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MODELLING AND ANALYSIS OF ALLOY MATRIX MATERIAL AS CONSIDERED FOR ROCKET BODY

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ABSTRACT

Aerodynamic drag and heating are the crucial in the thermal stability of hypersonic vehicles at various speeds. The latest developments in the design of nose cone structure demands an effective Thermal Protection System (TPS) meets the need of the space research technology. High temperature withstand materials have to produce for space applications to resist different atmospheric conditions to overcome. At different stages of orthogonal momentum there is a possibility of temperature variation and external stresses on front part of rocket. Even though many applications developed for durability of rockets still there is a need of analyzing the application with different matrix alloys. In the present paper we are modelling and analyzing the rocket structure by giving alloy matrix material mix with Ni, and TiB_2 whose liquefaction temperature is high. The project modelled in CREO 3.0 and the thermal analysis carried out in ANSYS work bench 15.0. The results obtained compared with the before researches to get optimal results for further combinations.

Key words: Modelling, CERO 3.0, ANYSYS, MMCs for aerospace, Comparison with other alloys.

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1. INTRODUCTION

A composite is an engineered material made from two or more ingredients with significantly differing properties, either physical or chemical. Composites have two significant advantages over some of the more traditional materials such as greater strength and lighter weight. The temperature distribution over the hypersonic vehicles indicators very high temperatures at the front parts 1200^0C-1400^0C like nose cone (called stagnation regions). The temperature gets reduced slightly as we go towards the rear portions (1000 to 600^0C).

Ultra High Temperature Ceramics (UHTCs) are good choices for several extreme applications such as thermal protection materials on hypersonic aerospace vehicles or re-usable atmospheric re-entry vehicles, specific components for propulsion, furnace elements, refractory crucibles, etc. The family of ceramic compounds is made of borides, carbides and nitrides such as which are characterized by high melting points, high hardness, chemical inertness and relatively good resistance to oxidation in severe environments. The applications of ceramic compounds is made of borides, carbides and nitrides are proved more effective in high temperature environment but expensive. This led the new scope of research in the area of reinforcement combinations as well as matrix.

2. OBJECTIVES OF PAPER

- Study the matrix preparation methodology application for aerospace applications.
- Study the thermal simulation properties by using ANSYS 15.0.
- Matrix alloys and its properties validation observed in present work.
- Present matrix alloys compare with the coated application for better optimisation.
- Transient analysis at different time contours observed for optimum results.

3. PROBLEM STATEMENT

The various literature studies reveal that transient flow of heat is one of the important parameter to access the stability of the material under the high temperature environment.

4. MATERIALS AND METHODOLOGY

4.1. Geometrical Configuration of Rocket Model

The matrix material used in this study is Al6061 with reinforcement material as TiB_2, Ni, and fly ash. The % volume fraction of constituents is 77%, 8%, 2%, and 4% respectively. This Al based Metal matrix Composite is fabricated by Stir-casting Process. The Physical, mechanical and thermal properties were given in the table 2 and were determined by carrying out various mechanical tests on material and those values are adapted to carry out FEM analysis by using ANSYS software 15.0.

Table 1 Physical Parameters of Rocket Body

S. No	Parameters	Value
1	Overall Length (Meters)	105.1
2	Gross take off (including Weight of fuel : 110T) (Tons)	278
3	Range (Kilometers)	9300
4	Radius of captured tip (mm)	1.0
5	Temperature withstand ability (^{0}C)	1150
6	Angle of attack (degrees)	4
7	Angle of back sweep (degrees)	65

Table 2 The different Al6061 alloy based MMCs properties defined to carry out thermal analysis.

S. No	Al Alloy MMCs Properties	Values
1	Density	2920 kg/ m^3
2	Coefficient of Thermal Expansion	2.3 x 10^{-5} / ^{0}C
3	Specific Heat	875 J/ kg / ^{0}C
4	Thermal Conductivity	90 W/ m / ^{0}C
5	Thermal Conductivity at -100^{0}C	114 W/ m / ^{0}C
6	Thermal Conductivity at 0 ^{0}C	144 W/ m / ^{0}C
7	Thermal Conductivity at 100^{0}C	165 W/ m / ^{0}C
8	Thermal Conductivity at 200^{0}C	175 W/ m / ^{0}C
9	Isotopic Resistivity at 0 ^{0}C	2.43 x 10^{-8} ohm m
10	Isotopic Resistivity at 20 ^{0}C	2.67 x 10^{-8} ohm m
11	Isotopic Resistivity at 100 ^{0}C	3.63 x 10^{-8} ohm m
12	Young's Modulus at 1100^{0}C	7.1 x10^{-10} Pa
13	Poisson's ratio at 1100^{0}C	0.33
14	Bulk Modulus at 1100^{0}C	6.9608 x 10^{10} Pa
15	Shear Modulus at 1100^{0}C	2.6692 x 10^{10} Pa

