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Impact Behavior of A356 Albite/ SiC Composites Subjected to Cyclic Thermal Fatigue

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***Abstract*—**The present investigation aims to study the effects of Albite and SiC ceramics on thermal cyclic fatigue of A356 composites containing reinforcement of weight fraction (3%) as well as the unreinforced alloy. The composites were fabricated by rheocasting in which the particles were added into the molten alloy in semi-solid state (SSM) with mechanical stirring at rotating speed of 700 r.p.m. The investigation emphasized on studying the impact toughness either before or after different stages of thermal cycling. Thermal cycling tests were performed on specimens between 40 and 450 ^{0}C for 1000 cycles. The results of study revealed that casting A356 alloy in SSM exhibited impact toughness in this alloy (25J) as for Charpy un-notched sample. Adding 3% of Albite particles to the alloy raised its toughness to become 28J. While degradation in impact toughness has been occurred when 3% SiC was added to the alloy to reach 12J. The results of impact test after applying the thermal cycling for all samples indicated significant improvement in their toughness for both the A356 alloy and A356/3% Albite MMC, which showed absorbed energy of 29J and 34J respectively, after repeated 1000 thermal cycles. An improvement in (A356/3% SiC) MMC toughness has been induced after applying thermal cycling up to 500 cycles to reach 22J, afterwards, degradation in its value has been occurred to reach 12J at 1000 thermal cycle. In addition, other phenomena involving the modification of matrix microstructure were observed after conducting thermal cycling.

***Keywords*—**Aluminum alloy, albite, SiC, MMCs, microstructure, mechanical properties, and thermal fatigue.

I. INTRODUCTION

Metal-matrix composites (MMCs) have been attracting growing interest. MMCs' attributes include alterations in mechanical behavior (e.g., tensile and compressive properties, creep, notch resistance, and tribology) and physical properties (e.g., intermediate density, thermal expansion, and thermal diffusivity) by the filler phase; the materials' limitations are thermal fatigue and thermochemical compatibility [1]. Recent interest in discontinuously reinforced cast composites in the automotive industry has focused attention on their physical and mechanical properties [2]. Thermal fatigue is a threat in any composite system that experiences thermal cycles during use [3]. Materials undergo thermal fatigue when subjected to thermal excursion while in use. Thermal fatigue could lead to catastrophic failure of materials, which, in turn, damages machine elements and could lead to loss of life in severe cases. Temperature fluctuating environments are among the most severe conditions for MMCs. This is because the matrix deform plastically when the induced stress arising from the difference in the CTEs of the matrix and reinforcement is more than its yield strength [4]. Composites usually possess lower CTE than the matrix alloy. A low thermal expansion is desirable because it involves low thermal strain and stress. Metals generally have high thermal shock resistance due to their high thermal conductivity and ductility [2]. Thermal shock resistance is the material's ability to withstand abrupt changes in temperature without fracturing [5]. There is a shortage of many thermal data of such materials. Limited number of searches handled drastic effects of thermal stresses on the mechanical properties. Among mechanical properties, impact strength of aluminum die casting alloys as it is a critical mechanical property needed by designers [6]. The properties which MMCs exhibit throughout their work life depend on the nature of the reinforcement phase(s). Consequently, different reinforcements behave differently in the same metal matrix as a result of differences in their thermal, mechanical, and chemical properties [4]. In the present search, A356 (Al-Si) casting alloy and two of its composites; (A 356- 3%SiC) and (A 356-3% albite) were selected to study their behavior under thermal cyclic fatigue test and how the cycling affects their impact toughness at different stages of cycling.

II. EXPERIMENTAL WORKS

The experimental work carried out through the present study included three stage; i) Material processing, ii) applying thermal cycling on fabricated samples, and iii) Microstructure characterization and carrying out impact test onto fabricated samples before as well as at different stages of thermal cycling.

2.1 Material preparation

2.1.1 Processing of materials

Three different categories of materials namely; A356 and (A356- 3%SiC) and (A356- 3% albite) MMCs were prepared by rheo-casting technique in which the particles were added into the molten alloy in semi-solid state (SSM) with mechanical stirring at rotating speed of 700 r.p.m. SiC particles' size ranged from 20-90 µm and albite one was from 2-20 µm. Albite is a common feldspar ceramic; a mineral aluminosilicate ($NaAlSi_3O_8$) that occurs most widely in acid igneous rocks such as granites, It's basically consisting of silicates [7], it's composition is ; (67%SiO_2 , 19%Al_2O_3 , and 11% Na_2O). The processing details of (A 356- 3% albite) are according to ref. [8] and processing of (A356- 3%SiC) is as in ref. [9].

2.1.2 Sampling

Large Number of un-notched impact specimens with dimensions 10×10×55 *mm* was prepared from cast ingots to investigate impact behavior of selected materials in different conditions.

2.2 Thermal Cyclic Fatigue Test

Cast samples were subjected to hundreds of repeated thermal cycles during carrying out thermal fatigue test with a specially designed apparatus. The heating process was conducted in resistance furnace and current water was used for cooling samples, a schematic diagram of working set-up is shown in figure (1). Thermal cycling was applied onto 4 patches at stages; 250, 500, 750 and 1000 cycles. In which each stage has own patch samples and each 20 samples are thermally cycled in one time. Repeated cycles were performed as; 12 continuous working hours followed with brake of 12 ones and then started again. Calibration of temperature measurement was applied at pretest stage because of the difficulty of obtaining readings from movable samples during thermal cycling. Dummy samples were holed to insert isolated thermo couple inside as shown in figure (2.a). Simulation for thermal test conditions was carried out several times till reaching steady temperature readings. Temperature measurements were with about 11% errors. Measured heating temperatures equaled (450 - 500 ^{0}C) i.e average one is 475 ^{0}C while cooling was 40 ^{0}C. The thermal cycle profile is charted in figure (2.b).

