

Structural analysis, mechanical and damping behaviour of Al-Zn based composites reinforced with Cu and SiC particles

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Abstract. The structural characteristics, mechanical and damping properties of stir-cast Al-10 wt.% Zn based composites developed using 6 and 8 wt.% Cu, and 8 wt.% SiC particles as reinforcements, were investigated. The low porosity (<4%), near absence of dissolved Cu in the Al-Zn matrix, and marginal presence of melt reaction-induced intermetallic phases, attest to the soundness of the castings. Besides hardness, the strength parameters – ultimate tensile strength (149.33 MPa and 138.64 MPa) and specific strength ($54.3 \text{ MPa cm}^3 \text{ g}^{-1}$ and $51.16 \text{ MPa cm}^3 \text{ g}^{-1}$) – of the Al-Zn composites reinforced with 6 and 8 wt.% Cu, were superior to that of the unreinforced Al-Zn alloy (103.47 MPa) and the 8 wt.% SiC reinforced composite (130.5 MPa). The fracture toughness ($17.32 \text{ MPa m}^{1/2}$ and $13.66 \text{ MPa m}^{1/2}$) and percentage elongation (15% and 12.5%) of the 6 and 8 wt.% Cu reinforced Al-Zn composites, also surpassed that reinforced with SiC ($K_{IC} = 12.28 \text{ MPa m}^{1/2}$; $\% \epsilon_f = 9.5\%$). Improved matrix/particles interphase bonding and the inherent ductile and tough nature of Cu over SiC, were cited responsible for the improved strength-ductility-toughness balance of the Al-Zn/Cu composites over that reinforced with SiC. The damping properties were generally temperature sensitive, with all compositions exhibiting increase in damping capacity at test temperatures 100–200 °C.

Keywords: Al-Zn/Cu_p composite / interface bonding / metallic reinforcement / mechanical properties / damping capacity / microstructure

1 Introduction

The adoption of Aluminium and its composites in the development of automobile and aerospace components has been considered worthwhile considering the global push for a more sustainable and eco-friendlier environment [1,2]. The quest to reduce carbon mono oxide (CO), carbon dioxide (CO₂), sulphur (SO₂), nitrogen dioxide and other toxic emissions that can pollute the environment as well as affect human health necessitate the design of more efficient engines, and the use of weight saving materials [3,4]. Aluminium in comparison with other light weight structural materials (such as Mg and Ti) has demonstrated practical promise in fulfilling these yearnings. This is due to its general high castability, relatively

low processing cost, and good mechanical, physical, and chemical properties [5,6]. As replacement in automobile engine components, it specifically offers combination of high strength, corrosion and wear resistance, high toughness and thermal fatigue resistance which are the material properties that are critical for satisfactory service function [7,8]. However, most Aluminium based alloys with the exception Al-Zn series have low damping capacity, and require reinforcement selection to meet the service damping capacity requirements [9,10]. Ceramics which are conventionally used as reinforcements have been noted to lower ductility and toughness considerably in comparison to what is obtainable in the unreinforced Al matrices [11].

Recently, the consideration of metallic materials used as reinforcement in aluminium matrix composites (AMCs) is gathering momentum – this is because they can offer improved ductility and toughness to AMCs without

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compromising strength and most service critical material properties [12–15].

Metallic materials are generally known to possess relatively low damping capacity than ceramics so their selection will naturally arouse concern on how they influence damping capacity of the AMCs. Although works have shown that the damping capacity of AMCs reinforced by metallic particles fall within the same range as that of ceramic reinforced AMCs [16,17], the studies are limited in number for generalizations to be made. Moreover, the damping properties are known to be material system sensitive [18].

In the present study, Al-Zn alloy which are known for their high damping capacity and heat treatability is considered as aluminum matrix for composite development. Efforts to enhance their mechanical properties often results in retrogression in damping properties. This is largely due to both phenomena-strengthening and damping capacity-needing defect structures present in the material for their enhancement [19]. This seeming inverse relation between strength and damping capacity has inhibited the selection of monolithic materials for applications (such as in automobile engine components) where a synergy of both properties is critical. The material design strategy adopted in this study is to meet the strengthening and toughening requirements for the composite through the selected reinforcement, while the Al-Zn matrix serves the purpose of meeting the high damping capability required. Hence in this study, the mechanical and damping behaviour of Al-Zn matrix composites reinforced with Cu particles is investigated. The rationale for the selection of Cu as metallic reinforcement is informed by the high ductility and toughness it possesses. This is coupled with the relatively higher melting point of Cu (1060 °C) compared to Al (660 °C), which can be harnessed during composite processing to ensure that most of the Cu added as reinforcement remain undissolved in the Al melt. Furthermore, it is noted that dissolved Cu in Al does not lead to the formation of deleterious phases [20].

There are few studies available in literature where Cu has been considered as reinforcement in AMCs [21–24]. These studies were limited to studying essentially the influence of Cu addition on selected physical and mechanical properties of the Al-Cu based composites. None of these studies have explored the use of Al-Zn matrix, and considered the influence of Cu reinforcement on both the mechanical and damping behaviour of the composites, which is the thrust of our investigation.

2 Material and methods

2.1 Materials

Al-Zn alloy processed to contain 10wt% Zn was utilized as the aluminium matrix in this study. Aluminium (Al – 99.92, Fe – 0.03, Si – 0.03, Mn – 0.02, others – 0.02) and Zn (Zn – 99.96, Fe – 0.02, Si – 0.06, Pb – 0.04, others – 0.01) billets were procured for the production of Al-Zn alloy. Also, analytical pure grades of Cu (99.99%) and SiC

Table 1. Composite compositions and designation.

Sample designation	Composite compositions
Al-Zn	Al + 10 wt.% Zn
Al-Zn/6wt%Cu	Al +10 wt.%Zn/6 wt.% Cu
Al-Zn/8wt%Cu	Al + 10 wt.%Zn/8 wt.% Cu
Al-Zn/8wt%SiC	Al + 10 wt.%Zn/8 wt.% SiC

(97.98%) with average particle sizes of 40 μm and 10 μm , respectively were selected as the reinforcements. The materials were all obtained from registered vendors of chemical and industrial materials.