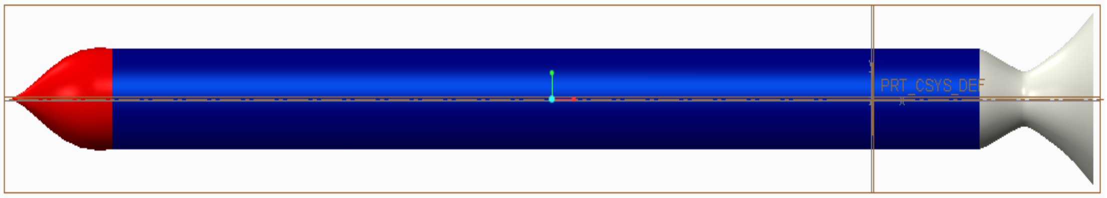


Figure 1 shows the orthogonal development of missile axis

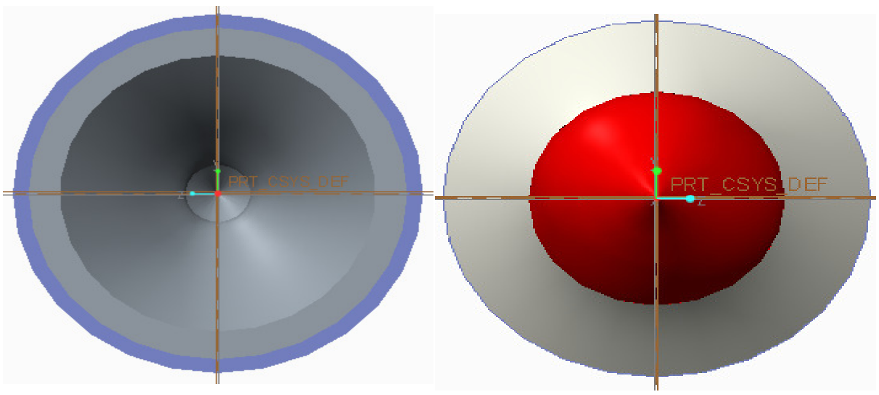
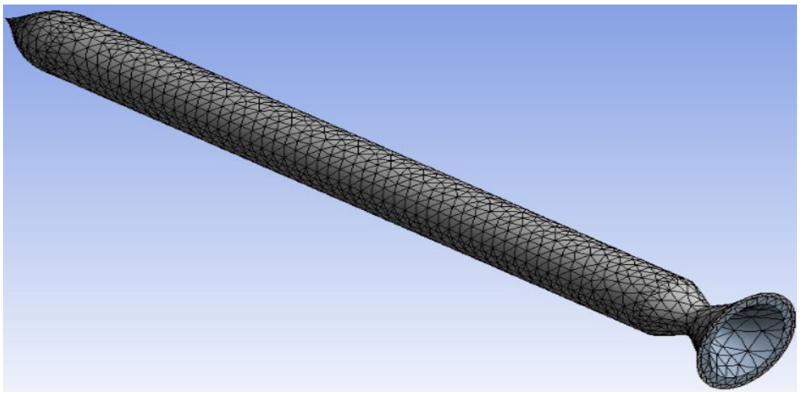


