To Study the Characteristics of Aluminum 6061 Material Using Zirconium Dioxide As Coating Material

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Abstract: The present study deals with the material characteristics of Aluminium using plasma coating. Ceramic coating on various parts of an IC engine provides excellent thermal barrier properties which are used in preventing the heat loss during the working cycle. Since melting point of Al is 650°C, using plasma coating, 0.35mm of ZrO2 is coated on Al and NiCrAlY is used as bonding material between Al and ZrO2. Using scanning electron microscope, microstructure of coated and uncoated is studied and found that porosity on the coated material was less and the surface was slightly abrasive. Hardness test is carried out on coated and uncoated material at various points on the surface and found that using ZrO2, hardness of the base material improved by 29.13%. Corrosion test was also carried out using Na2SO4 and V2O5 salts (by-products of combustion) and found that ZrO2 has better resistive capabilities towards corrosion than uncoated. At a thickness of 0.35mm for the coated material, it is found that thermal stability of base Al material has increased twice compared to the actual value.

***Index Terms* - Aluminium, ZrO_2, Microstructure, Hardness test, Thermal Stability.**

I. INTRODUCTION

Zirconium dioxide ceramics are used, among other applications, as tools for wire forming, as auxiliaries in welding processes, as materials for crowns and bridges in the dental industry, as insulating rings in thermal processes, and as oxygen measurement cells in lambda probes. The Plasma Spray Process is basically the spraying of molten or heat softened material onto a surface to provide a coating. Material in the form of powder is injected into a very high temperature plasma flame, where it is rapidly heated and accelerated to a high velocity. It is well known that the microstructure plays a predominant role in determining material behaviour. Material scientists, therefore, seek to control microstructure through processing. Increasing microstructure uniformity has long been considered a fruitful means of improving properties. Depending on this standpoint, the uniform microstructures have been produced by improving processing technique. Plasma coating is one of them, because the uniform and dense coatings are produced using this method. Thermal stability is the stability of a molecule when it is exposed to very high temperature. If a molecule has a higher thermal stability it will be more resistive to decomposition at higher temperature.

II. LITERATURE SURVEY

N.F Ak, C.Tekmen Et al. In this paper, A Metco Diamond jet was used to deposit coatings onto stainless steel coupons which had been grit blasted for a period of 30 seconds with alumina using compressed air at a desired pressure. Substrates were then degreased immediately prior to deposition. In this process, hydrogen is used as a fuel with nitrogen gas a powder carrier. Microstructural studies were also carried out using SEM and optical microscope to study the surface topography and composition of the surface as we know that microstructure plays a vital role in determining material behaviour.

Ekram Buyukkaya Et al. In this paper, the functionally graded coatings were used to reduce the mismatch effect. Therefore the thermal expansion and inter- facial stresses are an alternative approach to the conventional thermal barrier coatings. The functionally graded coating is utilized to eliminate the disadvantages of the conventional thermal barrier coatings. These coatings include traditional thermal barrier coating with a ceramic top coat and metallic bond coat as well as cermet coatings consisting of different amounts of ceramic and metallic components

X.Q. Cao Et al. In this paper, Yttria stabilized zirconia (YSZ) which is the most widely studied uses thermal barrier coatings material because it provides the best performance in high-temperature applications such as diesel engines and gas turbines. YSZ coating has been proved to be more resistant against the corrosion of Na2SO4 and V2O5 than the ZrO2coating stabilized by CaO or MgO. A major disadvantage of YSZ is the limited operation temperature (<1473 K) for long-term application. A practical upper-use temperature of 1223 K in gas turbine for the ZrO2 coating stabilized by CaO and MgO was reported.

Ekrem Buyukayya Et al. In the paper, although there are a lot of experimental studies on thermal barrier coatings in the internal combustion engines, there are a few numerical studies focused on 3-Dstructural and thermal analyses on a diesel piston model.

