# Design Analysis of Tensile Strngth And Mechanical Properties of $AlSi_3N_4$

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***Abstract-*** *The present work has been carried out to analyse the effect of adding silicon nitride with Al-6061 by analysing these materials using ansys software. The volume fractions of both the reinforcing constituents will be varied. Structural analysis is done to validate the strength. Modeling is done in solid works and analysis is done in Ansys. Solidworks is the standard in the 3D product design, featuring industry-leading productivity tools that promote best practices in design. After analysing, the results are showing the improvement in mechanical properties of the composite by adding silicon nitride.*

***Keywords***- Aluminium 6061, Silicon Nitride, Ansys, Solidworks.

## I. INTRODUCTION

Composite materials (or composites) are materials made from two or more constituent materials having significantly different physical or chemical properties, which when combined together, produces a material having different characteristics from the individual components. The individual components will remain separate and distinct within the finished structure. Typical examples of engineered composite materials include:

- Composite building materials like cements, concrete
- Reinforced plastics like fiber-reinforced polymer
- Metal Composites

Composite materials are generally used in boat hulls, race car bodies, shower stalls, bathtubs, and storage tanks, imitation granite and cultured marble sinks and countertops. The most advanced examples perform routinely on spacecraft in demanding environments. Composite materials achieve the majority of their beneficial properties from a strong bond between the strong, stiff reinforcement—usually metal (filaments) or reinforcements with other geometrical shapes, for example, particles, platelets—and the weaker, less stiff matrix. Clearly, the first type of damage that can occur is manufacturing defects of the type. However, provided there is good wetting between the matrix and the metals, and no porosity is present, it is rare for a good bond not to be formed between the metals and the matrix; consequently, aside from cracks caused by resin shrinkage or thermal stresses generated during cooling (or a combination of both), thermomechanical loading is normally the reason for metals–matrix debonding. Accordingly, these microscopic elements are the determining factors in predicting the composite material properties and are used to explain the properties of the composite materials at the macroscopic level. However, there are many cases in which the experimental results are unable to explain certain phenomena observed at the macroscopic scale. In fact, the properties of the composite are closely linked to its internal structures, which induce a high heterogeneity of the microstructure, so it is necessary to look more deeply into scaling-up approaches that establish the transition between the local heterogeneity state and the global homogeneity state. In general, the heterogeneity problem of composite materials at the microscopic level makes it difficult to move toward a homogeneous global level where the behavior of the material can be measured. The passage through the micro- to the macroscale can only take place through rough models and satisfactory calculation tools. The best knowledge of component (matrix and fillers) performance can, through homogenization methods, predict the new material's properties with acceptable precision.

## II. RELATED WORK

**Sachin Malhotra et al. [4](2014)** observed that influence of varying weight percentage of zirconia (5% and 10 %) and fixed percentage fly ash (10%) reinforced Al6061 metal matrix composite by stir casting method. It was identified that hardness and ultimate tensile strength increase with increase weight fraction of reinforcement material. A better hardness 94HV and tensile strength 278 MPa for 10% zirconia and 10% fly ash reinforced composite material. Aluminium alloy 6061 had the determinate elongation of 21.66%, which was significantly reduced to a range of 85% to 90% due to the addition of reinforcement material.

**Sandeep Kumar Ravesh et al.[3] (2014)** studied the effect of the different weight fraction of SiC(2.5%, 5%, 7.5%, and 10%) and 5% fly ash reinforced 6061 aluminium matrix composite by stirring casting technique. Tensile strength, hardness and impact strength increased with growth in weight fraction of SiC particles. A better tensile strength 115 N/mm2, hardness 93 RHN and toughness value 7.8 for a 10% SiC and 5% Fly ash reinforced composite material wasobtained.

**JohnyJames.Setal [13] (2014)** investigated about hybrid aluminium composite is reinforced with SiC and TiB2 with AA6061.The fabrication method is stir casting process with different compositions, the sample to be tested with the mechanical properties such as tensile, hardness(Vickers Hardness) and morphology(Optical microscopy).He stated that addition of reinforcements like TiB2 and SiC has effect on increase of strength and hardness..

