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EFFECT OF CRYOGENIC TREATMENTS ON MECHANICAL PROPERTIES OF 7075 ALUMINUM ALLOY MATRIX/AL2O3 PARTICLES REINFORCED COMPOSITES

Al-Alkawi Hussain Jasim Mohammed*, Abthal Abd Al-Rasiaq & Mamoon A. A. Al- Jaafari*****

* University of Technology, Electromechanical Engineering Department, Baghdad, Iraq
** University of Technology, Mechanical Engineering Department, Baghdad, Iraq
*** University of Al-Mustansiriya, Mechanical Engineering Department, Baghdad, Iraq

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Abstract:

Aluminum alloy7075was used as base material to the metal matrix composites ($MMMC_S$) with different wt % of Al_2O_3. (0.2, 0.4, 0.6, 0.8, and 1), the size of Alumina reinforced material particles is 10 Nano meter, were fabricated using stir casting technique. The effect of cryogenic treatments on adding Al_2O_3 nano particles content on the mechanical properties of the $MMMC_S$. It was observed that the nanomaterial reinforcement led to high improvement in ultimate strength (σ_u), yield stress (σ_y), BHN hardness and ductility the improvements were due to good distribution of Al_2O_3 and refinement of base metals matrix aluminum grains. The maximum improvement in ultimate strength, yield stress and BHN hardness was observed at 0.2 wt %. Al_2O_3. While the minimum value of Elongation % was obtained at 0.2 wt. % Al_2O_3.

Key Words: 7075 Al. matrix, Al_2O_3 Nanomaterial, The Metal Matrix Composites $MMMC_S$ & Mechanical Properties ($MMMC_S$).

Introduction:

Aluminum alloys are considers the most important Aerospace industrial alloys and due to toughness and strength. Aluminum matrix composite is being advance and one of the newest engineering materials. The aluminum alloys is low density compare to others materials which can be used in many applications by strengthened with nanoparticles like Al_2O_3 …etc. This alloys replaced steel, bronze and Cast iron to wear resistance. And these alloys are widely used in airplanes like (7075) [1].

By using Aluminum an alloy the mass can be lowered about 50% which makes it increased the flay speed, the load carrying capacity and enhances the flaying stability. Aluminum alloys are acceptable for plastic cold working and wieldable; The Aluminum –Zn-Mg alloys family like (7075) is higher strength property comparative to Aluminum –Mg family alloys [2].

Anthymidis, et al [3] investigated ceramic phases in an aluminum alloy in form of fibers or particles affects its mechanical properties. These results of Aluminum matrix composites boosted by ceramic particles are improving mechanical properties. Aluminum reinforced with TiB particles and Fe and Cr, although these composites are promising for getting the mechanical properties of this metal matrix improved without changing its corrosion behavior. On TiB, Fe and Cr reinforced aluminum manufactured by the stir-casting method.

Gxowa, et al [4] studied metallurgical process was employed to fabricate Metal Matrix Composites (MMCs). A 2124 aluminum alloy was booted with 5 and 10 vol. % of Al_2O_3 (40-70nm) to form Metal Matrix Nano Composites (MMNCs) as well as 10 and 15 vol.% of SiC (1-10µm) to fabricate low micron MMCs. It was noticed that the nano-sized Al_2O_3 particles were evenly scattered in the aluminum matrix while a lot of loose SiC particles settled on the grain boundaries in the low micron MMCs. The relative density of all the composites get increased owing to sintering, however full densification was not fulfilled. This result was attributed to the embedded motion of dislocations, grains and grain boundaries by bolstering particles. The 2124-Al/10%-SiC composite was cold extruded and the extruded part fractured. A metallographic evaluation was implemented and it was concluded that the mode of failure was intergranular cracking. Hardness tests carried out after sintering showed that hardness gets increased with an increase in volume fraction of reinforcement in the matrix. Annealing of the extruded part resulted in a decrease in hardness. Gao, et al [5] studied the deep cryogenic treatment experiments are applied to 5A06 aluminum alloy welded joint at liquid nitrogen temperature (-155°C) for (4h, 8h, 10h) respectively. 5A06 alloy before and after deep cryogenic treatment are noticed by XRD and SEM. The experimental results have indicated that the deep cryogenic treatment causes (β) phase of alloy to scatter and makes the grain smaller than that before deep cryogenic treatment. The mechanical properties of 5A06 alloy welded joints after deep cryogenic treatment are greatly improved.