2.2 Composite production

Four compositions, Al-10Zn, Al-10Zn +6wt%Cu, Al-10Zn +8wt%Cu, Al-10Zn +8wt%SiC were of interest in the present investigation. The selection of these compositions for the Cu reinforced Al-Zn based composites was informed by previous studies conducted on metallic reinforced AMCs, which showed that the 6 and 8 wt.% reinforcement compositions yielded the best processing outputs, while the unreinforced Al-Zn alloy and Al-Zn composition reinforced with 8 wt.% SiC, served as control compositions [11,12,22,24,25]. In order to achieve the composite compositions, charge calculation and composite development procedures in accordance with Alaneme et al. [25] were adopted in the study. The Cu and SiC alloy were initially preheated separately at 250 °C for 20 min to remove moisture, lessen the likelihood of temperature gradient, and improve wetting between the melt and the reinforcements [26]. The Al was melted at 710 ± 20 °C, after which Zn was added into the crucible furnace. The melt was cooled to 600 °C, then the preheated reinforcement was added, and the semi-solid mix stirred manually for 5 min. The semi solid composites were then super-heated to $720 \text{ °C} \pm 30 \text{ °C}$, and stirred with the use of a motorized stirrer at a speed of 400 rpm for 10 min. The composites were then cast in sand moulds for solidification. The composites' compositions and designations are presented in Table 1.

2.3 Deformation processing of Al-Zn alloy and composites

The Al-Zn alloy and composites produced were of cylindrical profiles and machined to 18 mm diameter and 200 mm length. The samples were cold rolled using a miniature cold rolling machine from 18 mm to 16.2 mm cross-sectional diameter (5% cold deformation). The rods were cold rolled using four passes of 0.45 mm reduction per pass. The essence of cold deformation was to reduce potential voids, blow holes and pores that are emblematic of sand cast products. The Al-Zn alloy and Al-Zn based composites were heat treated afterwards at 250 °C for 45 min and cooled in still air to eliminate deformation induced stresses.

2.4 Composite density and percentage porosity

The densities of the composites (in g/cm^3) were evaluated using the Archimede's (water displacement) principle; while the theoretical density for each system was determined using the rule of mixture – by summing up the densities based on the weight fraction of the components of the alloy/composite [27]. For the Al-Zn alloy and composites produced, the percentage porosity was determined by multiplying the ratio of the actual density to the theoretical density by 100.

2.5 Mechanical characterization

2.5.1 Hardness testing

The test was carried out using Rockwell hardness tester RBHT 202 to evaluate the hardness values of the Al-Zn alloy and composites. The samples with measurement 15 mm length and 10 mm thickness were machined and polished to obtain a plane parallel surface. The test was conducted by exerting 100 kgf load on the samples for a time of 15 s. The indentations were carried out 8 times to have different readings which helps assure consistency and reliability of readings from the hardness tester. The samples were tested in accordance with ASTM E92-17 [28] standard.

2.5.2 Tensile testing

Tensile testing of the Al-Zn alloy and composites were done using a Universal Instron Machine, model 3369 tensiometer having capacity of 50KN in accordance with ASTM E8/E8M-21 [29] standard. The samples were machined to dimensions 5 mm diameter and 60 mm gauge length, and subjected to tensile loading to fracture at a strain rate of $10^{-3}/\text{s}$. Repeat tests were performed to ascertain that the results were reproducible and deviations were within acceptable limits.

2.5.3 Fracture toughness

Circumferential notch tensile (CNT) test procedure was used to determine the fracture toughness of the Al-Zn alloy and composites [30]. The test samples were machined with dimensions: 60 mm (gauge length), 5.5 mm (gauge diameter), 4.5 mm (notch diameter), and 60° (notch angle). The test was performed with the use of a 50 KN capacity Universal Instron Machine, model 3369 at $10^{-3}/\text{s}$ strain rate. The load-displacement plots for the specimens were utilised to compute the notch tensile strengths, σ_{NTS} , of the samples. The fracture toughness was then determined using equation (1) [31]:

$$K_{IC} = 0.454 \times (D^{1/2}) \times \sigma_{NTS} \quad (1)$$

where “ D ” and “ σ_{NTS} ” are the specimen gauge diameter (mm) and notched tensile strength (MPa). For the material and specimen configuration, the attainment of plane strain was established using equation (2) [31]:

$$D \geq \left(\frac{K_{IC}}{\sigma_y} \right)^2 \quad (2)$$

where K_{IC} and σ_y are the fracture toughness ($\text{MPa m}^{1/2}$) and yield strength (MPa) of the specimens.

2.6 Microstructural analysis

A Zeiss Sigma field emission gun scanning electron microscope (FEG-SEM) with add-on functionality for EDS analysis was used for compositional and microstructural assessment of the Al-Zn alloy and composites. Preceding the microstructural examination, was samples preparation to mirror like surface finish, following standard procedures. Etching was performed on the samples by swabbing for 20 s using Wreck's reagent after which the microstructures were examined.

2.7 Damping behaviour

An artemis dynamic mechanical analyzer DMA 242 E was utilized for analyses of the damping properties of the Al-Zn alloy and composites, following recommendations of ASTM E756-05 [32] standard. Flat shaped rectangular bar samples with dimensions of $55 \text{ mm} \times 5.0 \text{ mm} \times 2.0 \text{ mm}$ were machined for the test. The DMA which operates on three-point bending mode, generated data for storage modulus (dynamic modulus) (\bar{E}) and loss modulus (\bar{E}''), which were used for analysis of the damping capacity ($\tan d$) using equation (3) [10]. The analysis was performed at a strain amplitude (\mathcal{E}) of $10 \mu\text{m}$, vibration frequencies (f) of 1 Hz, temperature range (\mathbf{t}) of $30\text{--}200 \text{ }^\circ\text{C}$, and heating rate (\mathbf{T}) of $8 \text{ K}/\text{min}$.

$$\tan d = \frac{\bar{E}''}{\bar{E}} \quad (3)$$

3 Results and discussion

3.1 Structural characterization

The SEM micrographs of the Al-Zn alloy and composites are presented in Figure 1. It is observed that the reinforcement particles are visible and mostly segregated around the grain boundary vicinities of the Al-Zn matrix. The settling of the reinforcements preferentially along the grain boundaries is essentially processing related and influenced largely by the solidification dynamics [20,33]. Image analysis for average grain size assessment indicated that the Al-Zn composites reinforced with Cu have relatively finer grain sizes (Al-Zn/6Cu – $55.86 \pm 2.42 \mu\text{m}$; Al-Zn/8Cu – $74.20 \pm 4.28 \mu\text{m}$) compared with the Al-Zn alloy ($84.67 \pm 1.98 \mu\text{m}$) and Al-Zn composite reinforced with 8 wt.% SiC ($81.25 \pm 3.04 \mu\text{m}$). This can be linked to the relatively higher thermal conductivity of Cu ($398 \text{ W}/\text{m K}$), which offers higher melt undercooling (lower barrier to crystallization), compared with SiC ($270 \text{ W}/\text{m K}$) and Al ($247 \text{ W}/\text{m K}$) [34]. Figures 2–4 are representative micrographs of Al-Zn composite reinforced with 8 wt.% Cu. They help in providing insight on the feasibility of producing Cu reinforced AMCs without encountering the problem of significant Cu dissolution in the Al matrix, noting that Cu has relatively