**Muhammad Rashad et al [18] (2015)** investigated about magnesium based composites with titanium-aluminium hybrids using base metal as Mg reinforced with Ti and Al particles. It can be fabricated by semi-powder metallurgy route followed by hot extrusion. It is found that synthesized composites exhibited improved hardness, elastic modulus ,0.2% yield strength, ultimate tensile strength and failure strain compared to monolithic Mg.

**Dora Siva Prasad et al(2016)** studied aluminium hybrid composites using base metal as aluminium alloy using reinforcements as RHA and SiC. It can be fabricated by stir casting process.It is found that yield strength and ultimate tensile strength increase with the increase in RHA and SiC content, density of hybrid composites decreases whereas the porosity and hardness increase with increase in percentage of reinforcement.

**Kenneth Kanayo Alaneme et al [20] (2013)** investigated aluminium alloy matrix composites using base metal as Al-Mg-Si alloy with reinforcement such as alumina(Al2O3) and rice husk ash(RHA).It is fabricated by stir casting method. It is found that hardness of hybrid composites slightly decreases with increase in RHA content. Tensile strength and specific strength were respectively observed for 3 and 4% of RHA containing hybrid composites.

**Fogagnolo et al. [50](2014)** studied the effect of Al- 6061 reinforced with zirconium diboride (ZrB2) particles processed by conventional powder metallurgy and mechanical alloying. It was confirmed that mechanical alloying produces a composite material with better distribution of the reinforcement particles, but only a small decrease in the size of reinforcement particles is observed.

**Devaraju Aruvi et al [29] (2013)** investigated aluminium alloy surface hybrid composites using base metal as 6061-T6 aluminium alloy using reinforcements as SiC,Gr, Al2O3. It can be fabricated by friction stir processing method. micro hardness increases due to presence and pining effect of hard SiC and Al2O3 particles. Tensile properties are decreased as compared to base material due to presence of reinforcement particles which is to make the matrix brittle.

**Eszter Bodis et al. [30] (2017)** investigated that incorporation of ZrO2 fibres into the Si3N4 matrix can be an effective way to increase fracture resistance and avoid the catastrophic fracture of particular composites, since ZrO2 fibres are able to improve mechanical properties in a complex way, by phase transformation and fibre toughning.

**S. Saravanan et al [41] (2019)** observed that the experimental study on explosive cladding of dissimilar aluminium sheets with varied percentage of SiC particle concentration leads to the following salient conclusions Explosive cladding is a viable technique to produce dissimilar aluminium clads dispersed with SiC particles. Micro- hardness and tensile strength tends to increase with the concentration of SiC particles at the interface. Thickness of SiC streak at the interface increases with the quantity of SiC particles dispersed. For 10% SiC concentration, a continuous streak of SiC particles, devoid of reaction compounds emerges, whereas for a higher SiC concentration, reaction compounds are formed at the interface. A mechanical bonding between aluminium and SiC particles was witnessed with the absence of transfer of elements across the interface.

**Shashi Prakash Dwivedi[42] (2019)** analysed that following conclusions may be drawn from the exhaust analysis. AA2014 aluminium alloy can be successfully developed by using boron carbide as reinforcement material through mechanical stir casting technique. Microstructure results showed the proper distribution of B4C in the AA2014 matrix material. Results showed that by adding the B4C in weight percent up to 10%, tensile strength and hardness were improved significantly. Minimum porosity was found for AA6061/7.5% B4C composite. Density and ductility of composite continuously decrease by increasing the percentage ofB4C.

**Wei Chen et al[31] (2018)** studied that in seawater and salt water, tribochemical reactions occurred on the wear surfaces of the sliding pairs. With the assistance of ions in seawater, the chemical reaction products apt to aggregation into a surface film composed of oxides and hydroxides (e.g. SiO2, B2O3, TiO2 and CaCO3). The film protected and smoothed the wear surfaces,and the tribochemical polishing phenomenon occurred at the hBN content of 30%. In this case, the friction coefficients of Si3N4–30%hBN ceramic composites/titanium alloy (Ti6Al4V) sliding pair under artificial seawater lubrication could be lowered to 0.01, and the wear rate was at the magnitude of $10^{-6}$mm3/Nm.