Jun Jie Wang, et.al [6] studied the Effect of cryogenic treatments on mechanical properties of (2A11) aluminum alloy. Cryogenic box with program control and furnace were used to have cryogenic treatment processes as well as heat treatment processes. Impact tester, tensile tester, three-coordinates measuring machine, high precision caliper and standard metallography were employed to implement tests. The impacts of different process parameters on mechanical properties of 2A11 aluminum alloy had been compared, and the results indicated that cryogenic treatment could get mechanical properties of this aluminum alloy improved. The dimensional stability increases after cryogenic treatment once, and increases more after cryogenic treatment again.

Jie Li and Xian Quan Jiang [7] investigated the microstructure and mechanical properties of AZ31 alloys. AZ31 alloys were cryogenically addressed at -196°C for 1, 5 and 24 hours, respectively. The results indicated the grains of AZ31 were initially refined and grew up by the increase of cryogenic time, the second phase got decreased gradually, and the rigidity and tensile stress decreased drastically and then increased. Owing to that, AZ31 alloys with 1 hour cryogenic treatment had been able to get the optimal combination properties

S. Rasool, et al [8] investigated deep cryogenic treatment manufactures a significant enhancement in the mechanical properties of metals. The mechanical properties of Aluminum Silicon composite had been ealt with when they were subjected to deep cryogenic treatment. Samples were made from two non-similar compositions of Aluminum silicon composites (Al 2024_5%SiC & 10%SiC). The samples were given controlled cryogenic treatment at -186 ^{0}C. Treated samples were compared with un-treated samples for their compressive and tensile strength, hardness and micro structural metallurgical changes. The treated samples have shown an improved compressive strength. The improvement is supplemented by the hardness survey and micro-structural changes.

Je Sik Shin, et al [9] had been aimed to develop new Al-Zn-Mg base Aluminum alloy having high, strength , electrical conductivity, and formability simultaneously. Owing to that, Al-Zn-Mg base low Aluminum alloy sheet gets hugely strong without essential thermal conductivity loss by multiply alloying precipitation hardening elements and properly controlling production process parameters.

Shan Gao, et al [10] studied 5A06 aluminum alloy welding was got by employing Mg-3 as welding wire with MIG (metal inert gas arc welding). The welded joint with deep cryogenic treatment at liquid nitrogen temperature (-155) for 4h, 8h, 10h were analyzed by metallographic and X Ray Diffraction examination. The outcomes have indicated that a lot of sub grain appears in the microstructure of the welded joint leading to the refined grain after cryogenic treatment. The obvious increasing in content of β-phase (Mg_2Al_3) is distributed and scattered equally, contributed to dispersion strengthening of the welded joint. Meanwhile, orientation phenomena is got for some grain after deep cryogenic treatment. Owing to that, the microstructure of the joint can be amended by the deep cryogenic treatment.

Guirong Li, et al [11]studiedthe Mg-Al alloy β ($Mg_{17}Al_{12}$) phase is the precipitate and reinforced phase. The microstructure and performance of alloy are strongly relied on the morphology and behavior of β phases. a kind of Mg-Al alloy is selected as the research object with 8.92 weight percent Aluminum element. The alloy is subjected to cycling cryogenic treatment. The microstructure evolution and thermodynamic balance are analyzed by scanning electronic microscope. The outcomes indicate that after two cryogenic treatments the quantity of the precipitate hardening β phase increases and the sizes of the precipitates are to be refined from 8-10 µm to 2-4µm. This is owing to the decreased solubility of aluminum in the metal matrix at low temperatures and the significant plastic deformation due to internal differences in thermal contraction between phases and grains. The purpose of this work is to study the influence of adding different wt% of Al_2O_3 to 7075 Al. alloy for fabricating the MMC_S composites , on the mechanical properties of the composites with cryogenic treatments i.e. hardness, ultimate tensile strength , yield strength and ductility . Also compare between the results with and without cryogenic treatments for the same MMCs.

Experimental Method:

The fabricate method used was stir casting to the 7075 Al/Al_2O_3 composites (MMC_S). Before introducing the Alumina (Al_2O_3) nano material with 10 Nanometer dimension, into the melt Aluminum they were preheated to 200°C. Five wt% of Al_2O_3 were used i.e. (0.2, 0.4, 0.6. 0.8 and 1). The stirring speed was 450 rpm and the casting temperature was 850 °C using the metal die casting [12]. The procedure was done by used the nano composites manifesting device shown in fig (1).