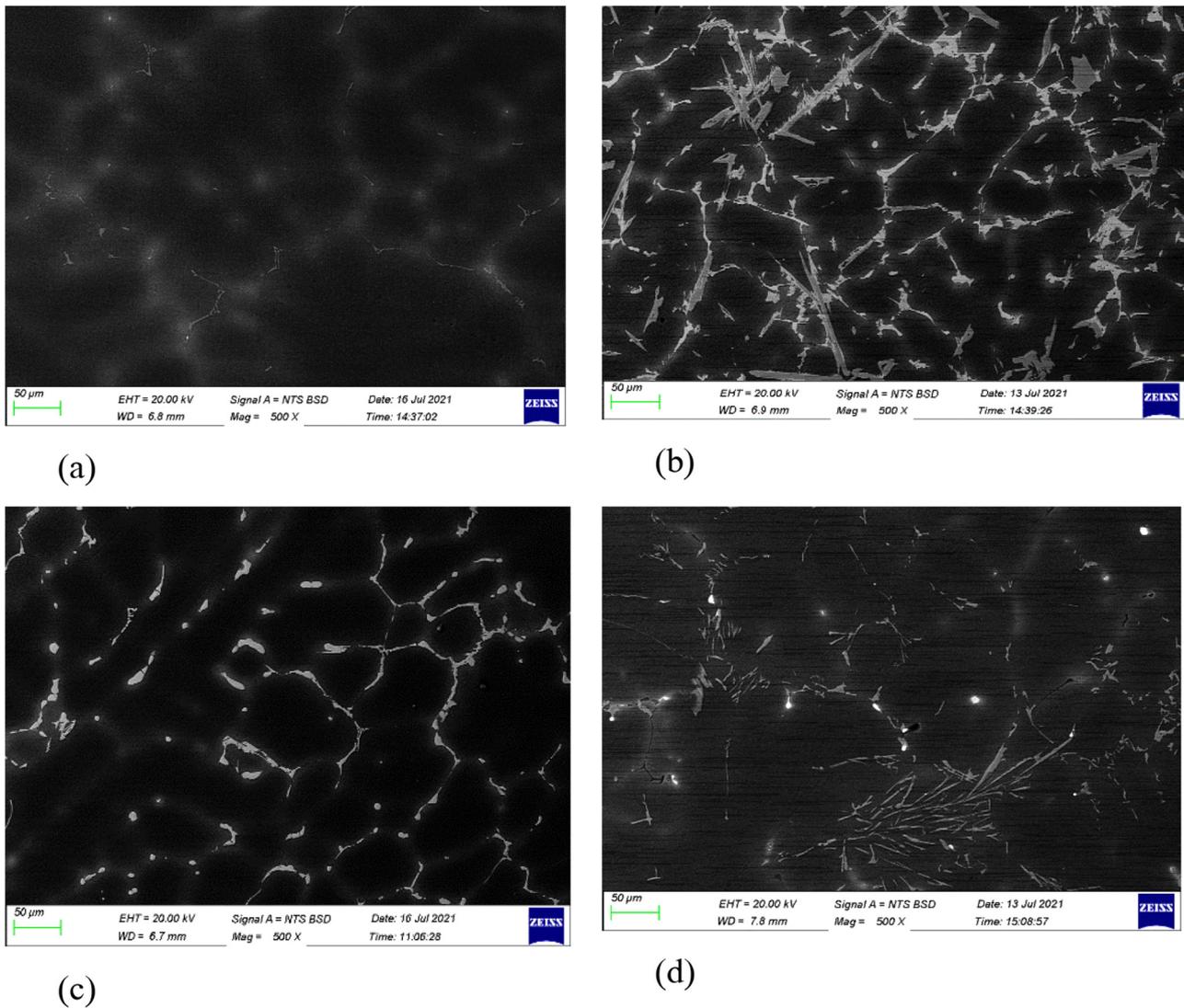


Fig. 1. SEM-BSE images of as-cast (a) Al-10Zn, (b) Al-10Zn + 6 wt.% Cu_p, (c) Al-10Zn + 8 wt.% Cu_p, and (d) Al-10Zn + 8 wt.% SiC_p.

good solubility in Al. From [Figure 2](#), it is seen that Al, Zn, and Cu are identified as elements in the composites, but [Figure 3](#), which is the microstructure of the matrix, shows only Al and Zn are captured. This suggests that there are no noticeable dissolution of Cu or dispersion in the Al-Zn matrix interior, unlike [Figure 4](#) which indicates a high Cu concentration in the Al-Zn matrix boundaries. The corollary from the observations is that the processing route adopted in this study assures that Cu remains a separate phase in the composite system but effort is required to achieve better dispersion of the Cu particles in the Al-Zn matrix.

3.2 Composite Densities and Porosity

The densities and percent porosities of the Al-Zn alloy and composites are presented in [Table 2](#). The porosity values are less than 4%, stated as the maximum tolerable in sand-cast metal matrix composites [26], hence the role of porosity on the material behaviour is considered relatively, marginal.