Figure 2 Shows rear and nose areas of the designed part

4.2. Thermal Analysis by Using Ansys 15.O

Adapting and applying new materials to missile structures and in building and integrating spacecraft, where our “footprint” still remains large enough. Heat Transfer Analysis Heat transfer is a science that studies the energy transfer between two bodies due to temperature difference. Conductive heat transfer analysis on honey comb sandwich panels and the tiny volume inside each honeycomb cell, convection heat transfer of the interior air mass were neglected. Before doing analysis to mesh the model so that the effectively find the change in temperature at each and every point. Perform heat transfer analysis under transient state condition. Transient Thermal Analysis Transient Thermal Analysis determines temperatures and other thermal quantities that vary over time. Engineers commonly use temperatures that a transient thermal analysis calculates as input to structural analysis evaluations. A transient thermal analysis follows basically the same procedures as a steady –state thermal analysis. The main difference is that most applied loads in a transient thermal analysis are functions of time. To specify time-dependent loads, use both the function tool to define an equation or function describing the curve and then apply the function as a boundary conditions or divide the load versus time load into load steps.



Statistics	
Nodes	23735
Elements	11802

Figure 3 shows the meshed Rocket Body Model with triangular mesh

4.3. Transient Thermal Analysis

In conduction, the heat flow is within and through the body itself. In contrast, in heat transfer by thermal radiation, the transfer is often between bodies, which may be separated spatially. Also possible is transfer of heat by a combination of conduction and thermal radiation. In convection, internal energy is carried between bodies by a moving material carrier. In solids, conduction is mediated by the combination of vibrations and collisions of molecules, of propagation and collisions of photons, and of diffusion and collisions of free electrons. In gases and liquids, conduction is due to the collisions and diffusion state of molecules during their random motion. But the distinction is often not easily observed, unless the material is semi-transparent. By checking and satisfying hat transfer conduction the body with outer shell have to be analyzed by using a software ANSYS 15.0 to get optimum withstand ability of newly prepared matrix composite.

Table 3 shows the thermal conductivity boundary conditions

Table of Properties Row 3: Isotropic Thermal Conductivity

	A	B
1	Temperature (C)	Thermal Conductivity (W m^-1 C^-1)
2	-100	114
3	0	144
4	100	165
5	200	175
*		

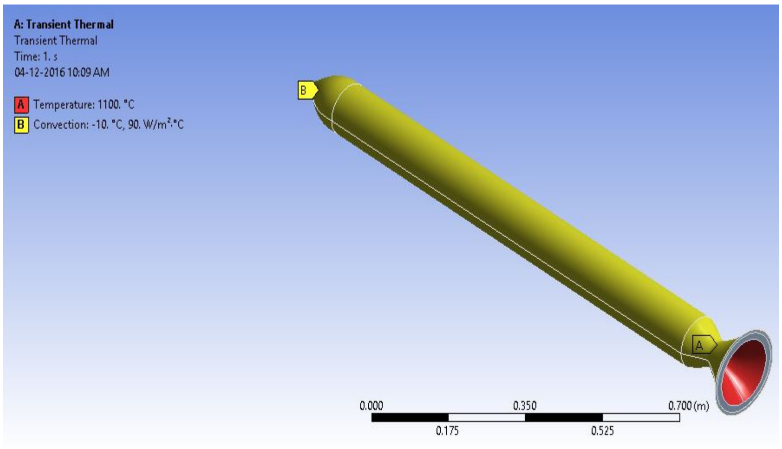


Figure 4 Shows Transient Thermal for the Rocket Body Model

5. RESULTS AND DISCUSSIONS

The temperature of the rocket body analyzed at various time intervals up to 90 sec. The fig 5 to fig 8 shows the transient thermal temperature of the rocket body at time interval of 0.1, 30, 60, and 90 sec. The table shows the maximum and minimum temperature attained by the along rocket body at time intervals of 30, 60 and 90sec.

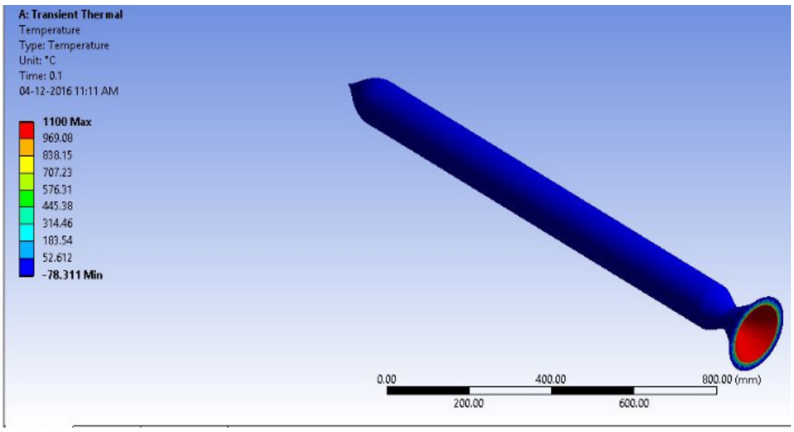


Figure 5 Transient Thermal Temp of the rocket body at time interval of 0.1 sec.