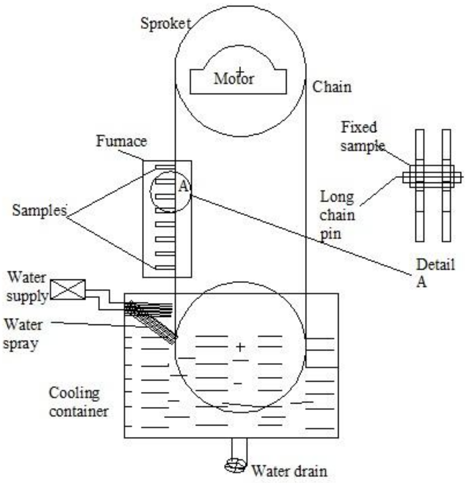
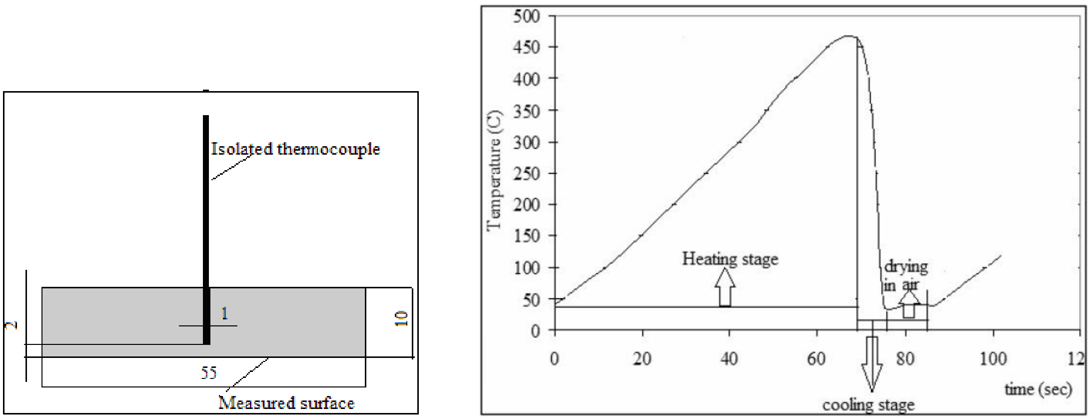


Figure 1: Schematic diagram of working setup



(a) (b)

Figure 2: (a); Temperature measurement onto dummy sample, (b); Thermal cycle profile

2.3 Material Characterization

2.3.1 Microstructure Characterization

2.3.1.1 Optical Microscopy

Samples were cut from ingots for carrying out metallurgical studies following the standard metallographic procedure. The echant used was Keller's reagent. The microstructure was conducted on the surface of polished samples using Olympus-12 optical microscope.

2.3.1.2 Fractography

Fracture characteristics were studied to understand the fracture mechanism. The fracture surfaces were observed by scanning electron microscope (Joel JSM 5410) using (Oxford-IMCA) for scanning electron micrographs.

2.3.2 Mechanical Characterization

The present investigation emphasized on impact test among different mechanical tests.

2.3.2.1 Impact test

Impact test was performed using RKP 450 Pendulum impact testing machine with capacity of 350 Joule and testing temperature 20.7 ^{o}C. Five patches were tested; before thermal cycling, after 250, 500, 750, and 1000 cycles.

III. RESULTS AND DISCUSSION

3.1 Dimension stability and surface observation

The use of aluminum and its alloys exposed to fluctuating-temperature environments is limited by their dimensional stability. Dimensional instability can cause malfunctioning and catastrophic failures of structural components which could lead to loss of life in severe cases [4]. In the present study, on the macro scale observation and measurements for samples before and after 1000 thermal cycles, it shows no deformation and insignificant change in dimensions of the thermally cycled samples for 1000 cycles, more over, sound surface and no cracks were observed onto samples. Figure (3) shows pictorial photos at different stages of thermal cycling. The result similar to W.A. Uju [4], who studied A535 and its MMCs during thermal cycling between 40 and 300 ^{o}C for only 10 thermal cycles. Sanjeev Kumar [10], Observed the effect of thermal cycling on the dimension stability of cast aluminium composites reinforced with SiC and Fly ash particles in which samples were subjected to a compressive load of 74.9 N before thermal cycling between 400–450 ^{o}C for heating and room temperature for cooling, in which cooling was conducted by air under forced convection. His study revealed that after the five thermal cycling, the deformations were occurred and the change of dimensions is found to be many order of mm, he also proved that the addition of fly ash up to 15% by weight improved the dimensional stability of specimen rather than either unreinforced alloy or with adding SiC.

Sobczak et al [2] have studied higher number of thermal cycles between 40-370 ^{o}C onto cast aluminum-matrix composites; they proved that obvious deformation has been occurred in AlSi12CuNiMg squeeze-cast and heat-treated (T6) alloy after 5000 cycles, also surface cracks have been occurred on in AlSi25 gravity cast after 1300 cycles, and less crack length in AlSi20 gravity cast after 1500 cycles while AlSi12CuNiMg squeeze-cast and heat-treated (T6) alloy shows less cracks length after 5000 cycles. Also AlSi12CuNiMg/22 vol.% Al2O3 squeeze cast composite had the least surface crack length after 5000 cycles.

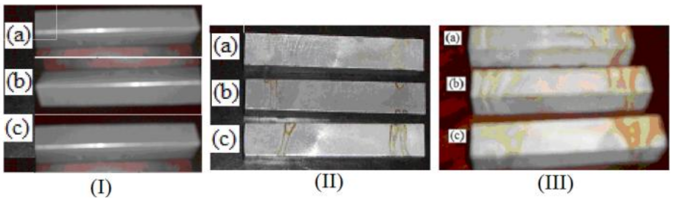
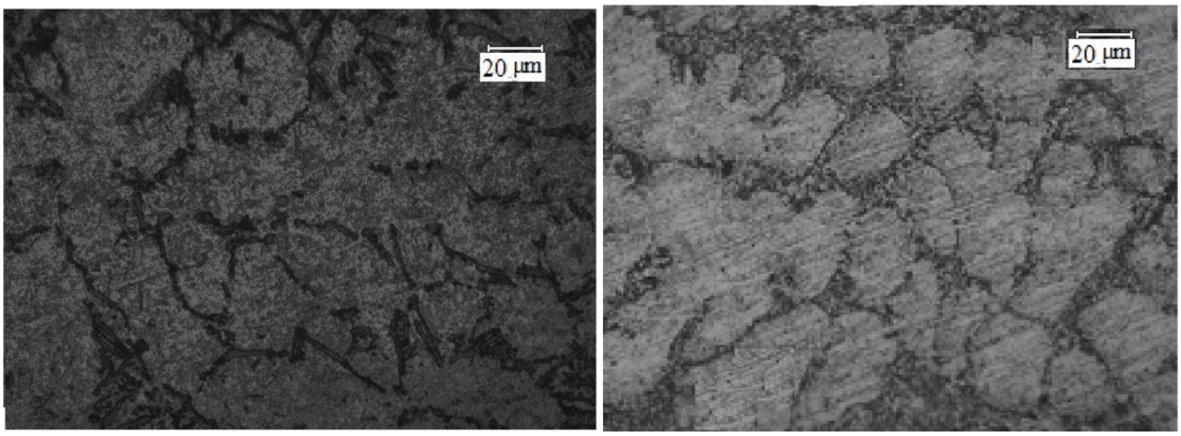


Figure 3: Pictorial photos of impact samples for (a); A356, (b); (A356-3% SiC) MMC and (c); (A356-3% albite) MMC at; (I); before thermal cycling, (II); after 250 cycles, and (III); after 1000 thermal cycles.