This paper presents 3-D finite element modelling of AlSi alloy and steel conventional diesel engine piston and ceramic coating diesel engine piston. The zirconia-based ceramic coatings are used as thermal barrier coatings owing to their low conductivity and their relatively high coefficients of thermal expansion, which reduce the detrimental interfacial stresses.

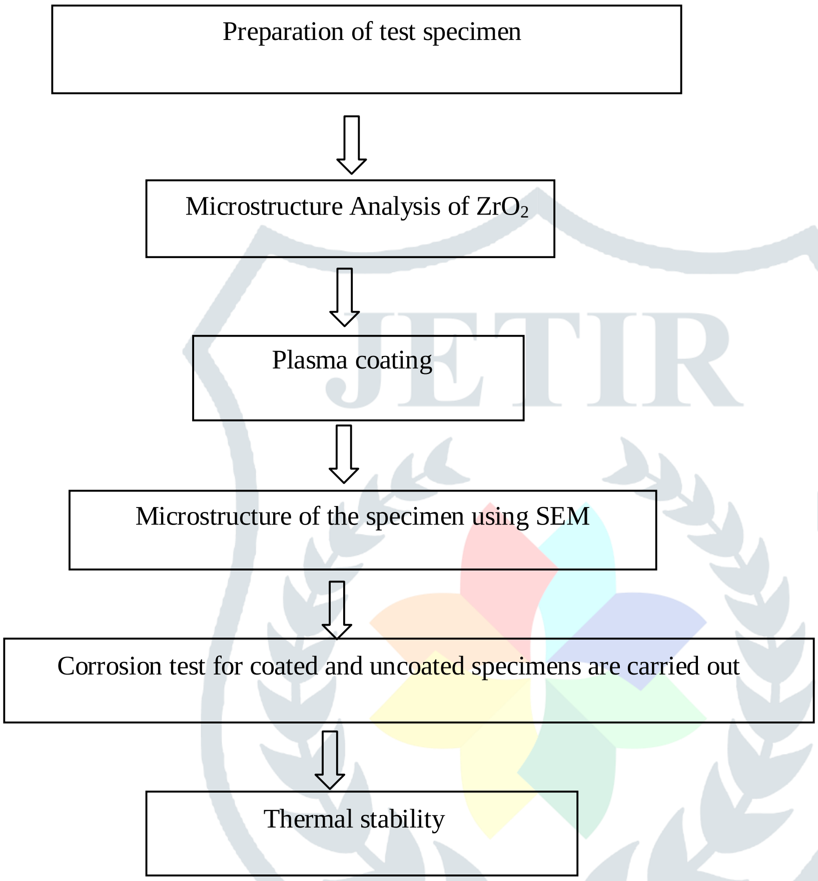
Ge´rard Barbezat Et al. In this paper, Advanced thermal spray technology is widely used in the automotive industry. Transmission and engine parts are coated in large volume using different processes. Some applications have already reached a status of maturity. Other applications are new and represent an important market for the future.

Ekrem Buyukayya Et al. This paper speaks about the comparisons between the standard engine and its low heat rejection version's engine performance, exhaust gas emissions, injection timing and valve adjustment. These tests were performed on a six cylinder, direct injection, turbocharged diesel engine whose pistons were coated with a 350 µm thickness of MgZrO3 with 150 µm thickness of NiCrAl as bond coat. CaZrO3 was used as the coating material for the cylinder head and the valves. The working conditions for the standard engine and low heat rejection engine were kept exactly the same to ensure a realistic comparison between them.

A.G. Evans Et al. In this paper, the mechanism controlling the durability of thermal barrier coatings was discussed. The durability of thermal barrier coatings are governed by the sequence of crack nucleation, propagation and coalescence events. Thermal barrier coatings are widely used in turbines for propulsion and power generation. They comprise thermally insulating materials having sufficient thickness and durability that they can sustain an appreciable temperature difference between load bearing alloy and the coating surface. By lowering the temperature of metal substrate, the life of the component can be prolonged.