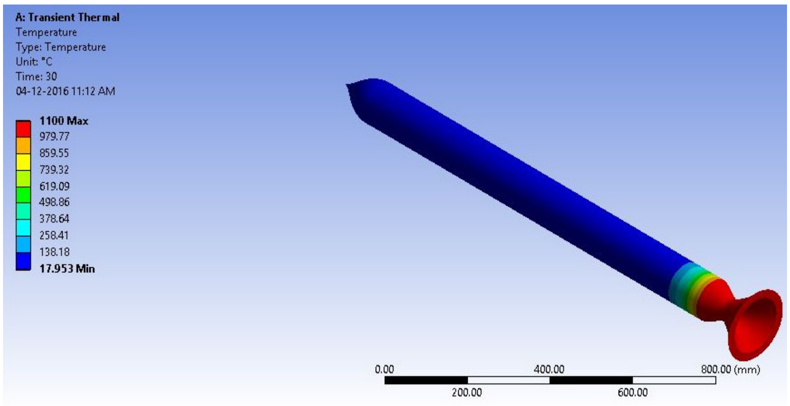


Figure 6 Transient Thermal Temp of the rocket body at time interval of 30 sec.

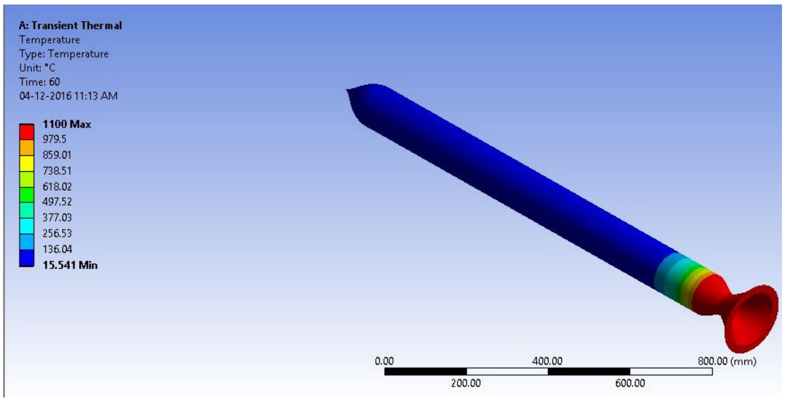


Figure 7 Directional heat flux at time interval of 60 sec.

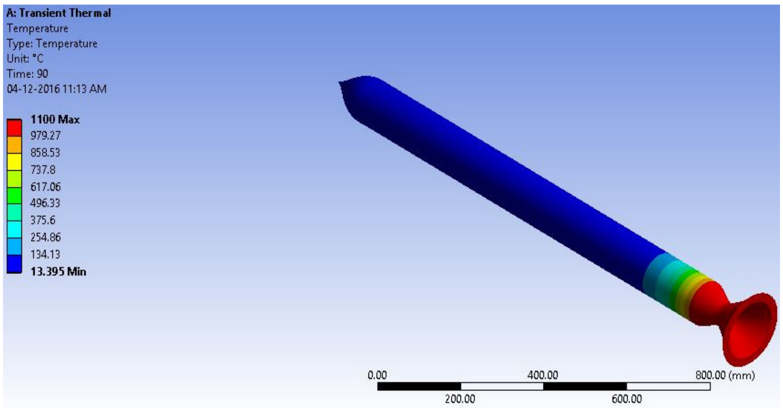


Figure 8 shows the directional heat flux at time interval of 90 sec.