3.2 Microstructure

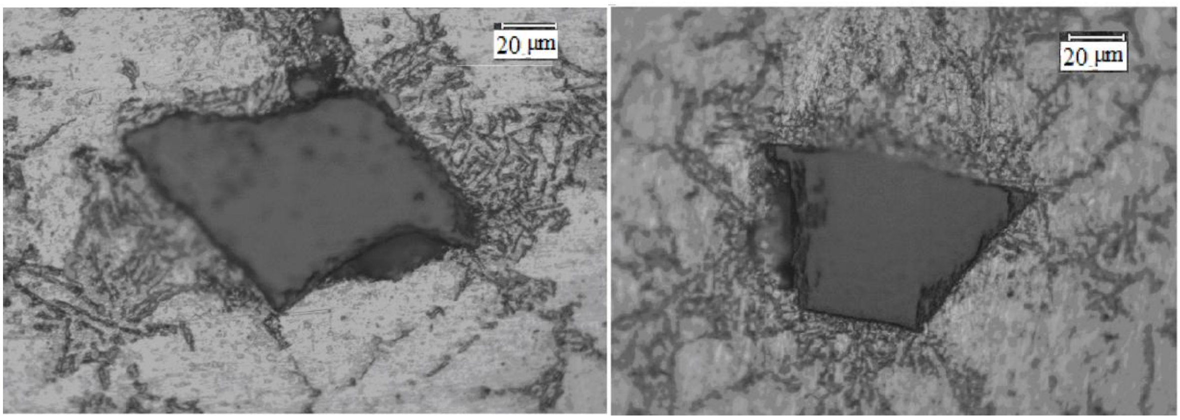
3.2.1 Optical Microstructure

Optical images of samples before and after thermal cycling are shown in figures 4-6 for unreinforced A356 alloy, and (A356-3% SiC) and (A356-3% albite) MMCs respectively. The observations of the microstructure before applying thermal cycling are shown in figures (4.a, 5.a, and 6.a). As it is indicated from figure (5.a) that present coarse SiC particle in the molten metal during casting helped pushing grains away leading to coarse grains formation during solidification process, also this composite distinguished with associated porosity at matrix-particle interface. On contrary, figure (6.a) exhibited the finest matrix grains in (A356-3% Albite) MMC. This is perhaps attribute to double refining mechanisms, the first; present fine particles in the molten which acts as nuclei during casting and hence accelerate the solidification process, and the second; the chemical composition of Albite ceramic ($NaAlSi_3O_8$) which contains Na that enhanced refining effect. The distribution of Albite particles is not clear on related optical magnification of figure (6.a), while SEM section dealt with this item. On the other hand, observation of microstructure after thermal cycling test (figure (4.b, 5.b, and 6.b).) exhibits absence of internal cracks in the optical images. Also the optical microstructure investigation reveals that applying thermal cycling on samples produces an effective change on the morphology of the eutectic acicular silicon to fibrous form; this change has been observed in all studied materials. The structure improvement can be explained based on the materials characteristics; basically, thermal cycling circumstances play essential role in the delivered results, particularly, both heating and cooling temperatures. In some engineering processes like hot rolling or extrusion, the working temperature of some Al alloys is on the same level as the solution treatment temperature of certain Al alloys. So it may possible to quench these products immediately by forced air or water spray to modify the structure and hence mechanical properties [11]. In the same manner, in the present study, according to the thermal cycles profile (figure (2.b)), materials during thermal cycling underwent temper resemble to T6 in repeated manner (repeated short heating periods at $T_{ava.} = 475\ ^0C$ followed with quenching in water at room temperature). T6 treatment includes heating to about 500 ^0C, solution heat treatment for certain period of time that changed according to the cross section of sample then quenching in water followed by artificial or natural ageing. T6 of heat treatment is well known with its effective change on the morphology of the sharp eutectic silicon to fibrous particles in A356 alloy [12]. In the present study, it is very essential to explain the mechanism of changing Si phase. Actually, morphology change of Si phase was occurred gradually with increasing thermal cycling number as it is clear from the microstructure examination of A356 alloy after each stage of thermal fatigue test (figure (7)), the same behavior of matrix has been obtained in both its MMCs . This interprets that despite of the very short period of heating time during the one thermal cycle (figure (2.b)) which is not enough for the phase transformation (Si form) but the repeated action during thermal cycling save enough time required for accomplish this transformation. Erhard [12] stated that silicon spheroidization in hypoeutectic Al-Si alloys could be obtained at different levels of heating temperature and different soaking time during heat treatment, in a modified Al-Si alloys (thixoformed), completely spheroidization of Si phase could be accomplished within minutes at 500°C < T < 540°C. Badini [13], proved that for the thermal cycling between 25 and 220 °C of 2014/Al2O3-SiO2 (Saffil® fibers) composite after 1000 cycles; the microstructure of the matrix of T6 treated composites was unchanged after thermal cycling and characterized by the presence of precipitates heterogeneously nucleated near the fiber interfaces. On the contrary, thermal cycling of as-cast composite resulted in an increased content of precipitates, heterogeneously nucleated at the matrix/fiber interfaces. Also Badini observed strong damage into long fibre during cycling. Sobczak [2], observed obvious internal cracks in the optical microstructures images of both of squeeze-cast and T6 heat-treated AlSi12CuNiMg alloy, and AlSi12CuNiMg/22 vol.% Al2O3 composite after 5000 thermal cycles in which severer crack in unreinforced alloy than that in the composite.