Albert Feuerstein Et al. This paper speaks about thermal barrier coating systems which are widely used in modern gas turbine engines to lower the metal surface temperature in combustor and turbine sections. Engines for both aero-jet propulsion and land-based industrial power generation vehicles have taken advantage of this technology to meet the increasing demands for greater fuel efficiency, lower NOx emissions and higher power. The engine components exposed to the most extreme temperatures and metal temperature reductions are possible when thermal barrier coatin systems are used in conjunction with external film cooling and internal component air cooling.

III. METHODOLOGY



3.1 WORKPIECE PREPARATIOIN

The 6061 grade aluminium pistons (2 No's) was taken to **Selomac industry**, Peenya for cutting it into 1×1 square inch using milling machine. The piston was cut into 5 pieces, each 1×1 inch in dimension.

3.2 COATING THE WORKPIECE

The cut pieces were taken to **Spraymet coating industries**, **Peenya** for the coating process. Four pieces were given for coating. Three pieces were coated on all the surfaces and one piece was coated only on one surface. The coating thickness is 300µm. the coated workpieces had a yellowish hue after coating process.

Bonding material used: NiCrAlY

Coating specifications:

- Current: 500A, 65-70V
- Powder feed: 40-45 gm/min
- Spray distance: 2-3inches
- Coating thickness: 300µm Gun: 3Mb spray gun

3.2.1 SEM: A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the surface topography and composition of the sample. The electron beam is scanned in a raster scan pattern, and the position of the beam is combined with the detected signal to produce an image.

3.2.2 HARDNESS TEST: Hardness is a property of a material to resist deformation, indentation or penetration by means such as abrasion, drilling, impact, scratching which is measured by harness test

Hardness test was conducted on both coated as well as the uncoated pieces in Material Science Lab, Reva University and calculations were done which will help us to compare the results of both coated and uncoated workpieces.

3.2.3 THERMAL STABILITY TEST: It is the test to check stability of a molecule when it is exposed to very high temperature. If a molecule has a higher thermal stability it will be more resistive to decomposition at higher temperature.