Type	Temperature
By	Time
Display Time	30. s
Calculate Time History	Yes
Identifier	
Suppressed	No
Results	
Minimum	17.953 °C
Maximum	1100. °C
Minimum Occurs On	SHELL
Maximum Occurs On	MSBR

Figure 9 Result table of Ansys software shows Max. &Min. Temp attained at time interval of 30 sec

Definition	
Type	Temperature
By	Time
Display Time	60. s
Calculate Time History	Yes
Identifier	
Suppressed	No
Results	
Minimum	15.541 °C
Maximum	1100. °C
Minimum Occurs On	SHELL
Maximum Occurs On	MSBR

Figure 10 Result table of Ansys software shows Max. &Min. Temp attained at time interval of 60 sec

Definition	
Type	Temperature
By	Time
Display Time	90. s
Calculate Time History	Yes
Identifier	
Suppressed	No
Results	
Minimum	13.395 °C
Maximum	1100. °C
Minimum Occurs On	SHELL
Maximum Occurs On	MSBR

Figure 11 Result table of Ansys software shows Max. &Min. Temp attained at time interval of 90 sec

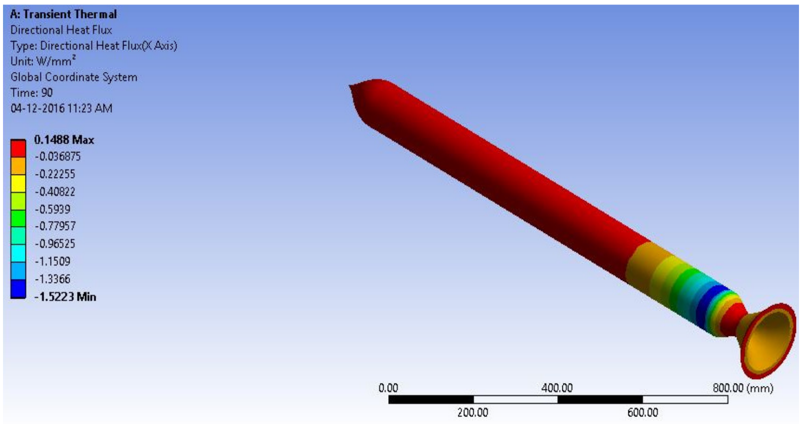


Figure 12 Directional heat flux at time interval of 90sec along rocket body

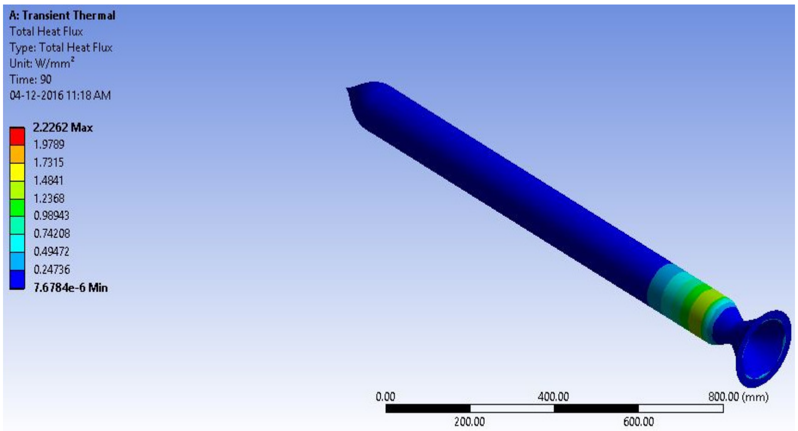


Figure 13 Total heat flux at time interval of 90sec

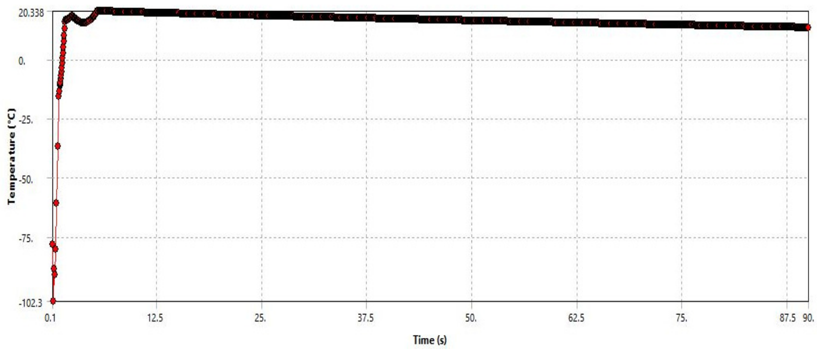
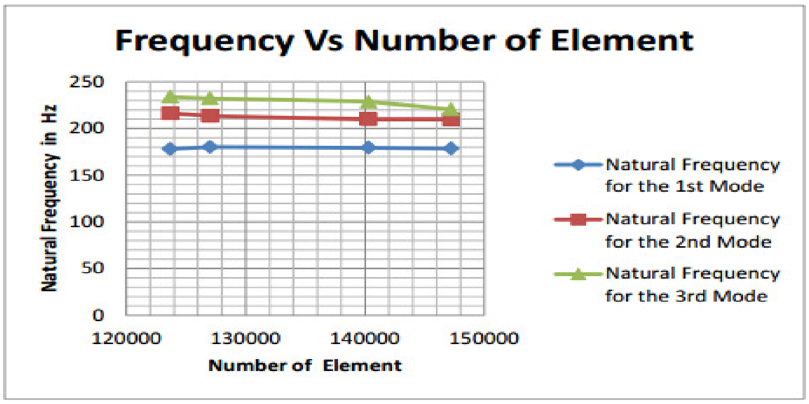


Figure 14 Heat Conduction Rate with respect to time interval



The analysis is conducted by applying the loads on each of the stages of the rocket outer shell model comparing using two materials as already mentioned aluminium and carbon epoxy. The material offering lesser deformation for the applied load is considered to be the effective one for the rocket casing to achieve the mission effectively. The comparison is made by applying same value of loads, boundary conditions and constraints on the model for both the materials considered separately. The results exhibited above are obtained when load is applied on the model comparing the displacement and contour results for the aluminum with nickel and TiB_2 alloy. Maximum heat flux generated at the front nose with a value of 1.7016 x 10^6 W/mm^2.

6. CONCLUSION