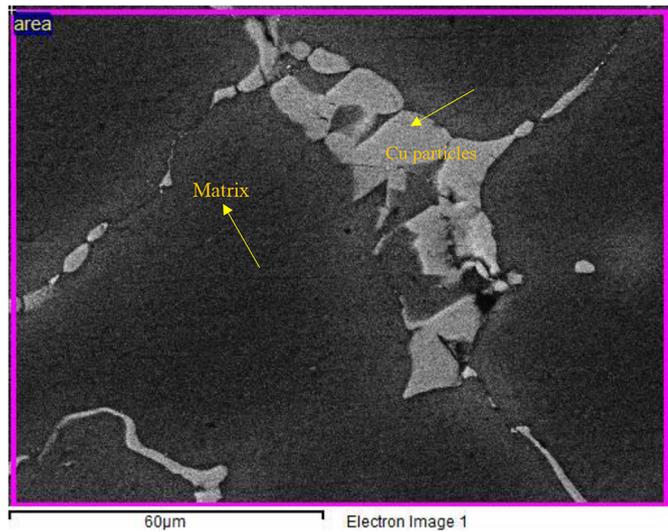
3.3 Mechanical properties

3.3.1 Hardness properties

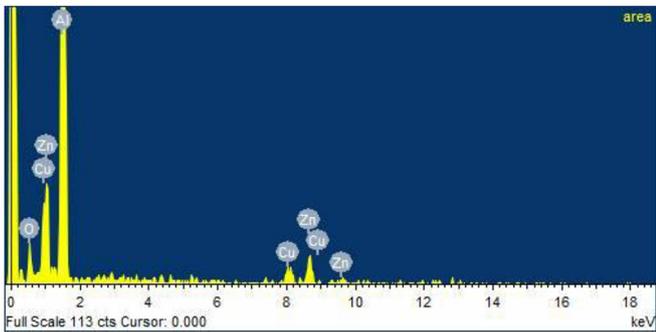
[Figure 5](#) shows the hardness of the Al-Zn alloy and composites studied. It is observed that the addition of reinforcements (either Cu or SiC) resulted in improvement in the hardness of the Al-Zn based composites. There was a corresponding increase in the hardness of the Cu reinforced Al-Zn composites with increase in the Cu wt.%. Specifically, 10.2% and 16.0% increase in hardness was obtained when 6 and 8 wt.% Cu were added to the Al-Zn matrix, while 18.4 wt.% increase was observed comparatively when 8 wt.% SiC was added as reinforcement. When the hardness of the 8 wt.% Cu reinforced Al-Zn is compared with that of 8wt% SiC reinforced Al-Zn, a marginal difference in hardness of 2.4% is obtained. This indicates that the substitution of SiC with same wt.% Cu as reinforcement does not results in adverse reduction in hardness of the Al-Zn composites. The mechanism of hardening on account of increase in the wt.% Cu can be linked to increase in particle hardening effect,

Table 2. Densities and Porosities of the Al-Zn Alloy and Composites.

Material	Theoretical Density (g/cm ³)	Actual Density (g/cm ³)	Porosity (%)
Al-Zn	3.14	3.09	1.68
Al-Zn + 6wt.% Cu	3.52	3.45	2.04
Al-Zn + 8wt.% Cu	3.65	3.55	2.69
Al-Zn + 8wt.% SiC	3.18	3.09	2.98



(a)



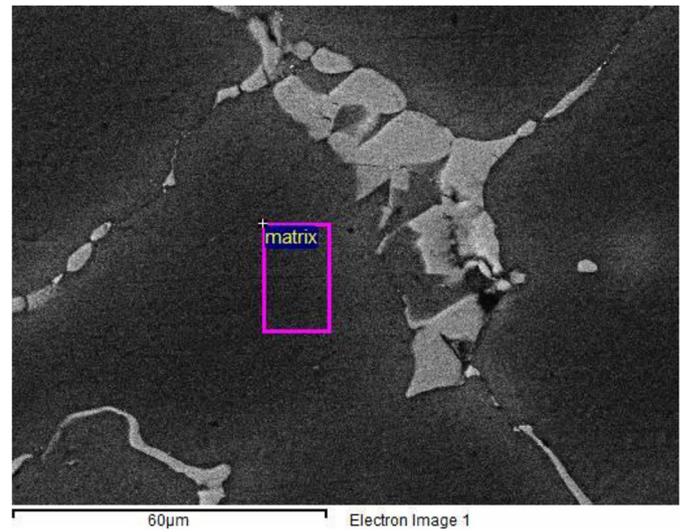
(b)

Fig. 2. a & b: SEM-EDX area analysis of Al-Zn reinforced with 8wt.% Cu particles.

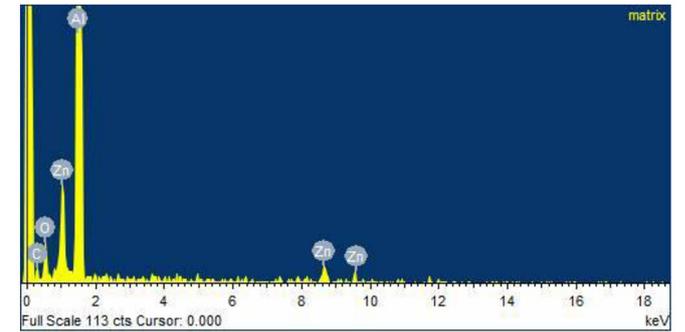
considering that Cu is harder than Al-Zn alloy [14,22]. Furthermore, increase in both direct and indirect strengthening due to both load transfer phenomenon and dislocation generated due to difference in thermal coefficient of expansion during solidification, have been mentioned in literature to be contributory factors to improved hardening in particle reinforced composites [12,35].

3.3.2 Tensile properties

The ultimate tensile strength (UTS), specific strength, and strain to fracture results for the Al-Zn alloy and composites



(a)



(b)

Fig. 3. a & b: SEM-EDX matrix spot analysis of Al-Zn reinforced with 8wt.% Cu particles.

are presented in Figure 6. The UTS values (Fig. 6a) are noted to improve with the addition of the reinforcements (Cu and SiC), as was the case with the hardness (Fig. 5). This is essentially due to the effects of particle strengthening (the particles serve as hard barriers to the motion of dislocation), matrix refinement (due to the undercooling effects created by the particles in the melt during solidification), direct strengthening (due to load transfer from the softer matrix to the harder particles), and indirect strengthening (arising from increased dislocation density due to disparity in thermal expansion coefficients, between the

