INVESTIGATIONS ON THE CRITICAL PARAMETERS INFLUENCING THE PROPERTIES AND FUNCTIONAL PERFORMANCE OF ABLATIVE COMPOSITES

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by

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ABSTRACT

Ablative composites are widely employed as thermal protection systems in the internal surfaces of solid rocket motors, in liquid engine throats and on the external surfaces of reentry space vehicles. These materials are simple, reliable and efficient in handling extreme hostile thermal environments encountered in aerospace applications. They are the best candidate materials for protecting the nozzle structures from the extremely high temperature and high pressure gas flows and the external surfaces of reentry vehicles from frictional heating during reentry into the earth's atmosphere. Carbon and silica are the most common fibres used as reinforcement in combination with phenolic resin for manufacturing the ablative composites used for aerospace applications.

Ablative systems are basically designed based on thermal considerations but the structural properties also play a vital role during the operating conditions. There is a sizeable number of key process variables which are to be carefully selected based on the end product requirements. This study is a series of systematic investigations on the critical factors affecting the properties and functional performance of ablative composites. A detailed literature survey of the raw materials, processing techniques, equipments etc and a survey at different ablative processing laboratories were conducted to understand the different processes and the process variables being followed currently. The raw materials were characterized completely. The important thermostructural properties required for an ablative were identified and the test methods were finalized. The entire spectrum of process variables were enumerated and broadly classified into critical and non critical parameters depending on their likely influence on the final product properties. Then, the chosen parameters were subjected to deeper investigations and the results were analysed. Composite laminates were made using carbon fabric/silica fabric and phenol formaldehyde resin by varying the different parameters selected for the study.

By a systematic study of the ablative materials, processing techniques and characterisation methods, all the raw material and process parameters were tabulated. From this exhaustive list, the most crucial factors affecting the material properties and functional performance of carbon phenolic and silica phenolic ablative composites have been identified. Complete characterization of the reinforcement fibres (carbon and silica) and matrix resin (phenolic) has been completed and the influential parameters have been identified by laminate level studies. Impregnation of the carbon and silica fabric with phenolic resin was done and the critical properties influencing the composite properties were quantified.

Subsequently, ablative composites were processed and the most influential process parameters in each process stage were identified. Processing was done following the standard process in which the chosen variable alone was changed each time and its effect studied. Laminates were subjected to non destructive evaluation techniques of visual inspection, alcohol wipe test and ultrasonic (pulse-echo and through transmission) testing to study the integrity and uniformity. After ensuring that the laminates were free from defects, specimens were fabricated from them as per accepted standards. Evaluation of mechanical and thermal properties was done and the results were tabulated. Apart from density, the crucial mechanical properties like compressive strength, modulus and interlaminar shear strength were studied. Heat of ablation, erosion rate, thermal conductivity and specific heat were the thermal properties evaluated and studied. From the results of the tests, the effect of each variable on the composite properties was quantified and inferences were made accordingly.

Sensitivity studies on the chosen variables to quantify the influence of these variables on the properties and performance of the ablative composites were systematically completed and the results were analysed. The possible effect of other related factors which may have a bearing on the ablative performance were also investigated and suitable inferences were derived.

The gap in the understanding of the dependence of the properties and performance of the ablative composites on the raw material properties and process parameters has been narrowed down by this study. The studies on the sensitivity

of the most critical raw material and process parameters on the important thermal, physical and mechanical properties of ablative composites, the important factors were completed. Significant gains in terms of cost, process cycle time and inert mass can be achieved by understanding the influence of the critical factors.