Material Used:

The base metal matrix for this work is 7075 Al alloy the chemical composition of this alloy is shown in table (1).

Table 1: Chemical Composition of Al 7075, wt%

Components	**Zinc**	**Magnesium**	**Silicon**	**Copper**	**Iron**	**Aluminum**
Element Wt%	**5.5**	**2.4**	**0.2**	**1.4**	**0.3**	**Balance**
components	**Titanium**	**Manganese**	**Chromium**	**Zirconium**	**Tungsten**	**Others**
Element Wt%	**0.1**	**0.2**	**0.21**	**-**	**-**	**-**

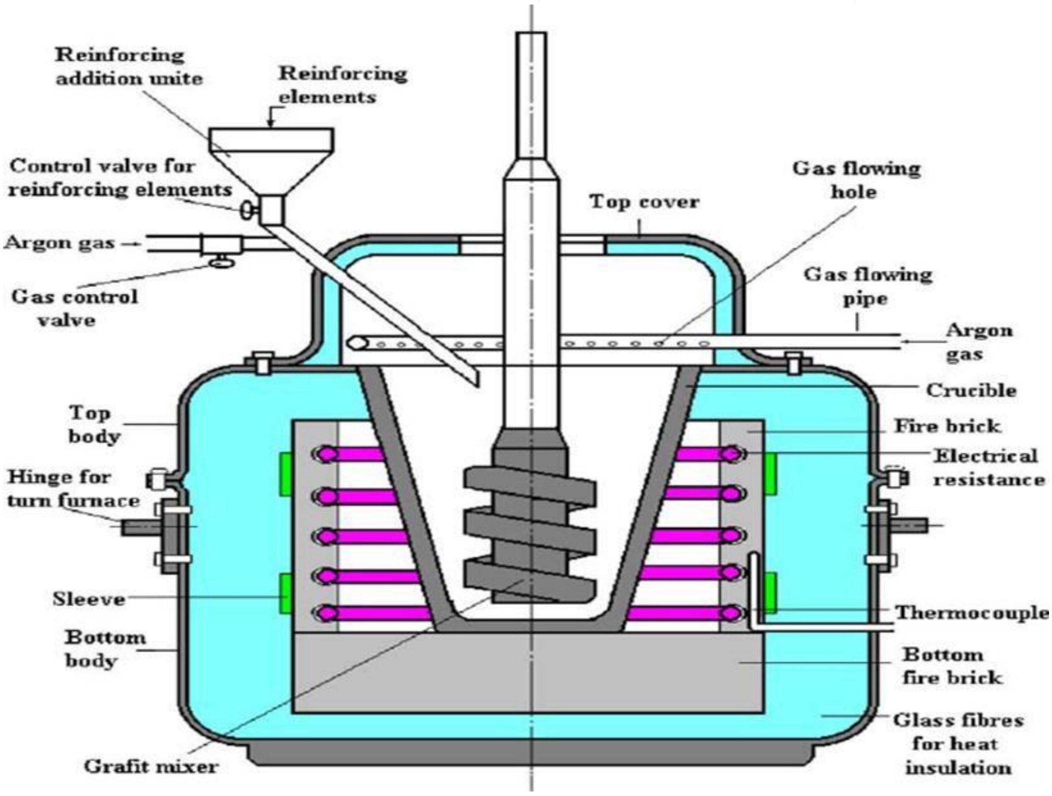


Figure 1: Manifesting Device For Manfuracte The MMC_S Composites

The nanomaterial used in this work is Al_2O_3 which has high hardness, good thermal stability, and wear resistance and this reinforcement was chosen because , up to now, Al_2O_3 particles is the most soluble with Al matrix to generate the metal matrix composition MMC_S .