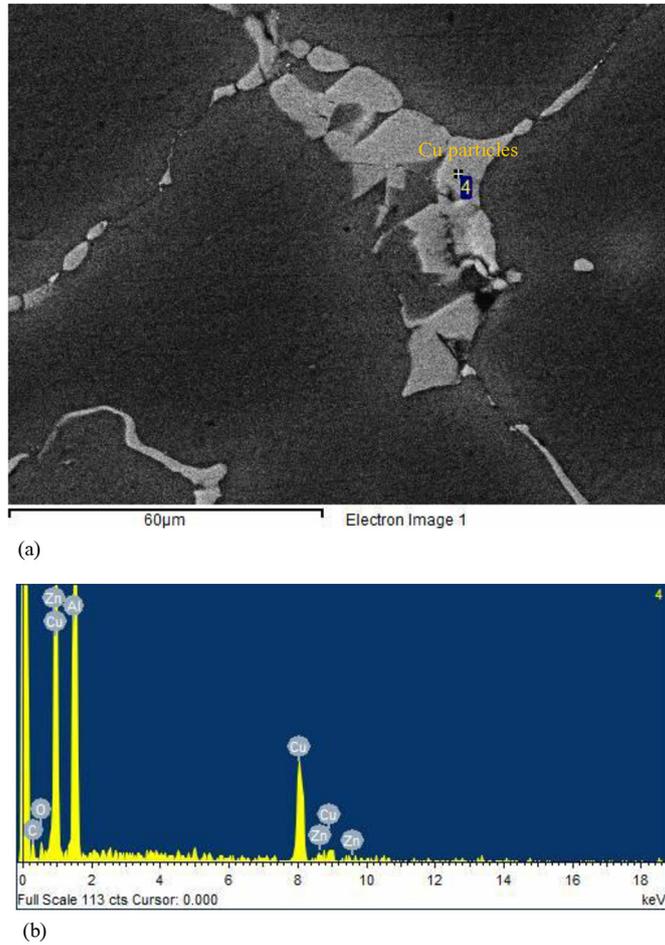


Fig. 4. a & b: SEM-EDX grain boundary spot analysis of Al-Zn reinforced with 8 wt.% Cu particles.

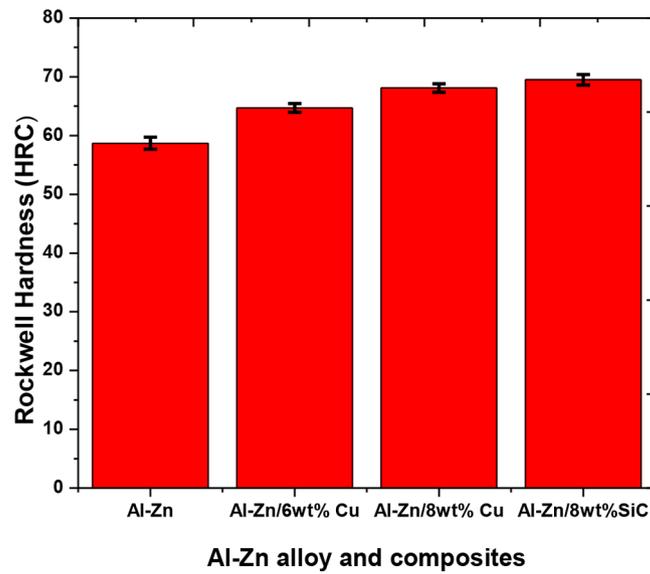


Fig. 5. Variation of hardness of the Al-Zn alloy and composites produced.

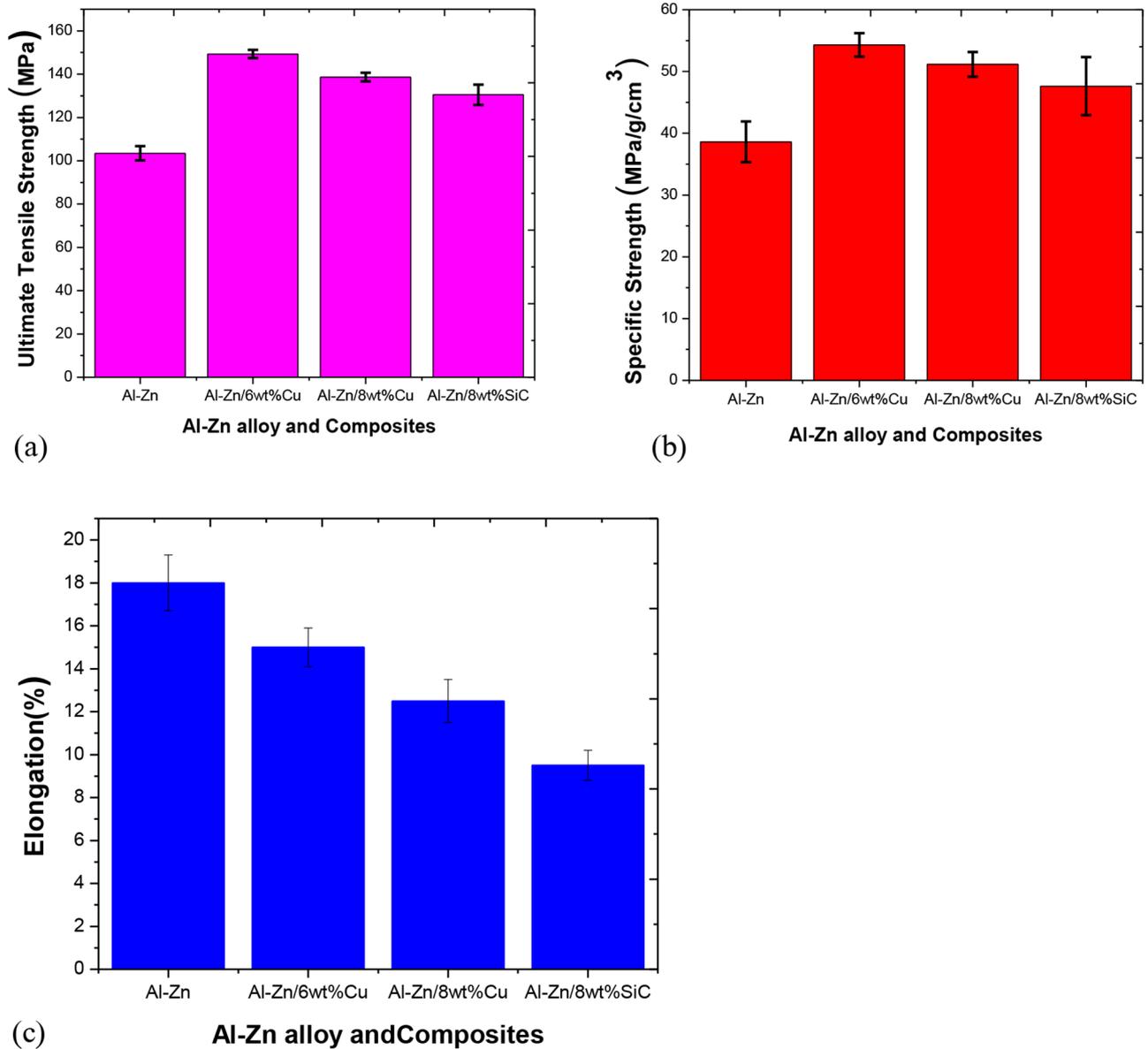


Fig. 6. Tensile properties of the Al-Zn alloy and composites produced: (a) Ultimate tensile strength, (b) Specific strength, and (c) percentage elongation.