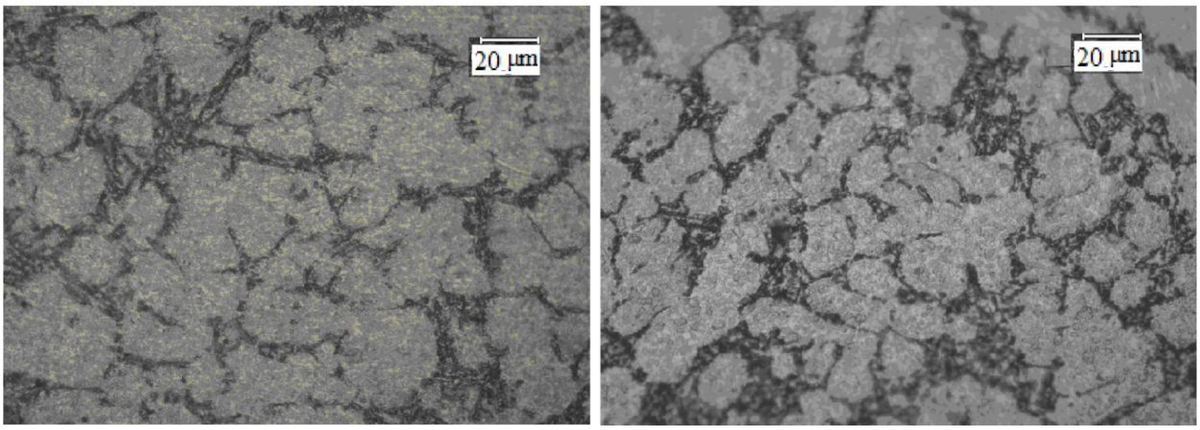
(a) (b)

Figure 4: Microstructure of A356 (a); before thermal cycles and (b); after repeated 1000 thermal cycling



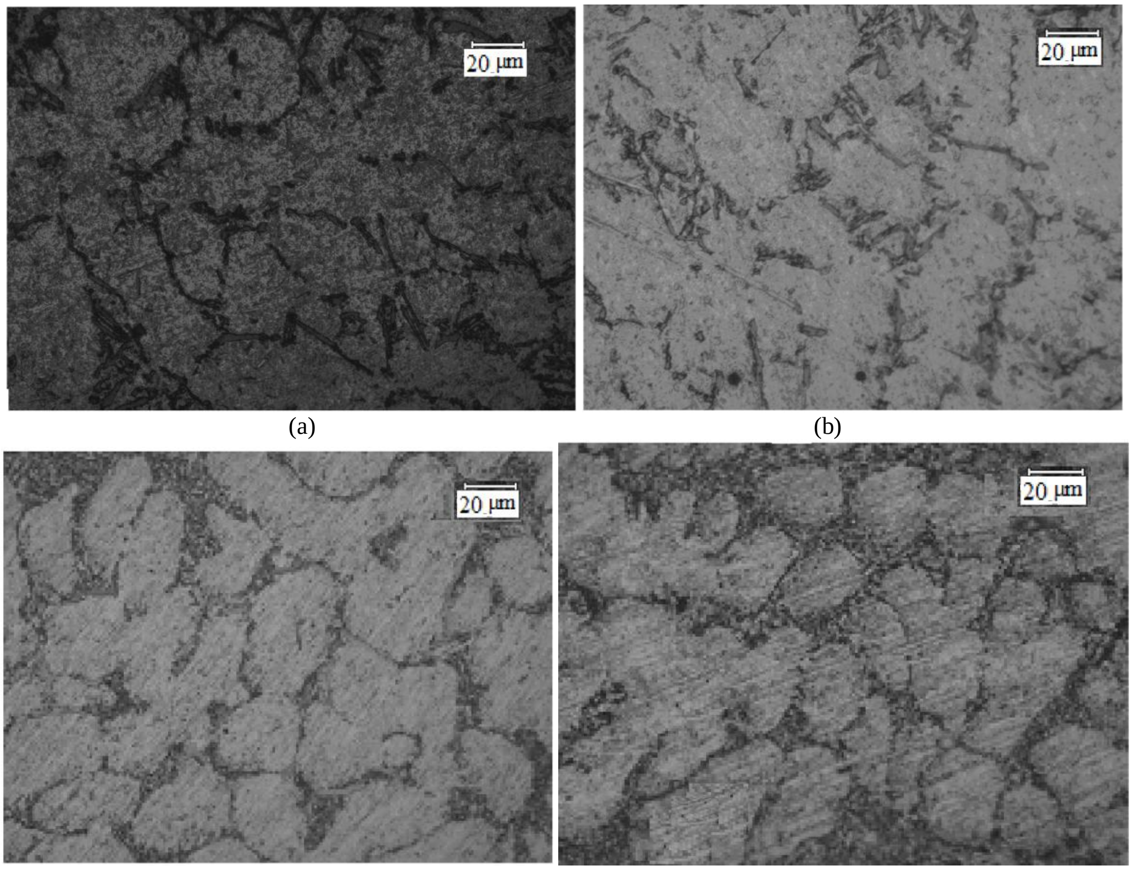
(a) (b)

Figure 5: Microstructure of (A356-3% SiC) MMC (a); before thermal cycles and (b); after repeated 1000thermal cycling



(a) (b)

Figure 6: Microstructure of (A356-3% albite) (a); before thermal cycles and (b); after repeated 1000 thermal cycling



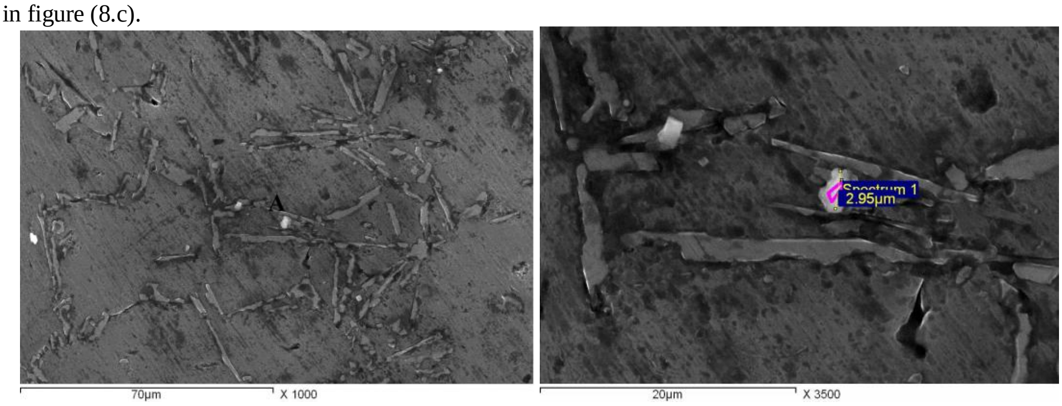
(a) (b)

(c) (d)

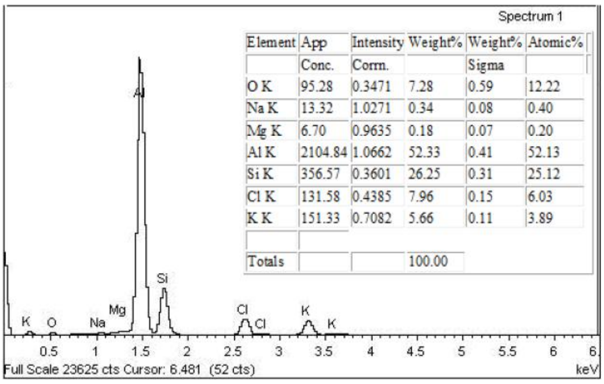
Figure 7: Microstructure of A356 alloy after; (a): 0.0 cycles, (b): 250 cycles, (c): 500 cycles, and (d): 1000 cycles.