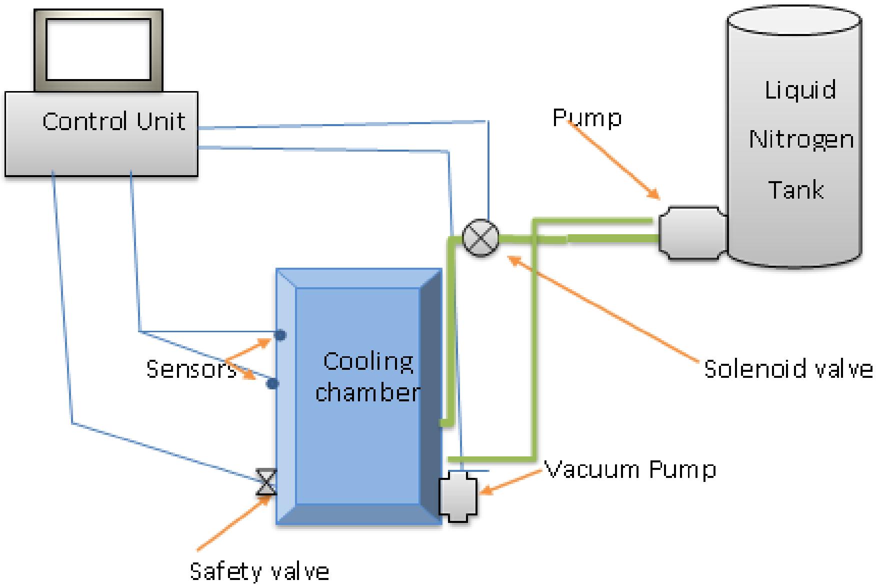
Table 2: Gives the chemical composition of Al_2O_3 in wt%. [14]

Element	CaO	TiO_3	Fe_2O_3	Other	Aluminum α-
Wt%	1.1	1.8	0.8	0.02	93

The specimen surfaces were grinded by different grit paper and then polished by 2 µm diamond paste). To study the mechanical properties characterizations of the composite the tensile tests were performed using three tests were done for each wt% of Al_2O_3. The average reading was adapted.

Cryogenic Treatment:

The deep cryogenic treatment (DCT) processing can be represented on diagram in figure (2), which shows the main parts of its process. Figure (2) Schemes Diagram of DCT Process. It had been used cooling instrument type skl 500 u as shown in figure (3), the specimens were put in vertical position in holder of the cooling chamber.



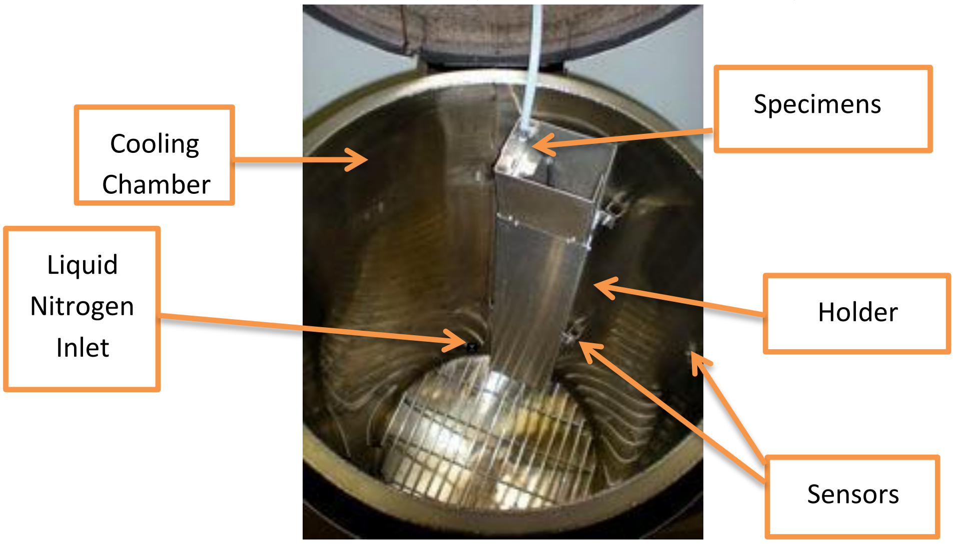


Figure 3: Specimens in Cooling Chamber

The specimens have been Slowly cooled to avoid thermal shock used to cooling chamber ,The feeding speed of liquid Nitrogen was approximately (0.95 Litter /Hour),The room temperature was (24^0 C) ,Room humanity (40%) and the initial temperature of liquid Nitrogen was(-184^0C), the cooling processes till the specimens reach (-184^0C) had been taken (4 hours) , Hold the specimens at approximately (-184 ^{0}C) for(24hours), the specimens have been reheated slowly without thermal shock to ambient temperature, The sequence of this treatment was done in vacuumed environment. The test is done according to ISO 21011-2013 specifies requirements for the testing, design and manufacture of the materials for a rated temperature of below -40^0C (the actual testing temperature used was -184^0C).