reinforcement material and the matrix on solidification) [36,37]. However, it is noted that the best UTS value was obtained from the Al-Zn + 6 wt.% Cu; and both Cu reinforced Al-Zn compositions had UTS values higher than the Al-Zn composite reinforced with SiC. The higher UTS value obtained for the Al-Zn + 6 wt.% Cu composite may be linked to more even dispersion of the Cu particles in the Al-Zn matrix for this composition. The improved UTS values for the Al-Zn composites compared to the composition reinforced with SiC, on the strength of experimental evidence can be linked to

improved interface strengthening in the Cu reinforced Al-Zn composites. Metals are reported to have stronger interface bonding when reinforced with metals compared with metals reinforced with ceramics [14,38]. In the case of metal reinforced metal systems, a more continuous interface bonding is achieved compared to the metal-ceramic system where discontinuities created by voids can serve as sites for stress concentration which invariably lowers the strength of the composite compared to when a more continuous interface is present.

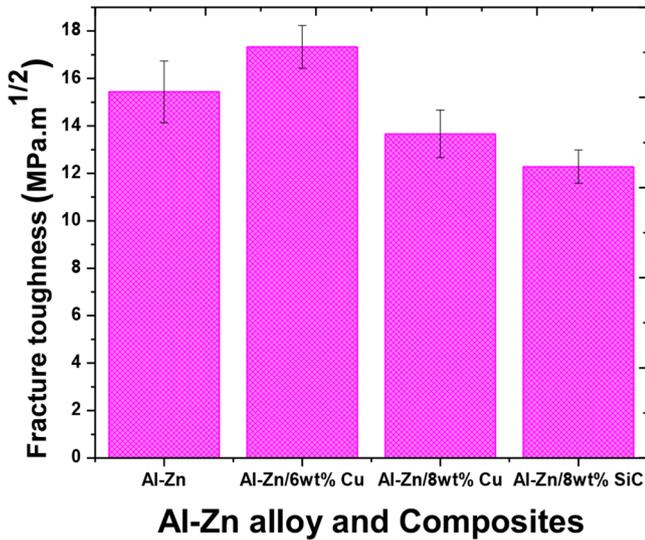


Fig. 7. Fracture toughness values of the Al-Zn alloy and composites produced.

Despite the higher densities of the Al-Zn composites reinforced with Cu (3.45 and 3.55 g/cm³ for the 6 and 8 wt.% Cu reinforced Al-Zn, respectively) compared to that reinforced with SiC (3.09 g/cm³), the specific strengths of the 6 and 8 wt.% Cu reinforced Al-Zn composites were higher than that of the 8 wt.% SiC reinforced Al-Zn composite (Fig. 6b). This implies that relatively thinner gauges of the Al-Zn composites having adequate strength can be produced with the use of Cu particles compared with the use of SiC particles.

In contrast to the trends observed for the strength parameters, it is observed from Figure 6c that the percentage elongation (strain to fracture) of the Al-Zn alloy was higher than that of the Al-Zn composites. It is however noted that the % elongation of the Al-Zn composites reinforced with Cu were higher than that reinforced with SiC. This can be rationalized to be on account of the inherent ductile nature of Cu in comparison with SiC, coupled with a greater likelihood of achieving a continuous interface bonding in the Cu reinforced composites than that reinforced with SiC [25].

3.3.3 Fracture toughness properties

The fracture toughness results for the Al-Zn alloy and composites are presented in Figure 7. Since the conditions for plane strain fracture toughness validation, detailed in Section 2.5.3 were met, the results are considered reliable and are hence reported. The fracture toughness was observed to be highest for Al-Zn composition containing 6 wt.% Cu, followed by the unreinforced Al-Zn alloy. It is noted that both Cu reinforced Al-Zn composite compositions (containing 6 and 8 wt.% Cu) had fracture toughness values higher than the 8 wt.% SiC reinforced grade. The Cu particles which are inherently more ductile and tougher than SiC offer more crack propagation resistance as they are more capable of yielding (deformable) which attenuates the potential stress intensification levels

ahead of crack tip at matrix/particle vicinities [11]. The superior metal-matrix interface bonding that can be offered by the metal-metal (Al-Zn/Cu) system compared with the metal-ceramic (Al-Zn/SiC) system, drastically reduces the tendencies of particle cracking or debonding generally observed as fracture micro-mechanism for ceramic materials reinforced AMCs [39,40]. These analyses are supported by Figure 8, which show the fractographs of the Al-Zn alloy and composites. The fractographs of the Al-Zn alloy (Fig. 8a) and Al-Zn reinforced with Cu particles (Figs. 8b and 8c), show more dimple features (characteristic of ductile fracture) than that of the Al-Zn composition reinforced with SiC (Fig. 8d). The corollary from the results is that the use of Cu as reinforcement in Al-Zn, offers relatively better improvement in toughness, and by extension, damage tolerance of Al-Zn based composites compared with the utilization of SiC as reinforcement.

3.4 Damping behaviour

The damping test results of the Al-Zn alloy and composites are presented in Figure 9. From Figure 9a, the Al-Zn based composite with 8 wt.% Cu particles is seen to have the highest storage modulus between 30° and 200 °C, while the 6 wt.% Cu reinforced Al-Zn based composite had the lowest values for the Al-Zn alloy and composites investigated. This indicates that the 8 wt.% Cu reinforced Al-Zn composite has the highest vibration energy absorption capability of all the compositions studied. It is also worth noting that the storage modulus of the Al-Zn alloy and composites diminishes as the temperature rises from 30 to 200 °C. The storage modulus decrease as temperature rises is due to a reduction in the dynamic stiffness of the Al-Zn alloy and composites on account of the decrease in bond strength, arising from atomic bond weakening in solids, and matrix/reinforcement bond weakening (in the case of the composites) [16].