3.2.2 Scanning Electron Microscope (SEM) and EDAX Analysis

The surface examination of (A356-3%Albite) MMC by SEM is shown in figure (8). A uniform distribution of 3% Albite particles inside the matrix alloy without agglomeration and round geometrical aspect of Albite particles are clear from figure (8.a). Also Albite particle size is measured and analyzed as in figure (8.b) by EDAX. The analysis of ceramic particle is shown in figure (8.c).



(a) (b)



(c)

Figure 8: (a); SEM, (b); Detail [A], and (c); EDAX analysis for (A356-3%Albite) MMC.

3.3 Impact results

3.3.1 Impact strength of material before thermal cycling test

The results of impact toughness of A356 alloy and composites reinforced with both Albite and SiC particles before thermal cycling are graphed in figure (9.a). As it is clear from figure (9.a), adding 3% Albite particles to A356 alloy has increased the absorbed energy from 25 J to 28 J. On contrary, present SiC in the A356 alloy deteriorate its impact toughness where as the absorbed energy has been lowered down to 11.2 J. The enhanced toughness (A356-3% Albite) MMC is attributed to microstructural improvement due presence of Albite dispersions into the matrix as it was explained in the microstructure characterization. While declination in the (A356-3% SiC) MMC's is because of SiC particles sharp adages and coarser grains of its matrix alloy beside associated porosity at matrix-particle interface (figure (5.a)).

3.3.2 Effect of thermal cycling on the impact strength of cast A356 alloy and (A356-3% Albite) MMC

The results at different thermal cycling stages are shown in figure (9.b). The present investigation, is studying the effect of applying thermal cycling on the impact behavior of A356 alloy and its composites. As it well known that the elevated deterioration in mechanical properties with increasing thermal fatigue cycles is the ordinary trend in practical service, this is based on increasing associated thermal stresses. From the present study, unordinary behavior of impact strength has been observed into studied materials. Where as the results graphed in figure (9.b) reveal that the toughness of A356 alloy and its composite reinforced with Albite particles is decreased by 54 and 51% respectively after subjecting to 250 repeated thermal cycles, this stage is a very critical interval in the thermal cycling test of the present investigation, thus, relevant comprehensive explanation will be conducted later in this paragraph. After the first stage (250 cycles), gradual improvement of toughness was obtained as they subjected to more thermal cycles number. More over, the values of toughness of both unreinforced alloy and its composite reinforced with Albite ceramic particles after ending thermal fatigue test (after1000 cycles) exceeded that those before applying thermal cycling as the absorbed energy increased from (25 to 29 J) and from (28 to 34 J) for A356 alloy and (A356/3% Albite) MMC respectively. Definitely, the obvious gradual change in Si eutectic morphology from acicular to fibrous form due to applying thermal cycling onto the samples as it was explained in the microstructure section, is the main reason of enhancing the toughness of the thermally cycled materials. This explained the gradual increase of the material toughness as the thermal cycling advances starting beyond the first stage (250 cycles). Erhard [12] recorded about 11J absorbed energy for notched Charpy samples of A356 alloy after subjecting to silicon spheroidization treatment instead of conventional and expensive T6 solution heat treatment. His treatment was applied by soaking thixoformed samples at 540 C for 3 minute followed with cooling in water or air. This conclusion means that during practical application improving properties are possible without relaying on additional processes and cost. On the other hand, the results were obtained in the present investigation doesn't mean that the enhanced toughness trend is going to ever last with additional cycles. This is because of handling intermediate interval of thermal cycling (1000 cycles) in the present study has been adopted, even temperature excursion in which was severe. Probably, at advanced cycling time, occurrence of gradual degradation in material properties is expected. This due increasing of thermal stresses which are always relieved by crack formation or plastic deformation that lead to deterioration in the material properties.

Again in the present investigation, an explanation for the dramatic declination in impact toughness obtained after 250 thermal cycles; it is may be refers to the formation of some undesirable precipitates during this time interval of thermal fatigue test (250 cycles) which could harden the materials and affected their ductility at this period. As it well known that the time factor is very essential in thermal treatment process so its period should be adjusted because either less or more time value could lead to undesirable structure and hence causes deterioration in the mechanical properties. However, perhaps modified precipitates have been formed during the advanced cycling number and caused great enhancing in ductility values. This conclusion agreed with Badini [13] who explained that the material in his study (both 2014 and its composites) undergo rapid solidification and cooling during casting, in which they stay at high temperature for periods not sufficiently long for allowing precipitation phenomena of strengthening secondary phases, and afterwards, strengthening by precipitation may occur during the thermal cycling, which involves sample heating for long discontinuous time. Any how, more investigation should be considered to study this phenomenon.

3.3.3 Effect of thermal cycling on the impact strength of (A356-3% SiC) MMC

Adding SiC particles to A356 alloy leads to causing variant effect of thermal fatigue on the impact behavior of this composite, figure (9.b) indicated that, slight decrease in toughness value has been occurred after subjecting to 250 repeated thermal cycles where as the absorbed energy changed from 11.2 to 10.5J, perhaps the variant behavior of (A356 -3% SiC) MMC at the first stage is because it has already low toughness before applying thermal cycling. On the other hand, distinct increase in the toughness value has been achieved after 500 cycles that it reached 22J while again gradual degradation has been occurred afterwards as it lowered down to 17.5 then 12 J absorbed energy after 750 and 1000 cycles in sequence. Actually, the improvement of toughness is mainly refers to modification of Si morphology as well as the behaviour of unreinforced alloy and (A356 -3% Albite) MMC. While the later degradation in its values in impact toughness is most probably due to particle–matrix interfaces decohesion during thermal cycling. The decohesion occurs as a result of localization of strains due to the CTE mismatch which increases with higher thermal cycling. This finding is agrees with Sharmilee et al study [14].