IV. RESULTS AND DISCUSSION

4.1 Microstructure of coated and uncoated specimen

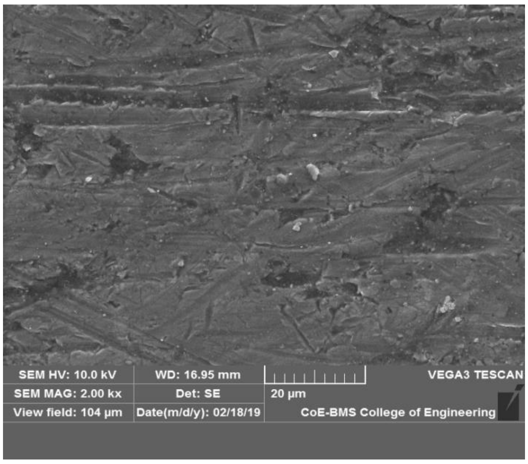


Fig 2: Uncoated SEM Image

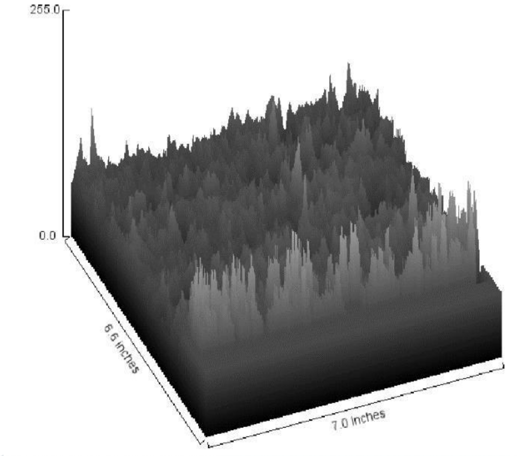


Fig 3: 3D Image

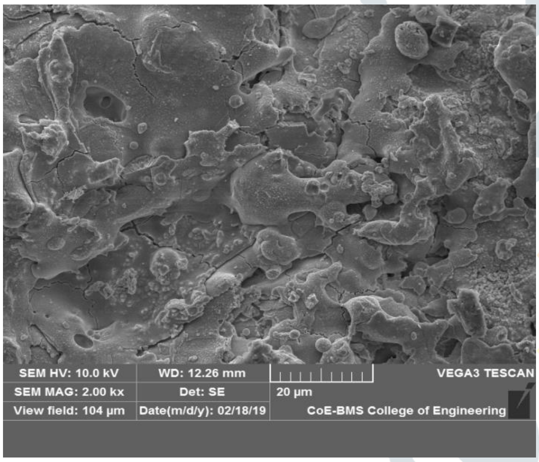


Fig 4: Coated SEM Image

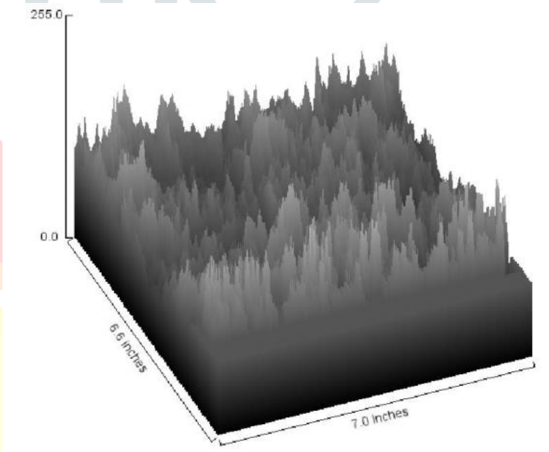


Fig 5: 3D Image

Fig: 4 show a typical microstructure of the coating produced by plasma coating. It is well known that the microstructure plays a predominant role in determining material behaviour. Increasing microstructure uniformity has long been considered a fruitful means of improving properties. Depending on this standpoint, the uniform microstructures have been produced by improving processing technique. Plasma coating is one of them, because the uniform and dense coatings are produced using this method. Hence there is less surface porosity in coated specimens compared to uncoated specimens.