Experimental Results and Discussion:

Hardness Test Results:

Brinell hardness (BHN) test was used; figure (4) shows the experimental results of BHN against the weight percentage of Al_2O_3 particles. It is clear that a significant increase in hardness of the metal matrix when adding the Al_2O_3 nanoparticles.

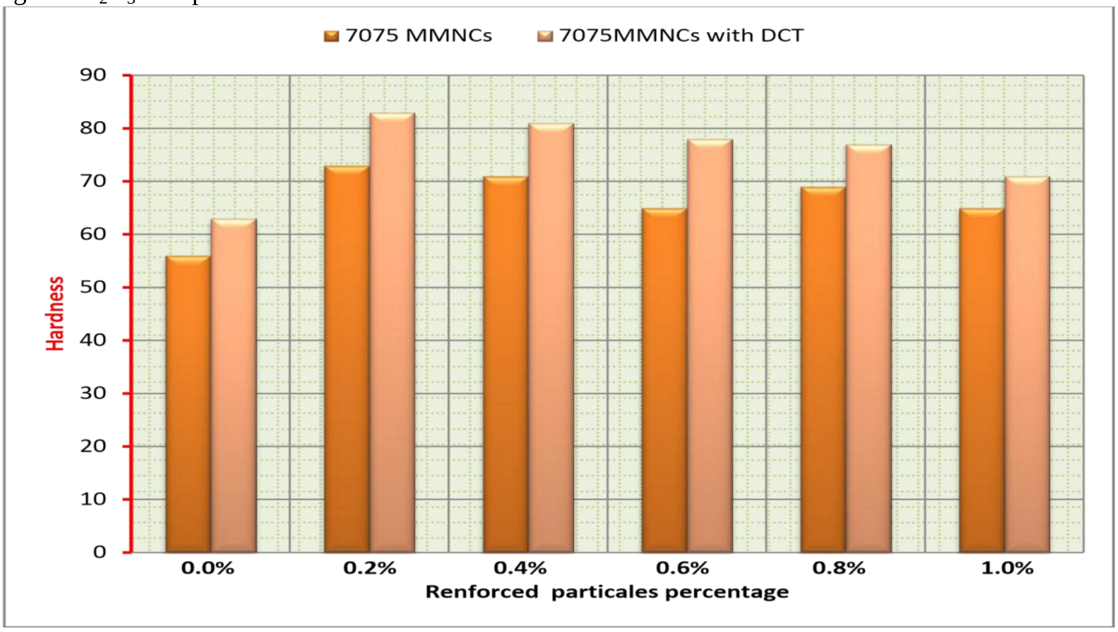


Figure 4: The experimental results of BHN against the weight percentage of Al_2O_3

Figure (4) shows that (BHN_s) of the MMCs specimens were increased with cryogenic treatment for all the weight percentage of the Al_2O_3 reinforcement Nano-particales significant, except the value of 0.0 wt. % which shows small increased in HB compared to MMCs and the reason may be the MMCs had uniform distribution of the Al_2O_3 particles had leaded to increased Van Der wales bond strengthen the composite or changes in phase of the nanocomposite of Al/ Al_2O_3. It is known that the hardness of (*Al-Zn-MgCu)* alloys highly depend on the fine precipitates located in the inner parts of grains and grain boundaries. The materials become harder if the density of the precipitates is higher while the precipitates are finer (10nm in this work

).The sequence of precipitation of this aluminum alloys coarsening of the two precipitates occurred based upon the size and amount of reinforced particles, Akhbarizadeh [15] studied the wear behavior of D6 he observed that, the cryogenic treatment increases hardness. The samples which were cryogenic treated for a longer time or deeper temperatures cryogenic treated showed increase in hardness. Mohan [16] studied the effect of cryogenic treatment on T1 high material and found that soaking at(203 ^{0}) K can attain the hardness of 67 HR .However Lulay et al., do not show any changes on their study (only - 0.5 %) in the hardness. Comparison has been made for state of hardness with and without DCT for base metal and reinforced used Al_2O_3nanomaterial as given in table (3). It is clear that the DCT improved the mechanical properties. The improvement may due to unformed grains.