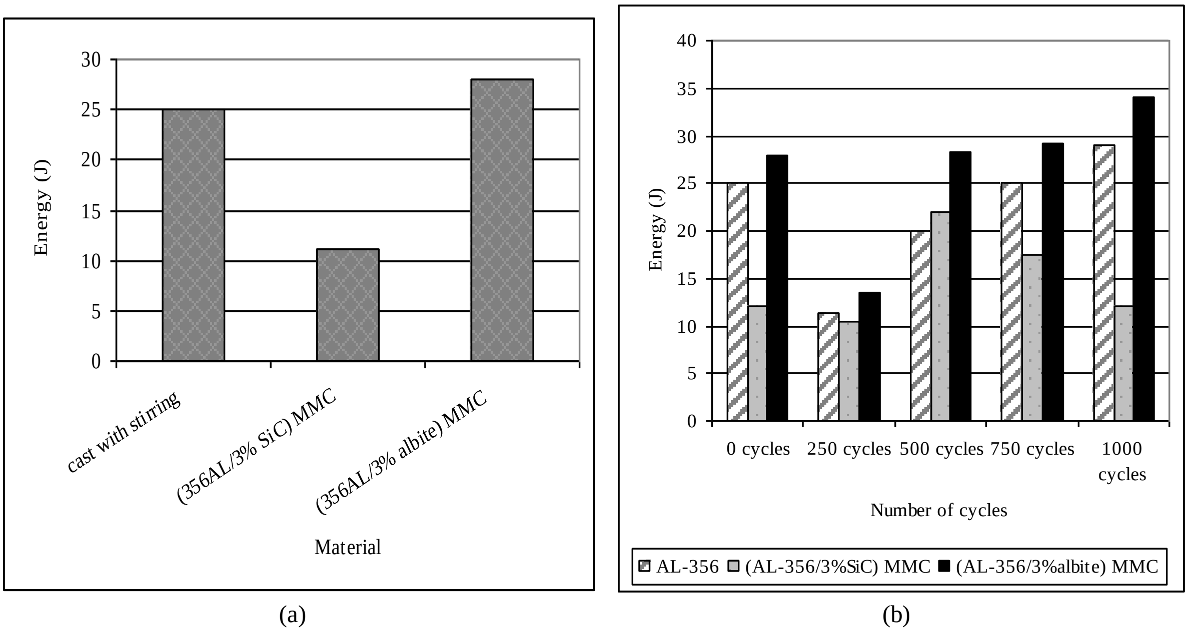


Figure 9: (a); Impact energy before thermal cycling, and (b); at different thermal cycling stages.

Finally, the experimental results of impact toughness revealed that excellent toughness was for (A356-3% albite) MMC followed by that of unreinforced A356 alloy while the lowest value was for (A356-3% SiC) MMC, where as the absorbed energies after thermal fatigue ending were 34, 29 and 12J for the materials in sequence.

It's noteworthy to show that the broken impact samples with high toughness values either before or after thermal cycles have been bent with some degrees proportional to its ductility. Pictorial photos of broken samples in figure (10) confirm the impact energy results that graphed in figures (9.a) and (9.b).

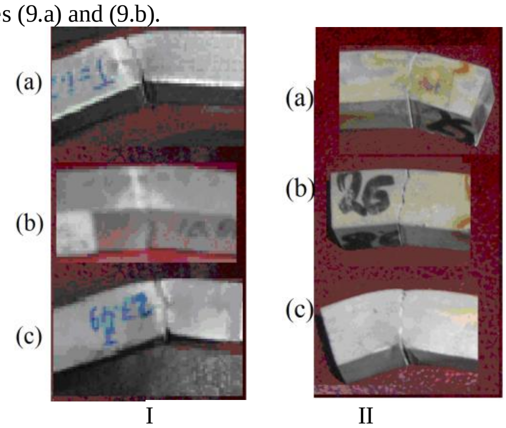


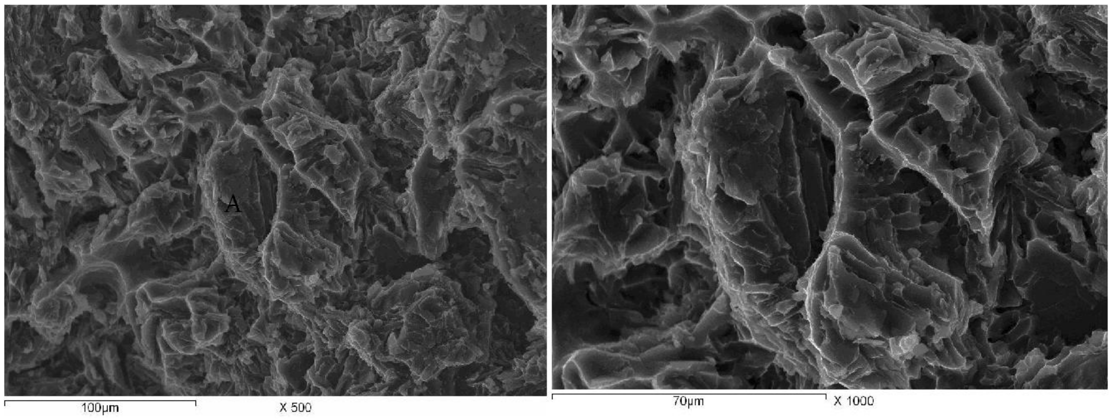
Figure 10: Pictorial photos of fracture zone of broken impact samples for (a); A356, (b); (A356-3% SiC) MMC and (c); (A356-3% albite) MMC at (I); before thermal cycling, and (II); after 1000 thermal cycles

3.4 Fractogragh

Fractographic examination of metals is used in metal science to evaluate the cause of material destruction by revealing and identifying internal discontinuities such as internal cracks, porosity, inclusions. Also to determine the decohesion mechanism by classifying the characteristic morphological features of the fracture surface [15].

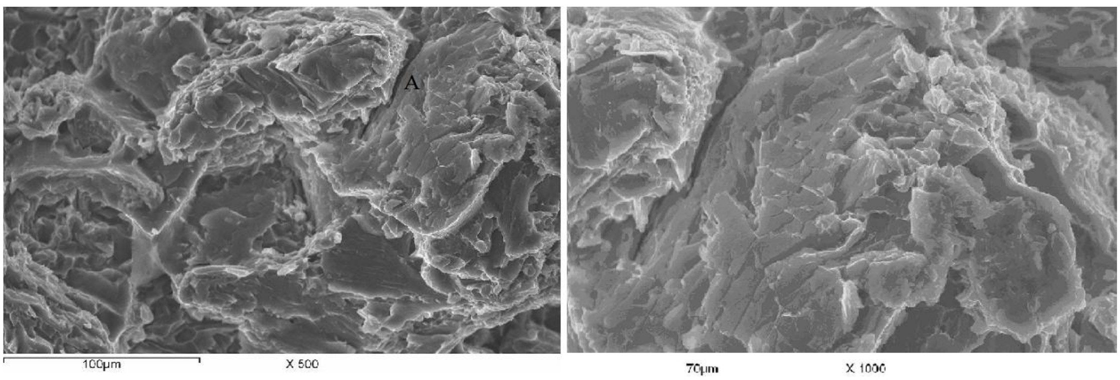
3.4.1 Fractogragh examination of samples before thermal cycling