4.2 Hardness Test

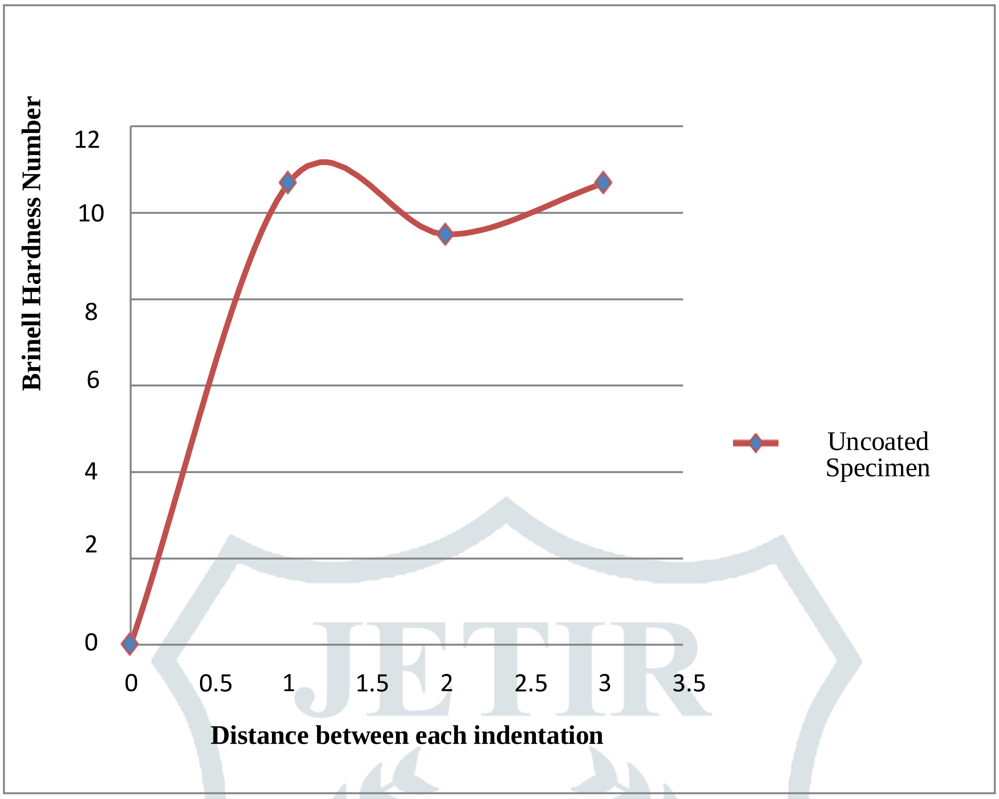


Fig 6: BHN Vs Distance for uncoated specimen

The graph is plotted between Brinell Hardness Number (BHN) on y-axis and distance between indentations on x-axis for uncoated specimen. From the graph, we get to know that the average BHN is in the range of 100-120.

