to the effect of grain growth and softening effect of ($FeAl_3$) phase. The increased strain with sintering time of both sintering temperatures (Figs. ٣ & ٤) can be attributing to the effect of relief of internal stresses while gradual decrease may be due to the affect of grain growth, reaching a steady state strain faster at ٥٠٠C˚ sintering temperature. The behavior of hardness with sintering time (Fig. ٥) shows clearly that the formation of ($FeAl_3$) is responsible for the increased hardness with greater values at ٥٠٠C˚ sintering temperature. This is due mainly to the reduced level of relief in internal stress at this temperature.

Conclusion

١- The sintered material is a composite in all sintering time and that is clear from the combination of the mechanical properties (strength and strain).
٢- Al soft phase is the matrix and ($FeAl_3$) phase is the hard reinforced phase.
٣- The (FeAl٣) phase improve the strength and hardness, because of its hardness (٧٣٠ Kg/mm٢).
٤- The mechanical properties studied (compression strength , yield strength and hardness) are better for ٢٥٪ wt. stainless steel than ١٢,٥٪ wt. stainless steel for all cases .

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