The natural conductivity is normal as before materials and the alloy also with stranded as before coated materials like zirconium. Heat-transfer, analysis are performed on a aluminum alloy thermal protection system (TPS) for future vehicles. The Aluminum alloy specimen researches its temperature limits in 90 seconds. For aerospace use, it is desirable to use the material which can attain its temperature limit after the elapse of more time. The heat-insulating performance of a honeycomb TPS is insensitive to the shape of the rocket cell under the same effective core density, but improves with the core depth. These results give us the stiffeners with low weight and high stiffness and also these study gives the knowledge of shifting the oval mode frequency to low or high value without changing the stiffness and help in avoiding resonance.

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REFERENCES

[1] Dr. P. Evans, “Composite Motor Case Design”, “Design Methods in Solid Rocket Motors”, Advisory Group for Aerospace Research & Development - Lecture Series No.150, September 27th, 1988.

[2] P. Mahesh Babu, G. Bala Krishna, B Siva Prasad, “Design & Analysis of Solid Rocket Motor Casing for Aerospace Applications”, International Journal of Current Engineering and Technology, Volume 5,No. 3, June 2015, pp. 1947-1954.

[3] Sheikh Naunehal Ahamed, Jadav Vijay Kumar, Mohammed Mushraffuddin, Parimi Shrawini, “Modeling and Analysis of Rocket Outer Shell”, international journal of scientific & technology research volume 3, issue 4, April 2014.

[4] Vicky Lad and Dr. L. P. Singh, Design Modelling and Analysis of Helical Gear Using Catia, ANSYS and AGMA Parameters. *International Journal of Mechanical Engineering and Technology (IJMET)*, 7(4), 2016, pp. 221–226.

[5] Suresh Kumar, K.V.V.S. Murthy Reddy, Anil Kumar, G. Rohini Devi, “Development and Characterization of polymer -ceramic continuous fiber reinforced functionally graded composites for aerospace application”, Aerospace Science and Technology ELSEVIER, No.26, 2013, pp. 185-191.

[6] Etele, J., Sislian, J. P., and Parent, B., “Effect of Rocket Exhaust Configurations on Ejector Performance in RBCC Engines,” Journal of Propulsion and Power, Vol. 21, No. 4, July–August 2005, pp. 656–666.

[7] N. Rajesh and Dr. M. Yohan, Recent Studies in Aluminium Metal Matrix Nano Composites (AMMNCs) – A Review, *International Journal of Mechanical Engineering and Technology (IJMET)*, 7(6), 2016, pp. 618–623.