**Sneha H. Dhoria et al [39] (2019)** investigated that Aluminium matrix composites have been successfully fabricated by squeeze casting technique with fairly uniform distribution of SiC& Gr particles. It is observed from the results that the density of Al6351 alloy decreases by adding 10% graphite when compared to pure alloy, but the density increases by decreasing the graphite percentage and adding SiC particles gradually.

**Isaac Dinaharan et al [32] (2018)**observed that MMCs based on aluminum alloy AA6061, magnesium alloy AZ31 and copper reinforced with FA particles were effectively produced by FSP. The microstructure and micro hardness were assessed. The micrographs revealed a homogenous distribution of FA particles irrespective of the type of metallic matrix. The homogenous distribution was a result of adequate distribution and plasticization under the experimental conditions employed. FA particles encountered fragmentation during processing. The broken up debris were found to be distributed homogenously in the composites without forming any agglomerations. The grains of the composites were extensively refined due to dynamic recrystallization and pinning effect of FA particles. The incorporation of FA particles increased the micro hardness of all the composites. The possible strengthening mechanisms were identified. FSP is a suitable process to produce FA reinforced MMCs regardless of the type of matrix material used.

**Rahul Gupta et al [33] (2018)** analysed that Different amounts of K2TiF6 powder was reacted with 6061 aluminium alloy at 750 °C for 5 min to form in-situ Al3Ti particles under ultrasonication to achieve better dispersion of intermetallics. Blocky morphologyofin - situformed Al3Ti particles was observed with the average size of 3.4 μm. All Al3Ti particles were observed within the grains instead of segregation at grain boundaries. The grain size of the composites decreased due to the presence of Al3Ti particles which actedas a nucleating agent and promoted heterogeneous nucleation during solidification, leading to improved yield strength, hardness and UTS. The best combination of mechanical properties with good ductility, yield strength and ultimate tensile strength are obtained in C2U composite with 5.4 wt % Al3Ti. The interface between Al3Ti particles and Al matrix was clear and well bonded which also played an important role in the improvement of mechanical properties. From the analysis, it is concluded that the thermal mismatch strengthening was the dominant strengthening mechanism followed by Hall-Petch strengthening. The contribution of Orowan strengthening mechanism is ruled out due to the coarseness of the Al3Tiparticles.

**Sudarshan Kumar et al [44] (2019)** observed that The optical microstructure of the Al 7075 in the as-received condition (T651) revealed the secondary phase particles in Al grains. Grains were in the range of 2 to 5μm size in the nugget zone. Hardly few TiC particles were seen inside the grains as well as along the grain boundaries. On increasing volume fraction of TiC from 2% to 6% the hardness of composite increased irrespective of the zone. Nugget zone was found to be harder than heat affected zone and thermo-mechanical affected zone..The corrosion rate of all the samples got increased with increasing the concentration of the NaCl irrespective of the amount of the TiC added. Pits and grain boundary attack were observed on the corroded surface.

**A.B. Li et al [45] (2019)** investigated that Mechanical alloying process of 10 vol% SiC-Al nanocomposite powders reached a steady state after 15 h. Nanocomposite powders with nanocrystalline Al grains and high content SiC nanoparticles homogeneously embedded in the Al powders were obtained at a milling time of 15 h. Thecompositebilletpreparedbysinteringat580°Cunderapressure of20MPa exhibited obvious PPB, a few nanoparticle clusters and pores. Hot extrusion at 450 °C with an extrusion ratio 25:1 not only eliminated PPB retained in the as-sintered nanocomposites, but also produced submicron Al matrix grains.

**Wei Liu et al [31] (2017)** analysed that In this study, a PVD-based multi-arc ion plating technique was employed to prepare TiAlN coatings on the surface of commercially available silicon nitride ceramic cutting tools. The effects of bias voltage on the microstructure, mechanical properties, cutting performance, and wear mechanisms of the resultant TiAlN-coated silicon nitride cutting tools were investigated. The optimal bias voltage for preparing such cutting tools with optimal cutting performance was ultimately discovered by this investigation.