Table 3: Hardness Test Results

Workers	**Matrix**	**Zero % wt**	**0.2% wt**	**0.4% wt**	**0.6% wt**	**0.8% wt**	**1.0% wt**	**Reinforcement**
MMNCs with DCT (Recent)	7075Al alloy	63 BHN	83 BHN	81 BHN	78 BHN	77 BHN	75 BHN	Al_2O_3
MMNCs (Rref.17)	7075Al alloy	56 BHN	73 BHN	71 BHN	65 BHN	69 BHN	65 BHN	Al_2O_3

Tensile Strength:

Table (4) gives the tensile strength results with different weight percentage of the nano reinforcement material. it is clear that the tensile strength values of metal matrix composite for all the amount of weight percentage Al_2O_3 with cryogenic treatment is larger than the metal matrix compared and the as cast 7075 Al without cryogenic treatment and that may be due to secondary phase transformation .

Table 4: Ultimate Strength Results with DCT in Comparison with Ultimate Strength Results

Metal Matrix Composite 7075			
Without DCT		**with(DCT)**	
Wt% of AI_2O_3	**σu (MPa)**	**Wt% of AI_2O_3**	**σu (MPa)**
0.0	228	**0.0**	240
0.2	245	**0.2**	285
0.4	236	**0.4**	266
0.6	228	**0.6**	256
0.8	238	**0.8**	259
1.0	216	**1.0**	251

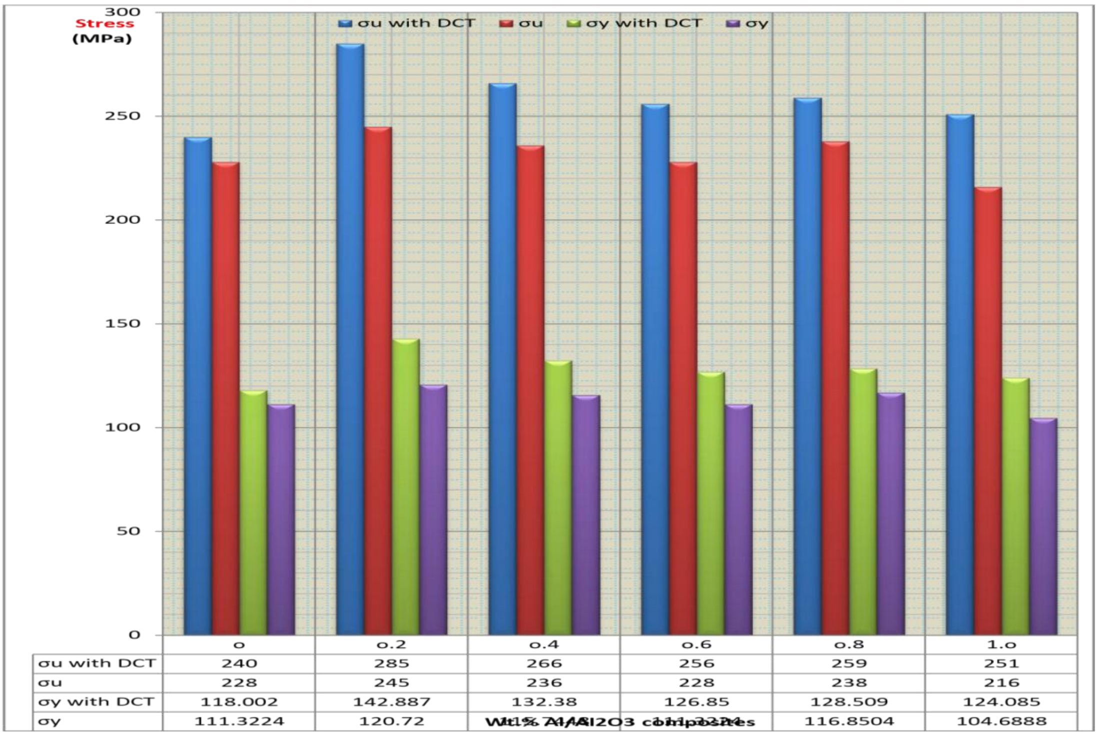


Figure 5: Ultimate Tensile and Yield Stress Vs with the Weight Percentage of the Al_2O_3 Reinforcement Nano-Particales

The tensile strength results obtained from the experimental work observed that the tensile strength .of the MMCs increase with DCT of all the amount of Al_2O_3.Xiong et al. [18] reported that the ultimate tensile strength, and yield strength of three cryogenic treated magnesium alloy added with zirconium with different ratio have improved to 38%, 57% and 280% respectively, as compared to the same alloy without DCT. Baldissera [19] have shown that tensile strength improves by 11% due to deep cryogenic treatment over conventional heat treatment for $18NiCrMo_5$.