Figures 11–13 show the SEM fracture images of the tested materials before thermal cycling. Figures (11 and 13) indicates that the fracture surface of both unreiforced A356 alloy and (AL356-3% albite) MMC is distinguished with taking place plastic deformation in the aluminum solid solution resulting in the bands of the dimples formation implies cleavage planes of the brittle fracture between them which can be a result of the mixed (dimple-brittle) mechanism of fracture. While weakly-developed surface and cleavage planes of brittle fracture is obvious in (A356-3% SiC) MMC (figure (12)). These morphological features of the fracture surfaces have proved the significant increase of impact toughness of both A356 alloy and (A356-3% albite) MMC rather than that of the composite reinforced with SiC particles. Accually, formation of mixed fracture demands higher energy input which is consumed in plastic deformation compared with brittle cracks. Where as the energy absorbed during plastic deformation, causes an activation of the slip systems in successive micro-regions [15].



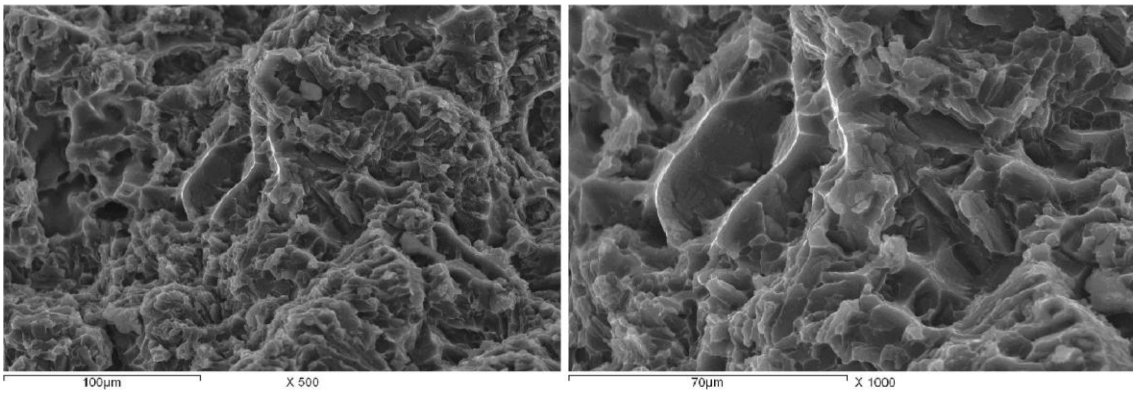
(a) (b)

Figure 11: (a); Impact fractograph of stirred unreinforced A 356 alloy before thermal cycling and (b); Detail [A].



(a) (b)

Figure 12: (a); Impact fractograph of (A356-3% SiC) MMC before thermal cycling and (b); Detail [A]



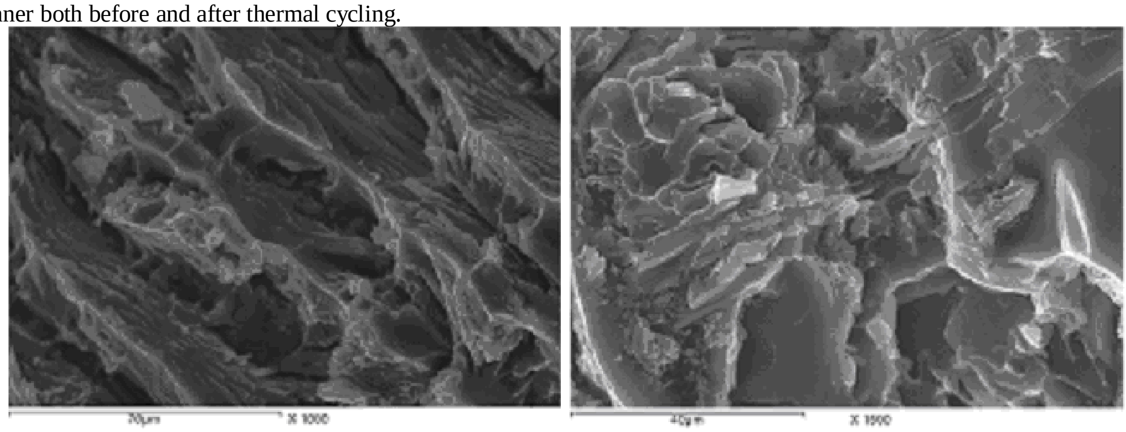
(a) (b)

Figure 13: Impact fractographs of (A356- 3% albite) MMC before thermal cycling (a); small magnification and (b); higher magnification.

3.4.2 Fractogragh examination of samples after applying thermal cycling

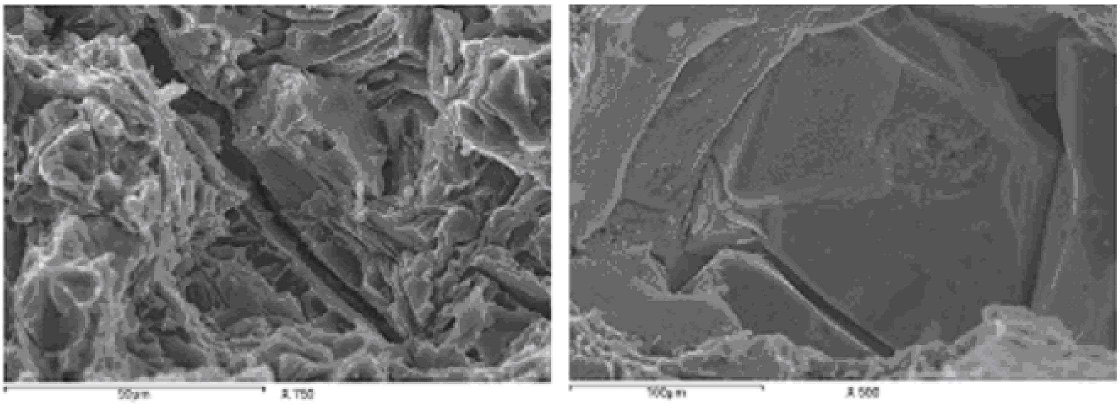
Figures 14-16 show the SEM fracture images at two locations of each impact sample after applying thermal cycling. Bands of the dimples formation were observed in A356 alloy (Figure (14.a)), also mixed dimple-brittle fracture is shown at other locations (figure 14.b). Basically, the mixed fracture mechanism in A356 subjected to thermal cycling is most probably due to the modification of Si morphology. As Małgorzata [15] explained that Plastic deformation could take place in the α -aluminum solid solution resulting in the bands of the dimples formation which can be a result of the mixed mechanism of fracture in most cases in alloys of modified silicon morphology. Also fracture images of (A356-3% albite) MMC indicate clear mixed dimple-brittle fracture mechanism in figure (16.a) and undergoing this composite interdendritic fracture as shown at other locations (figure (16.b)). The dendrite fracture is most probably occurred due to voids coalescence arisen from shrinkage porosity during material processing [16] and enhanced during thermal cycling due to induced thermal stress. While weakly-developed surface and cleavage planes of brittle fracture is obvious in (A356-3% SiC) MMC (figure 15.a) and it is as the case before applying thermal cycling. More over, fracture is characterized with propagated cracks (figure (15.a) and (15.b)). Perhaps severe cracks propagation is due concentrated thermal stress at sharp edges of SiC particles. The crack propagation is in some cases of brittle materials, very fast, it is sometimes estimated as equal to 0.7 times the speed of sound [15].

