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Processing and Properties of ZA-27 Alloy Metal Matrix Hybrid Composite Reinforced with Nanonitrides

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K E Y W O R D S

ZA-27 alloy, Stir Casting, Hybrid Composite, Nanoparticles, Hardness & Tensile Test.

A B S T R A C T

In general, internal vibrations within the pipelines caused by fluids being passing through a pipeline system can cause. These pipeline system can damage by the sudden amplified vibrations that were not considered at the design of the system, and flow induced vibrations resonate with the pipes natural frequency. Therefore, it is important to predict and identify the pipeline system vibrations during its lifetime. In this study by using MATLAB code as a CFD solver, it studied the forced and free vibrations caused by fluid flows at Reynolds number ranged as $0 < Re < 2500$ *for laminar flow and ranged as* $10^4 < Re < 10^5$ *for turbulent flow. The working fluid has chosen as of (*Al_2O_3*,* TiO_2*,* SiO_2 *and water) with different nanoparticle volume fraction of (0 to 2% vol.). These fluids flow in simply supported pipe with different lengths and diameters. The results presented the effect of pipe and fluid parameter upon the fluid critical velocity and fundamental natural frequencies. The results showed that the pipe natural frequency increased with increasing with decreasing the pipe length and diameter. In addition, it showed that the pipe natural frequency decreased when using the different nanoparticle depressed in the water and with increasing the volume fraction.*

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1. Introduction

Zinc-aluminum alloys (ZA alloys) are widely used in for both scientific researches and industry, as a tribomaterials, due to its good castibility and other properties, which become an alternative alloy for bearing bronze [1]. They are known to be cheap material processed energetically, efficiently and without endangering the environment [2].

ZA-27 have higher aluminum and copper contents, which give high strength, excellent, wear and creep resistance, and lower density [3]. However, when wear resistance properties are needed, ZA-27 has demonstrated extraordinary performance [4].

Nowadays, the most researchers were studied the properties of the ZA-27 alloy reinforced with ceramic dispersions such as silicon carbide and graphite for improving mechanical and tribological properties [5]. The purpose of applied metal matrix composite based on ZA-27 matrix because of lightweight and good materials from wear resistance [6].

The hybrid metal matrix composites contains two or more type of reinforcements. Reinforcements in terms of mixtures of particles, whiskers and fibers with different weight percentage and varying sizes are utilized in metal matrix for multi-functional properties [7].

Seah et al. [8] investigated that the hardness of artificial aged specimens of ZA-27/Gr increased as compared with as cast alloy.

Babic et al. [9] tested ultimate tensile stress for as ZA-27 alloy and heat-treated it, The results showed reduce UTS and hardness with increase in elongation for as cast alloy while for heat treated alloy showed reduction in hardness.

Ranganath et al. [10] evaluated the effect of weight percentages of TiO_2 additives as reinforced particles on the mechanical properties of ZA-27. The results indicated that the reinforced particles reduced the alloy ductility, and improved UTS, yield strength and hardness. Prasad [11] evaluated the effect of microstructure composition on the tensile property of ZA-27 alloy. Experiments were performed at different strain rates and temperature. The results showed when increasing the strain rate then improving the tensile strength of the alloy.

Fadhil et al. [12] concluded the wear rate for (ZA-27) alloy hybrid composites reinforced by nano particles (BN and Si3N4) with various weight percentage-producing stir casting technique. The results indicate that the value of hardness increased with increasing the additives of nano (BN and Si3N4) percentage for ZA-27 hybrid metal matrix composites. It was found that the nano particles important effects for improving the wear properties of alloys.

The aims of this study have been evaluated the mechanical behavior and study the microstructure of ZA-27 alloy was produced by stir casting and study the effect hybrid composite with different percentages of nanoparticles.

2. Materials and Methods

I. Materials selection

a. Matrix Material: Matrix material used in this research was ZA-27, which has excellent properties with a wide range of applications .Its chemical analyzes; composition is shown in Table 1. The test was obtained at the State Company for inspection and Engineering Rehabilitation.

b. Nano Boron Nitride and Nano Silicon Nitride as a Reinforcing Materials. It was used a ceramic powders (nano BN with average size 57nm) and (nano Si3N4 with average size 34nm) as reinforcement for ZA-27alloy. The morphology of raw powders were done made with Scanning Electron Microscopy (SEM) as shown in Figure 1.