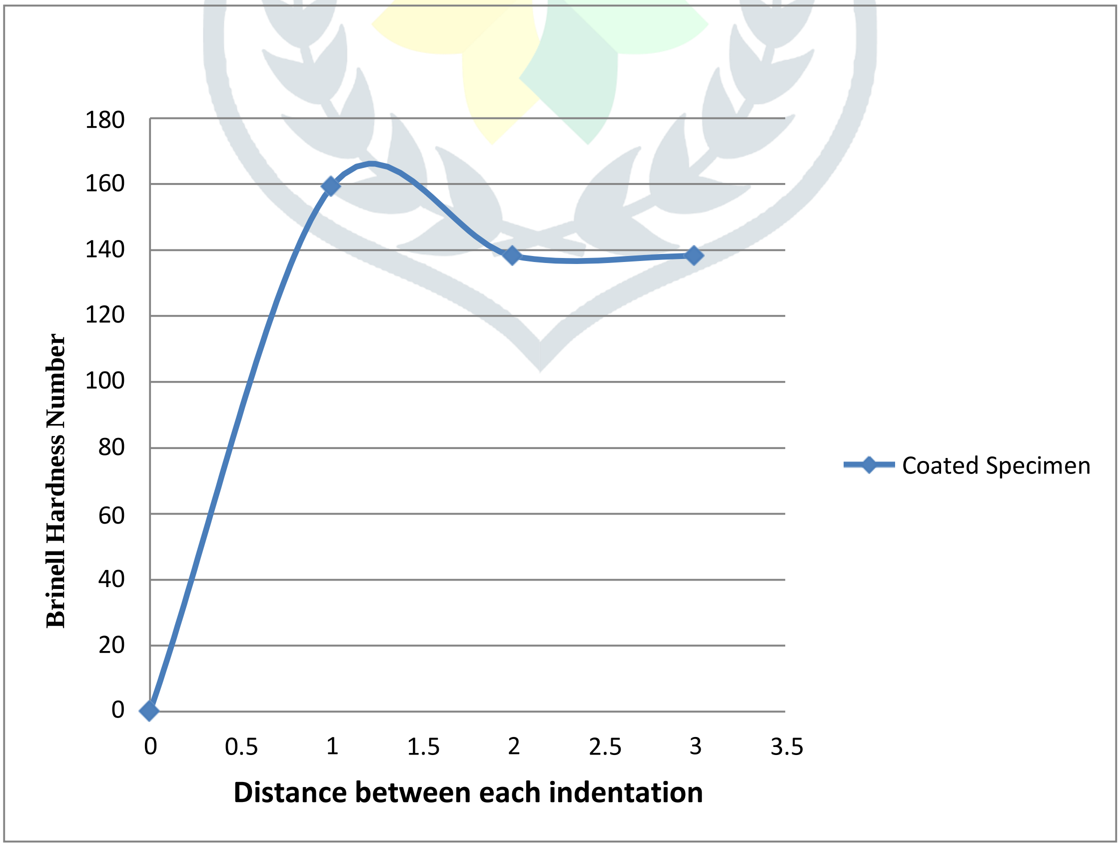


Fig 7: BHN Vs Distance for coated specimen

The graph is plotted between Brinell Hardness Number (BHN) on y-axis and distance between indentations on x-axis for coated specimen. From the graph, we get to know that the highest BHN is observed in the range of 160-180.

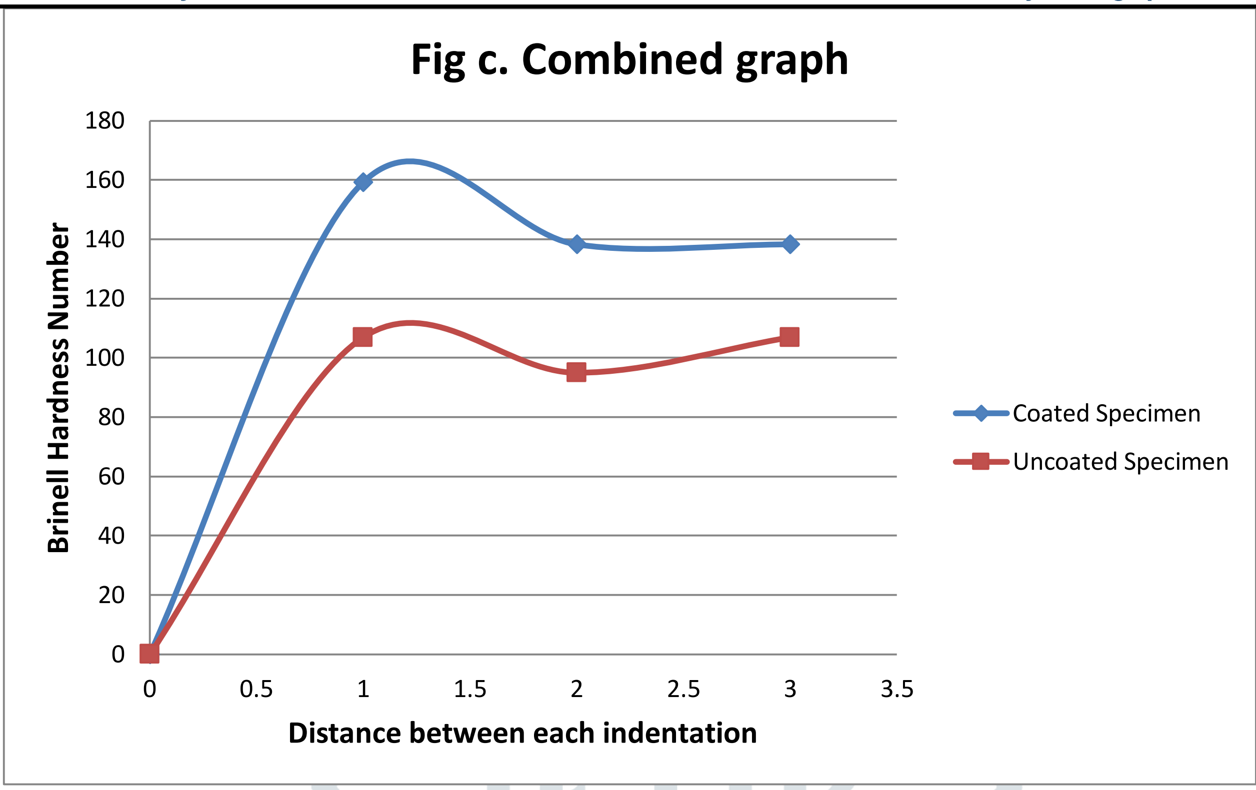


Fig 8: Combined graphs of both coated and uncoated specimens

A combined graph is plotted between both coated and uncoated specimens and is clearly evident that the coated specimen has higher BHN compared to uncoated specimen.