Ductility:

The ductility was calculated from the failed specimens after fracture and table (5) illustrates the comparison between the ductility of MMCs results with MMCs cryogenic treated.

Table 5: A Comparison between The MMCs Ductility Results With MMCs Cryogenic Treated Results.

	7075 Al matrix		
Wt % of Al_2O_3	**Ductility %**	**Ductility % with DCT**	**Method**
0.0	18	16	Stir Casting
0.2	12	9	
0.4	14	11.5	
0.6	15	12.5	
0.8	13.5	11.5	
1.0	14	12	

Table (5) shows the ductility is reduced by cryogenic treatment for all metal matrix nanocomposite with different ratio of wt.%Al_2O_3 that may be due to immigration of dislocations through the crystal lattes , the lowest value of decreasing accord at 0.2wt.% of Al_2O_3 by 25% . The results of both cases with and without cryoginc treatment of MMCs are piloted on figure (6).

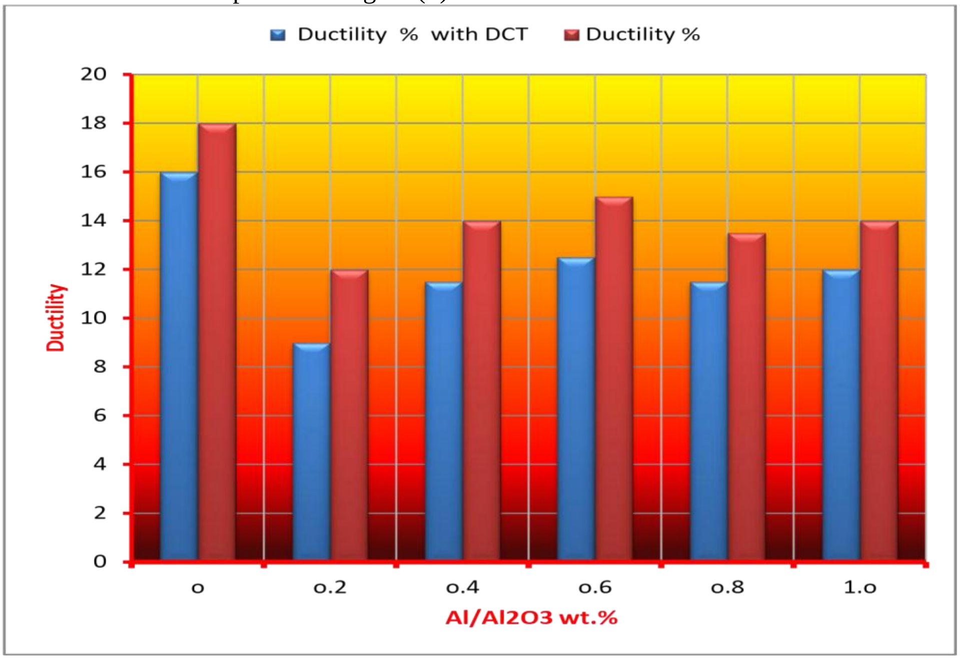


Figure 6: Ductility Compared between MMCs and MMCs with DCT

Conclusion:

- ✓ Tensile strength of 7075Al nanoparticles composite with DCT was higher than to 7075Al nanoparticles composite, the highest value of Tensile strength was observed at 0.2 wt.% of Al_2O_3.
- ✓ It was obtained that the HB hardness of specimens with DCT was higher compared to the 7075Al with and without nanoparticles. The best BHN was revealed at 0.2 wt.% of Al_2O_3.
- ✓ Yield strength of 0.2 wt% Al_2O_3 with DCT showed great value of yield strength compared to 0ther alloys.
- ✓ Ductility was observed to be enhanced with DCT .the lowest ductility was obtained at 0.2 wt% of nanoparticles

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