Table 1: Chemical analyses of ASTM ZA-27

Element	Al %	Cu %	Mg %	Fe %	Cd %	Pb %	Zn %
Nominal Chemical Comp. Standard [13]	25-28	2-2.5	0.01-0.02	0.1	0.003	0.004	Rem
Actual chemical Composition of ZA-27 alloy	26.23	2.17	0.013	0.054	0.0011	0.0006	Rem

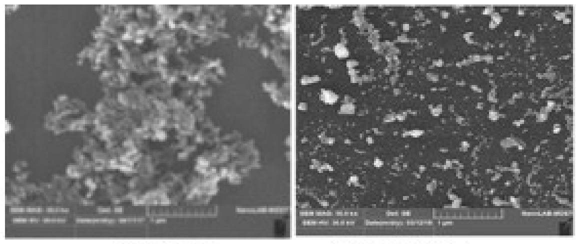

Figure 1: SEM of nano BN and Si_3N_4 nano powders

II. Production of matrix material and its composite

For the production of matrix material (ZA-27alloy) it used. The weight of melting alloys was approximately equal to 264 gm, which included 185 gm electrolytic zinc (99.99%), 78gm pure aluminum, 20 gm master alloy 50 Cu-50Al and10gm AA2024. The melting for all alloys in a graphite crucible by using gas furnace to about 700 °C (above its melting point) to ensure full melting at 15 min [14]. The molten material was mixed using a mechanical stirrer to get a homogenous mixture. Flux cleaning (KCl- NaCl- NaF) with weight percentage 0.25% were used which usually richer in chlorides to facilitate wetting of the oxide inclusions for easier separation from the melt. For reduced the impurities and gases dy using hexachlorethane as degassing [15]. The reinforcement nanoparticles BN (purity 99%, average size 33.41nm) and Si_3N_4 (purity 99%, average size 58.44nm). with (2,3%) weight percentages were added to the melted matrix as packaged in aluminum foil and continuously stirred using a mechanical stirrer for 2-3 times and speed 1000-1200 rpm. to obtain a uniform mixing for all melted material. The slag was removed and then pouring the molten material into a cylindrical graphite mold (permanent mold casting) for casting and the temperature was gradually lowered. Figure 2 and Figure 3 show the mold preparation and sketch of mold with dimensions, respectively.

III. Hardness

Hardness test was carried to the base metal and its composites using standard Vickers hardness test machine. Vickers hardness test were indicated the influence of weight percentage of the particles on the matrix hardness. Loads that applied are 0.2kg at 10 sec. and the indenter used was square-based diamond pyramid.

III. Tensile test

The tensile test was performed on cylindrical specimens. The test applied at a uni-axial load to the both ends of specimens. The sample's dimensions were according to the standard sample of tensile test ASTM E82. The dimensions of tensile specimens are shown in Figure 4.

V. Microstructure

Optical microscope were using to study the microstructure of ZA-27 alloy and its all composites. The samples are etched using 200 gm CrO_3, 15 gm Na_2SO_4, 1000 ml H_2O [16].