**Shuang Li et al (2019)** investigated that When silicon nitride ceramics were heated at 1780 °C for 60 min, the α-Si3N4 phase transformed to β-Si3N4 completely. The TEM graphs showed that the growth of β-Si3N4 grains was accelerated in the OPS specimen, which was ascribed to the increased diffusion rate of Si and N in the liquid phase. Unlike the smooth and flat grain surface in HP specimen, obvious fringes were observed in β-Si3N4 grains in OPS specimen. Moreover, the oscillatory pressure induced a large number of Moire' patterns at the grain boundaries of the OPS specimen. Owing to the microstructure evolution, the fracture load and fracture work of OPS specimen increased up to 705 N and 1240 J/m2, respectively. Moreover, typical grain bridging and grain deflection mechanisms occurred during the propagation of cracks.

**O.A Lukianova et al (2017)** analysed that the main crystal phase of both produced ceramics was α-Si3N4. The microstructure of the produced ceramics with a predominance of the equiaxial α-silicon nitride grains observed. The features of the investigated microstructure in the first approximation can be interpreted within the framework of the Kingery model. The micro hardness of produced silicon nitride was high and more than 1900 HV and could be expressed by a Hall-Petch relationship in the context of comparison with the pressure less sintered at 1800 °C ceramics with a lower micro hardness equal to 1511 HV. It was shown that the self-made magnesium oxide and high content of aluminum oxidedoes not significantly affect the phase transformation of silicon nitride with an increase in the temperature of spark plasma sintering from 1550 °C to 1650 °C.

**Shahid Manzoor et al[40] (2019)** studied that The addition of TiC to Si3N4 resulted in increasing the hardness of the ceramic composites. The hardness tends to increase proportionally with the added weight percentage of TiC. The greatest value of hardness was attained for the composite of Si3N4and 2 wt% TiC. The friction coefficient shows a decreasing trend with increasing load for pure Si3N4 as well as Si3N4-TiC ceramic composites. The lowest value for each ceramic was attained at a normal load of 60 N. The addition of TiC to Si3N4 resulted in reduced value of the friction coefficient. This reduction varies proportionally with the increasing weight percentage of TiC. The lowest value of friction coefficient at each load condition was attained for the composite of Si3N4 and 2 wt%TiC.

**R.K. Mishra [43] (2019)** investigated that The pre corrosion of aluminum alloy 8011 in the aqueous solution of NaCl had significantly reduced its mechanical properties and fatigue life. The exposure of the alloy to corrosive environment created corrosion pits on the surface of the alloy which initiated crack propagation. These cracks were results failure of the alloy. Ultimate tensile strength and other mechanical properties decreased very slowly but fatigue strength decreased fast. When bending stress is 120 MPa, life of the un-corroded specimen was just double of the corroded specimen.

**V. Mohanavel et al (2019)** studied that the various types of aluminium alloy based ZrB2 particles reinforced metal matrix composites. The above literature works are exhibits the mechanical and tribological properties of the composites are enhanced after the dispersion of ZrB2 particles. Massive number of research works are exhibit the ZrB2 particles based composites are manufactured through in situ casting method. But very limited research works are done in the powder metallurgy, stir casting, compo casting, centrifugal casting and squeeze casting method.

**Amir Pakdel et al (2018)** analysed that a comprehensive analysis of extrudability, microstructural evolution, and mechanical properties of 6063 Al reinforced with 10wt% B4C particles was performed for the first time. The composite samples were prepared in two stages: initially Al and B4C powders were formed into discs by spark plasma sintering, then the discs were added to Al alloy melt and were stir cast followed by hot extrusion under different conditions. The extruded composites displayed a wide range of strength and elongation to failure depending on their microstructural modification governed by extrusion parameters. Higher extrusion temperatures resulted in lower porosity, more texturing along the extrusion direction, and larger sizeparticles.

**Risheng Pei et al (2018)** the thermo-mechanical properties of P100/1199, P100/6063, P120/1199, and P120/6063 composites fabricated by squeeze casting have been investigated. Composites with higher thermal conductivity, low thermal expansion, and higher mechanical properties have been achieved.

**R. Seetharaman et al [47] (2019)** observed that the corrosion rate increase as the chloride ion concentration increases. For every pH values and immersion time, the weld metal usually exhibited an increase in the corrosion rate with an increase in the chloride ion concentration. The corrosion rate decreases with the increase of pH value from acidic to neutral. Further increase of corrosion rate was seen from neutral to alkaline. This is due to instability of aluminium oxide layer in acidic and alkaline solutions. The high corrosion rate was obtained in alkaline solutions comparing acidic and neutral solutions.