However, the above explanation of fracture mechanisms interpret the nature of fracture zone of broken samples at (figure (10.b).II) where as composite reinforced with SiC has straight fractures zone without significant bending (i.e it has lower ductility and hence no significant plastic deformation). While both unreinforced alloy and (A356- 3% albite) MMCs have bent fractured zones (figure (10.a).II and (10.c).II) respectively) which reveal higher ductility of those material. Also photos of fractured impact samples in positions (I) and (II) (figure (10)) reveal that the materials behaved the same fracture manner both before and after thermal cycling.



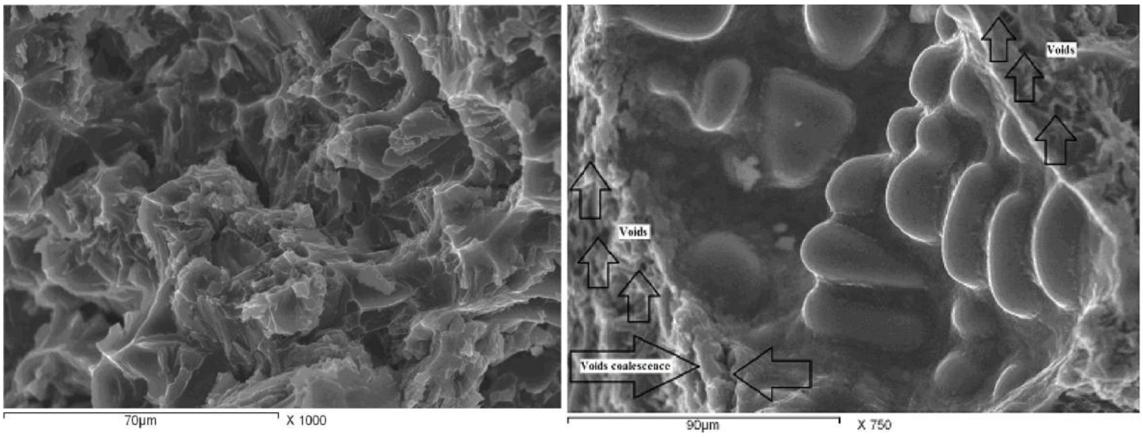
(a) (b)

Figure 14: Fractographs of unreinforced A356 alloy after 1000 repeated thermal cycles at two different locations (a) and (b).



(a) (b)

Figure 15: Fractographs of (AL356-3%SiC) MMC after 1000 repeated thermal cycles at two different locations (a) and (b).



(a) (b)

Figure 16: Fractographs of (AL356-3%albite) MMC after 1000 repeated thermal cycles at two different locations; (a) and (b).

Finally, as a benefit of using MMCs rather metal alloys, their intermediate properties. Variation in those properties is definitely huge, so intensive studies should be conducted in this field to provide designers right approach for selecting proper material. The results obtained from present investigation make (A356-3% albite) MMC a candidate material in relevant thermal application rather than both (A356-3% SiC) MMC and unreinforced A356 alloy.

IV. CONCLUSION:

1. The high toughness values (28 J) of (A356- 3% albite) MMC is mainly due to grain refining effect in the matrix alloy which refers to fineness and chemical composition of Albite ceramic, beside geometrical features of rounded Albite particles.
2. Adding 3 % of SiC particles to A356 alloy have dramatically decreased its toughness; whereas the absorbed energy changed from 25J in the unreiforced A356 alloy to 11.2J in the (A356- 3%SiC) MMC before applying cyclic thermal fatigue, is due to sharp- irregular edges of SiC particles and associated matrix-interface stress localization. Beside associated porosity at matrix- particle interface.
3. The thermal fatigue behaviour of both unreinforced and their metal matrix composite is controlled by matrix structure change during thermal cycling. Where as conducting cyclic thermal fatigue on the materials produced gradual change on the morphology of the eutectic acicular silicon to fibrous form in A356 matrix alloy.
4. Applying thermal fatigue cycling up to 1000 cycles onto A356 alloy as well as on (A356- 3% Albite) MMC has improved their toughness; whereas the absorbed energy has been changed from 25 to 29 J and from 28 to 34 J before and after cyclic test in these materials respectively.
5. Despite obtaining an increase into (A356- 3%SiC) MMC toughness at the intermediate stage of cyclic thermal fatigue (500 cycles) in which the absorbed energy has been changed from (11.2 to 22 J) at this stage, but gradual degradation in this value has been occurred at advanced cycling stages. This is most probably due to interference-decohesion between matrix and particles arising from mismatch of CTE during thermal cycling and stress concentration at sharp SiC particles' edges.
6. Even though high CTE mismatch between the matrix and albite ceramic but its rounded geometry benefit make (A356- 3% albite) MMC has the highest toughness value after undergoing 1000 repeated thermal cycles. Beside,

owing Albite ceramic lower elastic modulus make the composite reinforced with it has the highest thermal shock resistance.

7- despite drastic effects of thermal cycling due temperature difference excursion ($\Delta T=410^{0}C$), but improvement of impact toughness has been occurred after repeated 1000 thermal cycles as it is unordinary finding in this search. So, some times practical context lead to some sort of treatment and as a sequence advantageous effects are occurred when specific conditions are convenient. In thermal application some of these parameters are; (temperature, medium of heating or cooling, time intervals, and rate of heat transfer).

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