The loss modulus of the Al-Zn alloy and composites are presented in Figure 9b. It is observed that between 40 °C and 100 °C test temperatures, the loss modulus was fairly stable for the Al-Zn alloy and composites. Within this temperature range (40–100 °C), the loss modulus of the Al-Zn, Al-Zn + 8 wt.% Cu and Al-Zn + 8 wt.% SiC, appeared to be within the same range. The Al-Zn composite reinforced with 6 wt.% Cu, had the least loss modulus within 40–100 °C. Above 100 °C, a sharp increase in the loss modulus was registered for all the Al-Zn systems investigated. The increase was significant for the Al-Zn, Al-Zn + 8 wt.% SiC, and Al-Zn + 6 wt.% Cu compositions. The Al-Zn composite reinforced with 8 wt.% Cu, only exhibited a slight increase in loss modulus. This suggests that at above 100 °C, the Al-Zn composite reinforced with 8 wt.% Cu had the least vibration energy dissipation capacity. Potentially greater particle mobility and particle/grain boundary sliding, have been stated as micro-mechanisms responsible for increased loss modulus (energy dissipation) at higher temperatures [16,41].

In similar manner, the damping capacities of the Al-Zn alloy and composites (Fig. 9c), follow the trend established for the loss modulus (Fig. 9b). At 30 °C, the

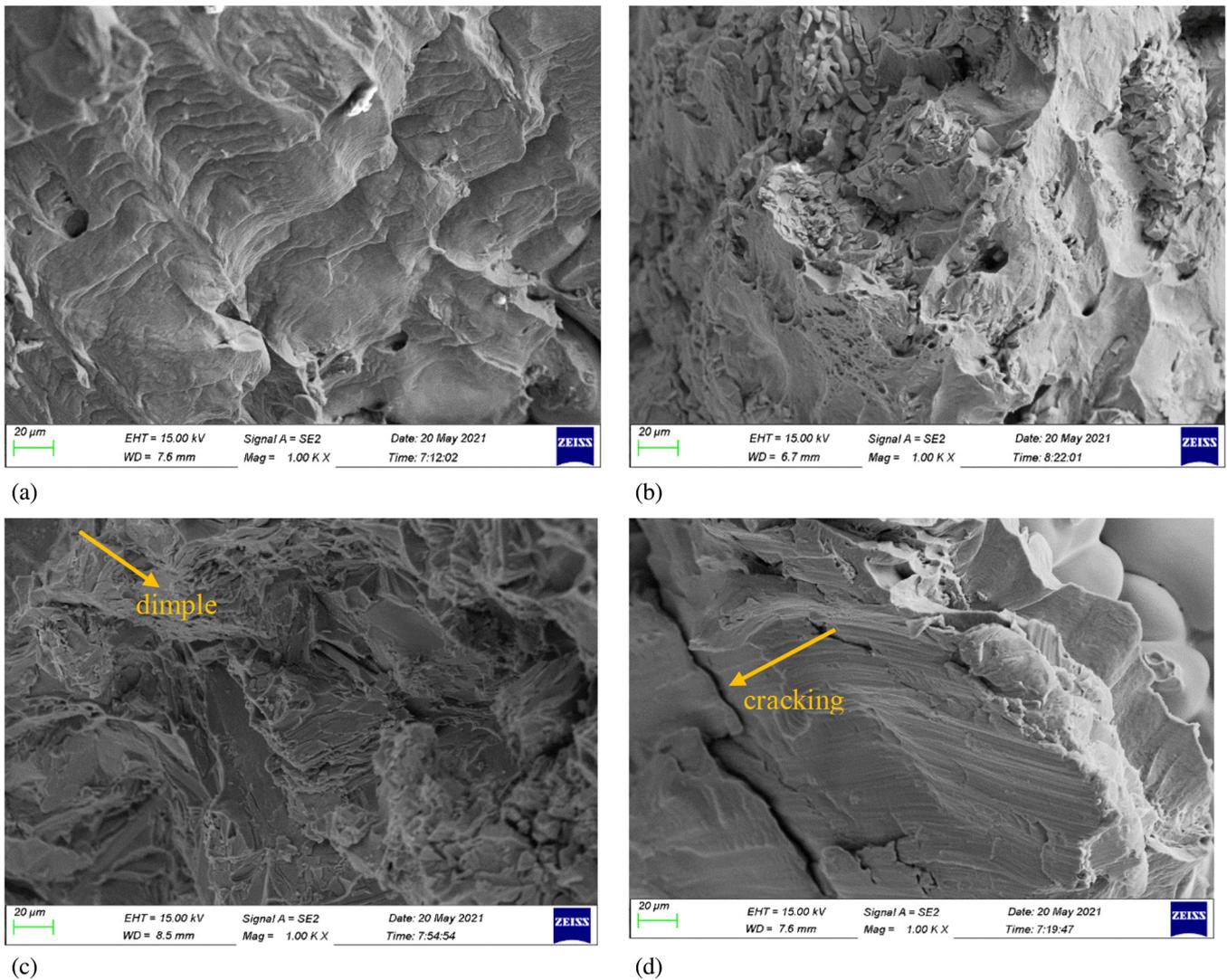


Fig. 8. SEM Fractographs of the Al-Zn alloy and composites: (a) Al-Zn, (b) Al-Zn + 6 wt.% Cu, (c) Al-Zn + 8 wt.% Cu, and (d) Al-Zn + 8 wt.% SiC.

Al-Zn composite reinforced with 8 wt.% SiC had the highest damping capacity. But for temperatures within 40–100 °C, the damping capacity was essentially within the same range for all with the exception of the Al-Zn reinforced with 6 wt.% Cu, which had the least value. For temperatures above 100 °C, there was a significant surge in the damping capacity for all except the Al-Zn reinforced with 8 wt.% Cu which experienced a marginal increase. This is due to its low loss modulus (energy dissipation capacity) relative to its storage modulus (energy storage capacity). The general rise in damping capacity as temperature increases may be attributed to enhanced particle mobility and interface/ boundary sliding [17,42]. This mechanism appears somewhat inhibited for the Al-Zn reinforced with 8 wt.% Cu. The higher damping capacity in the Al-Zn composite reinforced 8 wt.% SiC compared with the composite composition reinforced containing 8 wt.% Cu, can be linked to dislocation

damping and the intrinsic damping phenomena exhibited by multiphase systems (in this case, the matrix and reinforcements) [10]. Silva Prasad et al. [19] reported that SiC powder has damping capacity higher than that of Ferrous based metallic reinforcements. Thus, based on the rule of mixture, it is expected that the damping capacity of the SiC reinforced Al based composite will be higher than that of the composition reinforced with Cu particles when the same wt.% reinforcements are utilized. Furthermore, the contribution from dislocation damping is expected to be higher for the Al-Zn based composite reinforced with 8 wt.% SiC than that reinforced with 8 wt.% Cu because of the larger difference in coefficient of thermal expansion between Al and SiC compared with Al and Cu [19]. A greater difference in thermal coefficient of expansion between the matrix and reinforcements is reported to facilitate the generation of more dislocations within the composites systems [42].