**S. Sivananthan et al[48] (2019)**investigated that Aluminium oxide particle (0–4 wt%) reinforced Al6061 alloy metal matrix composites have been prepared using stir casting process. Mechanical properties such as hardness, tensile strength and compression of composites have been tested and the values are compared with Al6061 alloy.

## III. METHODOLOGY OFDESIGN ANALYSIS OF TENSILE STRNGTH AND MECHANICAL PROPERTIES OF $AlSi_3N_4$

Methodology is the systematic, theoretical analysis of the methods applied to a field of study. It comprises the theoretical analysis of the body of methods and principles associated with a branch of knowledge.The fig 2.Describes a lock diagram of monitoring and controlling process The machine performance analysis is done here. Creation of data base for the monitoring values will help the user can find particular date of data values.

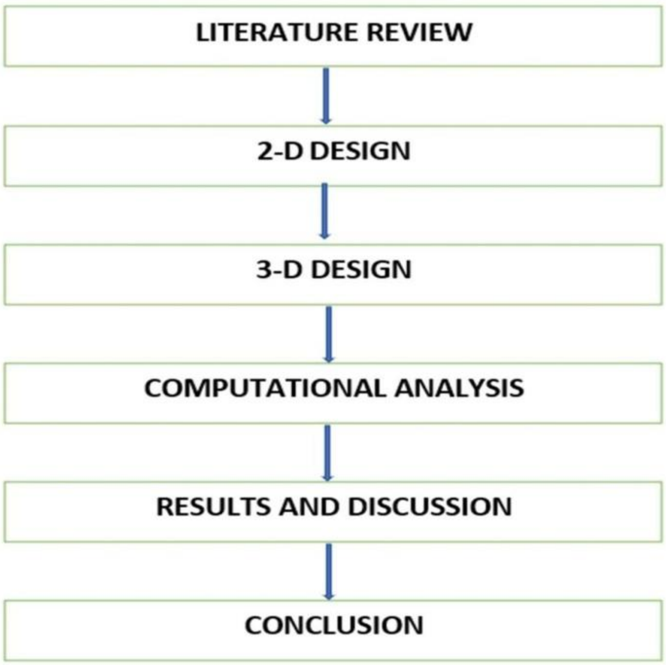


**Fig.1:Methodology diagram**

## IV. RESULTS

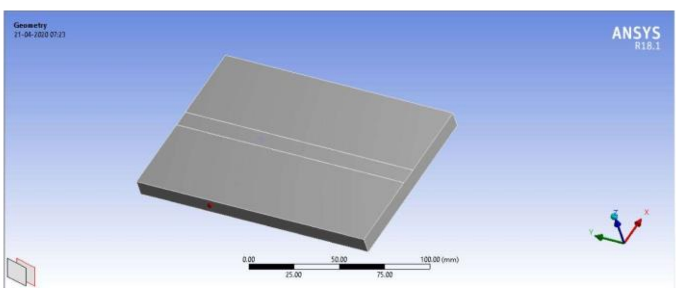


***Fig.2:***Geometrical view of the component

**Result of sample 1:**

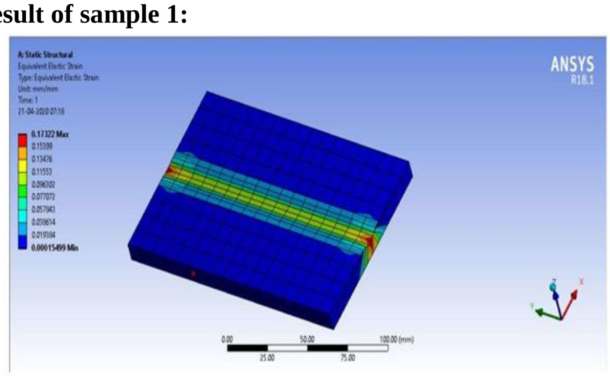