4.3 THERMAL STABILITY

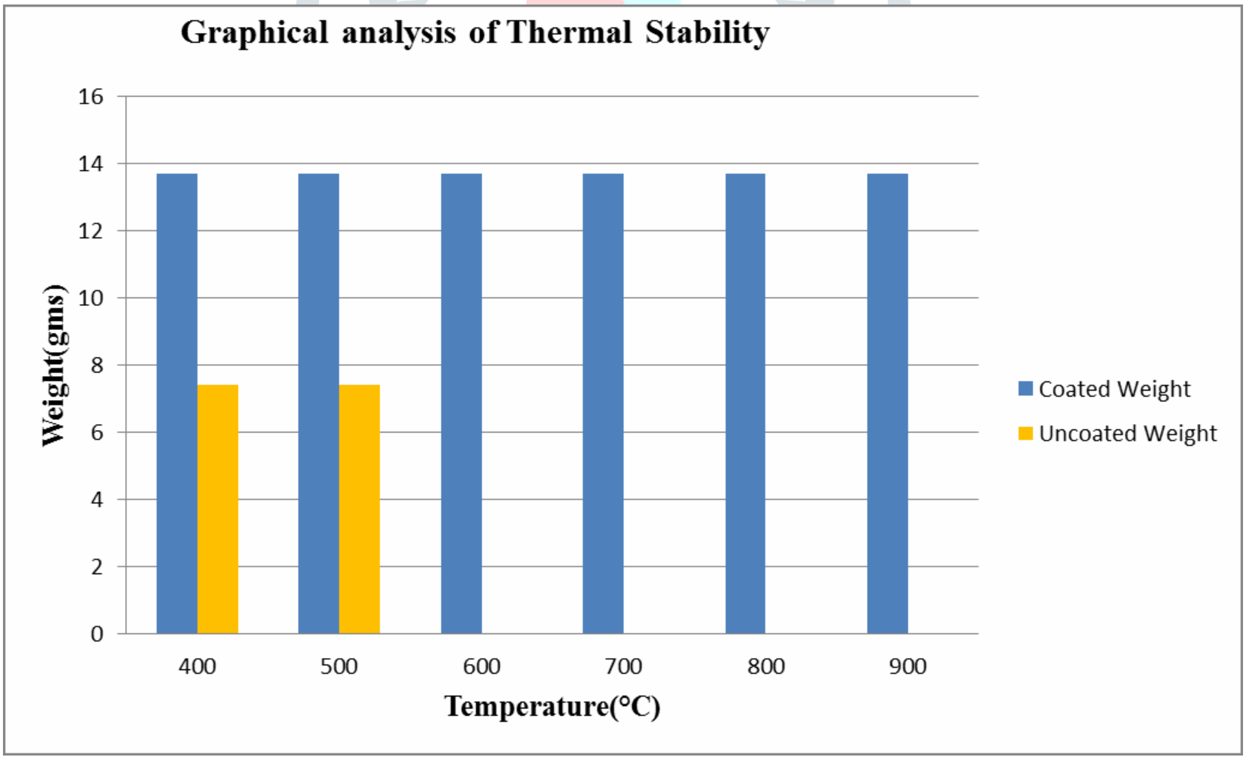


Fig 9: Graphical Analysis of thermal stability

From the tabular column and picture shown above, we can observe that the uncoated specimen melts at 600°C and the coated specimen was still intact at 900°C. Hence coated specimen has better thermal stability than uncoated specimen.

V. ACKNOWLEDGMENT

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