Figure 2: Mold preparation

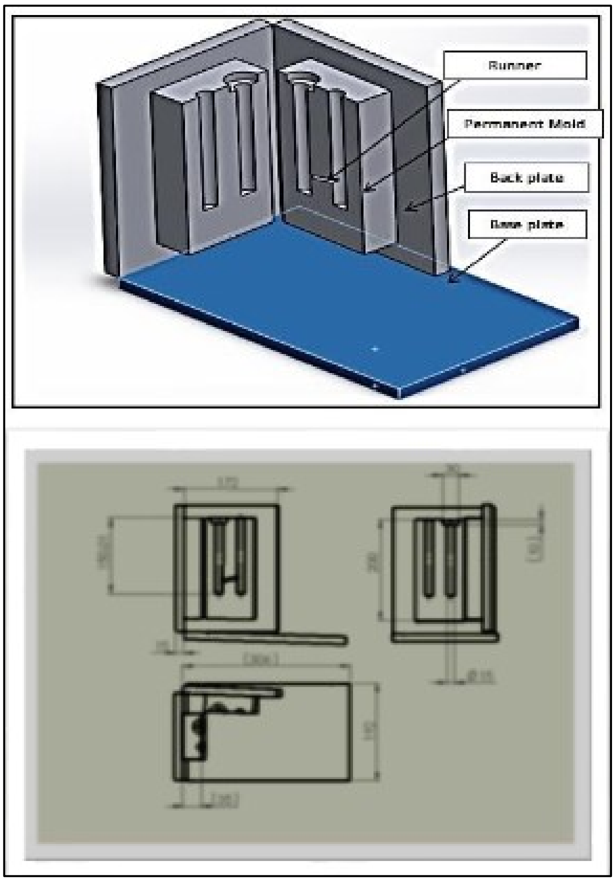

Figure 3: Sketch of mold with Dimensions
(All dimensions are in mm)

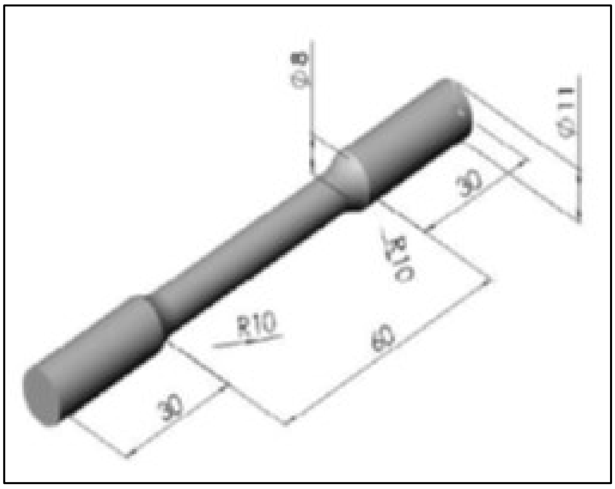

Figure 4: Tensile specimen's dimensions according to (ASTM E82) (All dimension are in mm)

3. Results and Discussion

I. Micro hardness measurement

The value of Vickers micro hardness are given in Figure 5. The results indicate that the hardness of matrix material and its composite increased when increasing the weight percentage of nano particles. The presence of hard reinforcement particles (BN and Si_3N_4) increase load-bearing capacity of the composite and limit the matrix distortion by impeding the movement of dislocation. The maximum value of hardness were observed at (3%BN and 3%Si_3N_4) weight fraction.

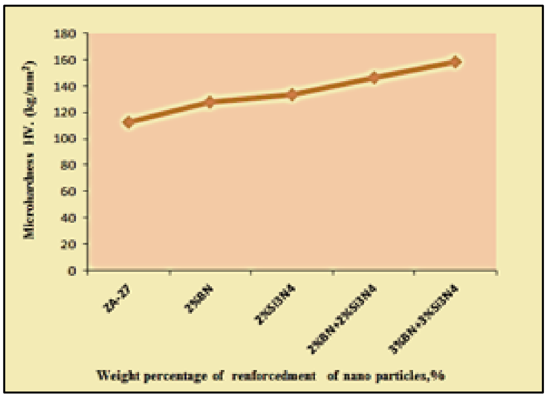

Figure 5: Micro hardness values of ZA-27 alloy and its composites

II. Tensile test

The strength has main importance in engineering design, as the ultimate tensile strength (UTS). ASTM standardized testing method was used to determine most of these properties.

Table 2 shows the fabricated tensile strength values of alloy ZA-27 and its composites. Mechanical properties (σT) are reported. Figure 6 depicts the stress - strain diagram of the fabricated ZA-27 alloy and its composite produced by casting.