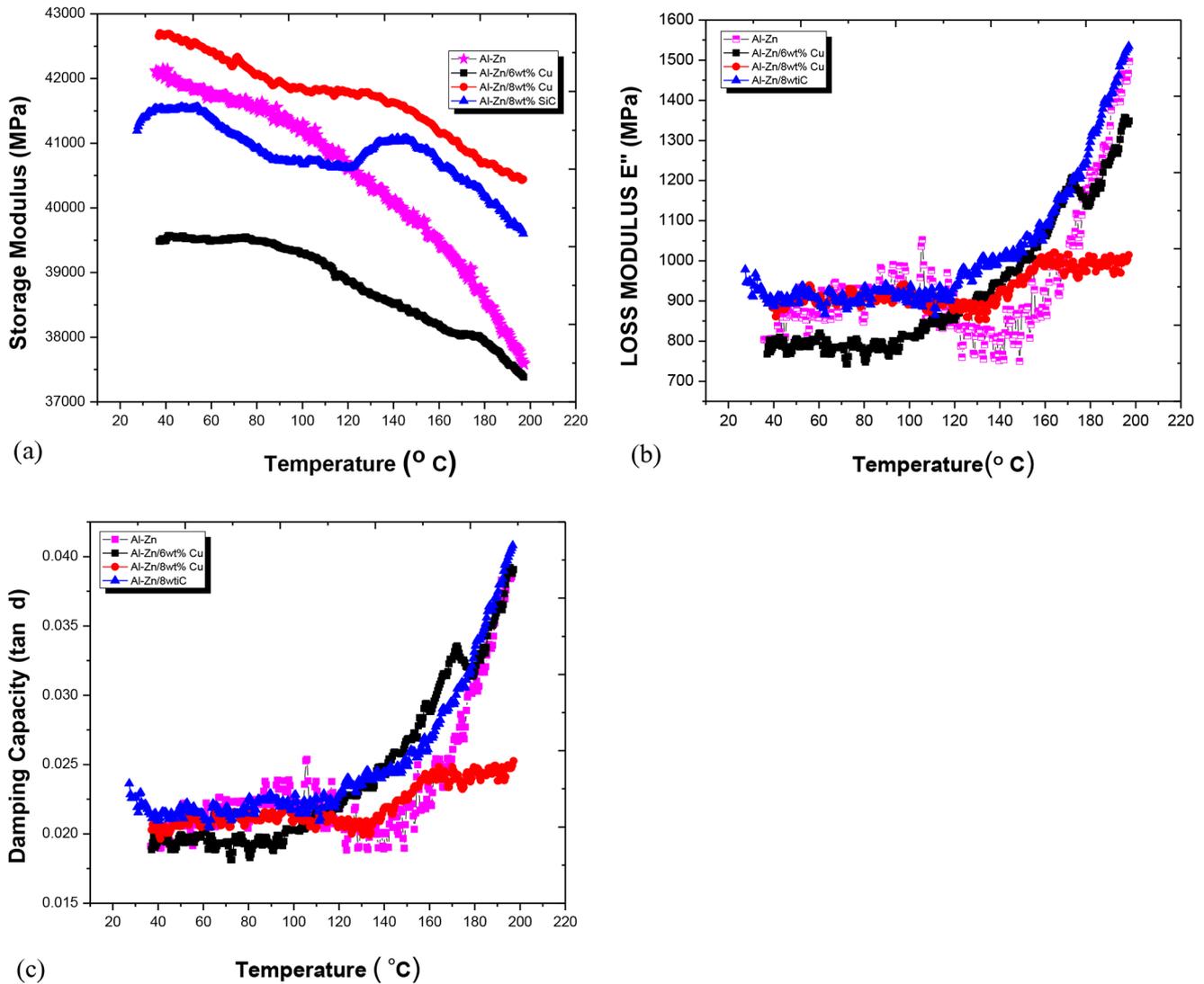


Fig. 9. Damping properties of the Al-Zn alloy and composites as a function of temperature (a) Storage Modulus, (b) loss Modulus, and (c) damping capacity.

4 Conclusion

The structural features, mechanical and damping properties of Al-10 wt.% Zn based composites developed using Cu-, SiC- particles as reinforcements were investigated. The results show that:

- Exempting the preferential segregation of the reinforcement particles within the grain boundary vicinities, production of sound Al-Zn composites reinforced with Cu particles was viable. This is on account of the low porosity levels (<4%), the near absence of dissolved Cu in the Al-Zn matrix, and marginal presence of melt reaction-induced intermetallic phases, recorded in them.
- Besides hardness, the strength parameters – ultimate tensile strength (149.33 MPa and 138.64 MPa) and specific strength ($54.3 \text{ MPa cm}^3 \text{ g}^{-1}$ and $51.16 \text{ MPa cm}^3 \text{ g}^{-1}$) – of the Al-Zn composites reinforced with 6 and 8 wt.% Cu, were superior to the

unreinforced Al-Zn alloy (103.47 MPa) and the 8 wt.% SiC reinforced composite (130.5 MPa).

- The fracture toughness ($17.32 \text{ MPa m}^{1/2}$; $13.66 \text{ MPa m}^{1/2}$) and percentage elongation (15%; 12.5%) of the 6 and 8 wt.% Cu reinforced Al-Zn composites, surpassed that reinforced with SiC ($K_{IC} = 12.28 \text{ MPa m}^{1/2}$; $\% \epsilon_f = 9.5\%$).
- Improved matrix/reinforcement particles interphase bonding and the inherent ductile and tough nature of Cu over SiC, were regarded as the crucial factors responsible for the improved strength-ductility-toughness balance of the Al-Zn composites reinforced with Cu particles over that reinforced with SiC.
- The damping properties were generally temperature sensitive, with all compositions exhibiting increase in damping capacity at test temperatures 100–200 °C.
- In general, the Al-Zn composite reinforced with 6 wt.% Cu particles, had the best combination of mechanical and damping properties.

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