Fig.3: Static structural of the Component 1

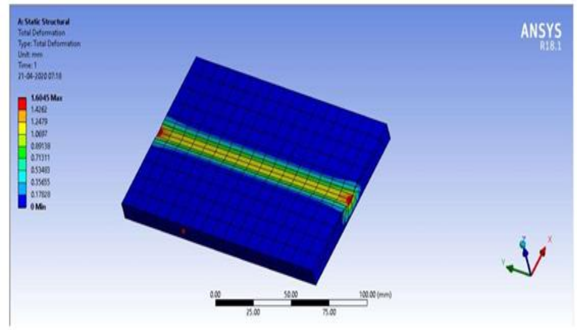


Fig. 4: Total deformation of the component 1

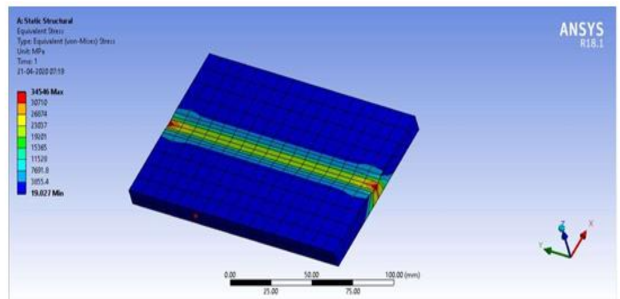


Fig.5: von-misses stress of the component 1

**Result of sample 2:**

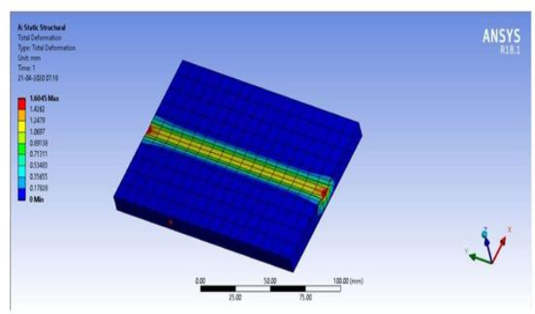


Fig.6: Total deformation of the component 2

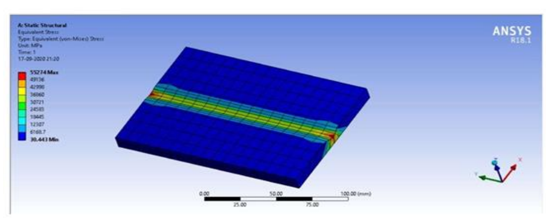


Fig.7: Equivalent stress of the component 2

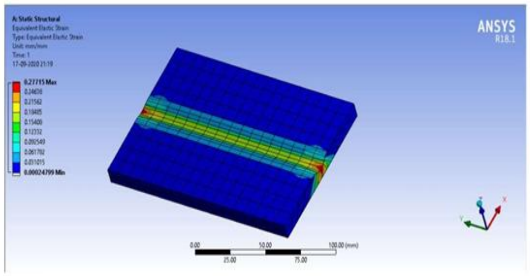


Fig.8: Equivalent elastic strain of the component 2

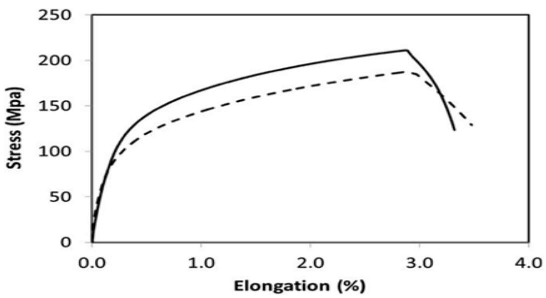


**Fig.9: Relationship between stress and elongation**

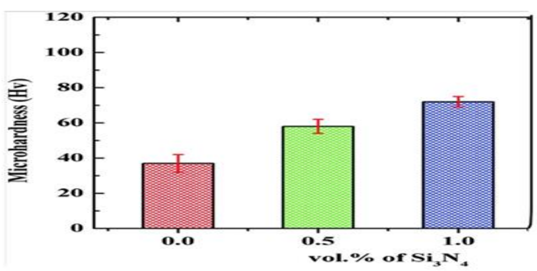


**Fig.10: relationship between hardness and volume**

## V.CONCLUSION

In this Project, after analyzing Aluminium 6061 and Silicon Nitride results shows that it can possess excellent wear resistance and hardness intrinsically, and cheaper. So, this can be used as composite materials for various applications for the improvement of surface properties. The composite uniformity can be increased by implementing experimental method stir casting process.

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