Table 2: Tensile properties for ZA-27 alloy and all composites

Materials	Tensile Strength, σT (MPa)
ZA-27 alloy	**424**
ZA-27 alloy + 2%BN	**427**
ZA-27 alloy + 2%Si_3N_4	**435**
ZA-27 alloy +2%BN + 2%Si_3N_4	**448**
ZA-27 alloy +3%BN + 3%Si_3N_4	**452**

The results were identified the this figure shows the influence of nano additive on the tensile strength for ZA-27 alloy and all composites. The best composite in tensile strength is ZA-27 alloy/3wt% nano BN+ 3wt% nano Si_3N_4 where an increase of 21% than base alloys.

From the above, it is concluded that the UTS of ZA-27 alloy and all composites are totally controlled by increasing the wt.% of nano additives with reduced the particles size and the presence of strong matrix composition. Additional enhancement in mechanical properties of ZA-27 alloy and all composites can be accomplished by adjusted the bonding between the dispersions and matrix, the process parameters of metal treatment and the decreasing of micro porosities in the casting.

In general, the proof stress increases with the particle weight percentage [17]. The distribution of the reinforcements and homogeneity plays a significant role in this property. It is identified the nano additives effect on the tensile strength according the Orowan mechanism for nanoadditives act as obstacles to impede the movement of dislocations near the reinforcing particles in the ZA-27 alloy. Therefore, the dislocations were interacted with sharable nano additives increases the strength level of composite specimens. This can be improved by the increase of weight percent of particles

The tensile strengths results for of the composites reinforced with nano particles were shown the effect of different nano ceramic particulates at different percentages on the (UTS) ultimate tensile strengths, the results showed that the UTS increased in with increasing wt% of the nano ceramic particulates, the largest increase being in ZA-27/ alloy/3wt% nano BN+ 3wt% nano hybrid composite, and the least being in single reinforcement composite. These results manifest the effectiveness of the particulates in strengthening of the ZA-27 alloy and improvement in tensile strength is generally caused by grain refinement from Hall-Petch theory and the limited movement of dislocations in the matrix due to nano additives according to Orowan mechanism.

The increase of UTS of the composites over the ZA-27 matrix can be concerned to the interaction between the dislocations and particulates within the matrix, and to the grain refinement of ZA-27 with increasing addition of the particulates.

The test results revealed that the tensile strength of ZA-27 composites are mainly depended on the distribution of the nano particles in the matrix. The increase of tensile values for composites can be attributed to the presence of brittle (BN)p and (Si_3N_4)p which may act as stress concentration area.

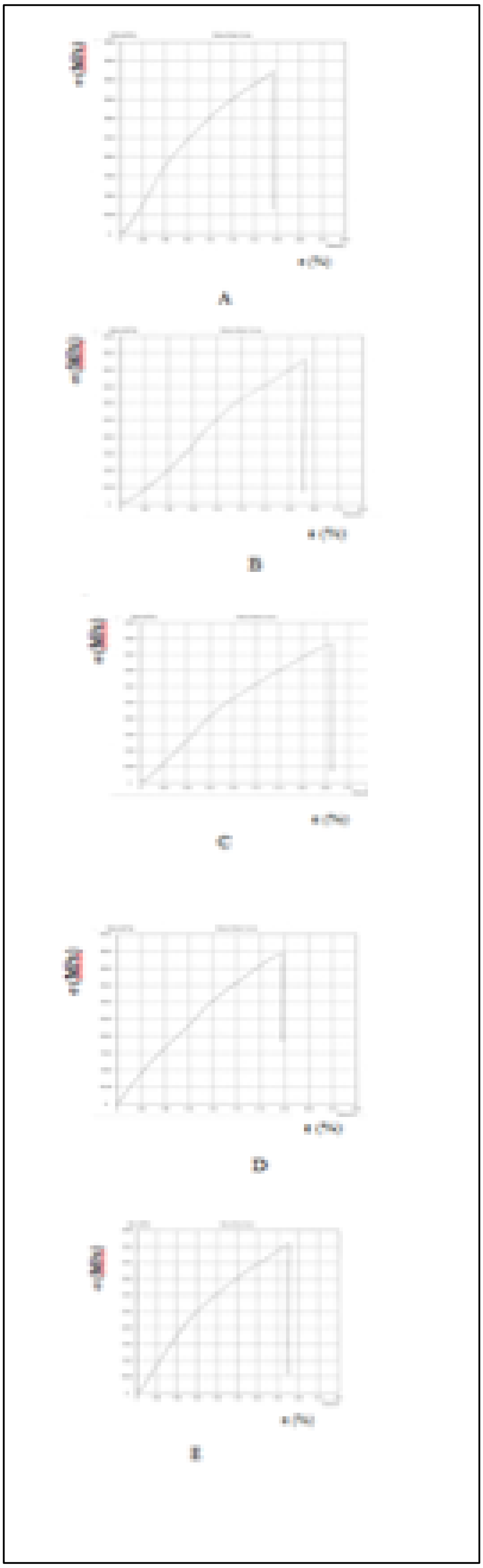

Figure 6: Tensile strength for nano boron nitrite and silicon nitrite particles at different weight percentages in ZA-27 alloy- matrix. A) ZA-27 alloy; B) ZA-27 alloy/2%BN; C) ZA-27 alloy/2% S3N4; D) ZA-27 alloy/2%BN+2% Si_3N_4; E) ZA-27 alloy/3%BN+3% Si_3N_4

4. Microstructure Analysis

Optical microscope was used to study the microstructure and the phases formed. From which it has been shown that better dispersion of the reinforcement in the matrix. It is also observed that the weight percentage of the nano particles increases in the matrix, the reinforcement particles increases and the inter particle space decreases. The microstructure exhibits no agglomeration of reinforcement in the matrix. The microstructure is primary dendrite due to fragmented caused by mechanical stirring which contribute the improvement in the possibility of incorporating and entrapping nano-sized particles within the interface developing during the solidification of the dispersed alloy, as shown in Figure 7.

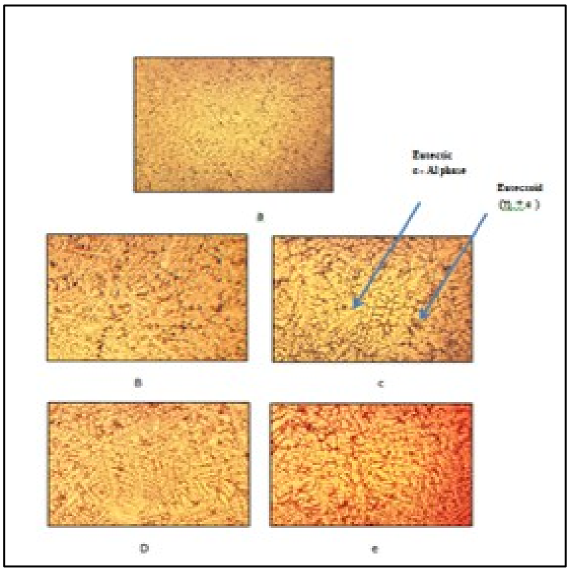

Figure 7: Microstructure of ZA-27 alloy- matrix with nano particles at different weight percent A) ZA-27 alloy; B) ZA-27 alloy/2%BN; C) ZA-27 alloy/2% S_3N_4; D) ZA-27 alloy/2%BN+2% Si_3N_4 E) ZA-27 alloy/3%BN+3% Si_3N_4

5. Conclusions

From the results have been provided the following conclusions:

1. The micro hardness values for ZA-27 alloy and all composites were increased with increasing the reinforcement percentage.
2. The ZA-27 composite reinforced with (3% BN+3%Si3N4) hybrid nanocomposites exhibited maximum tensile strength due to presence of two ceramic materials.
3. The microstructure of ZA-27 alloy is dendritic structure, and the hybrid composites reinforced with nano particles observed to be uniform distribution and noting to presence the agglomeration particles. Thus, the mechanical properties of the composites were increased eith increasing the eight percentages of nano additives
4. Thus, increased nanoparticles with weight percentage increases the mechanical properties of the composite.
5. The hybrid composites were cast successfully with liquid metallurgy technique.

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