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Enhancing Reusability of Conventional Apollo Modules by proposing change in design and use of new ablative material

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Abstract

The paper deals with the reusability of command modules used during Apollo space missions. During Apollo missions in 1960-70's the module surface becomes charred up to some extent, hence decreasing the strength and scope of further reusability of the module. A new design has been proposed and simulation results have revealed the possibility to reuse the module again for another mission. The new design has incorporated an in-built mechanism that will extend some part of the module surface outwards near to the periphery of the base of the module. The design, mechanism, material and other details are discussed in succeeding sections. New ablative material has been introduced for more getting more promising results.

Introduction

Reusability of modules has always been an issue of great concern for Apollo missions. As the module splashes down in the ocean the salt water oozes inside the module damaging various subsystems beyond repair and the extensive heating during reentry to Earth decreases the strength of the structure as well, hence greatly threatening any possibility to reuse the module. The concept of ablation was also used in order to decrease the amount of heat transferred to the module during reentry. Various types of ablative materials are there that can be used for heat shielding. These are broadly classified as Homogeneous Ablators and Composite Ablators [1]. Under these various subclasses materials such as plastics, ceramics, reinforced plastics, reinforced ceramics and impregnated systems exist [1]. NASA performed variety of tests for various materials (ablative and non ablative) that could be used as heat shields in Apollo missions. The material used in some missions was Avcoat 5026-39/HC-G, that is an epoxy navolac resin that contains additives in fiber-glass honeycomb matrix [2]. It was the best material that was selected for heat shielding purpose in late 1960s [2]. With the advancement in field of materials various ablative materials have been discovered, some of them are being utilized in Solid Rocket Motor nozzles. Utilization of Carbon cloth phenolic and Glass cloth phenolic has made Solid Rocket nozzles reusable [3]. Recently, better heat shielding materials such as Norcoat-Liège etc. are developed which are cork based materials and provide better shielding and promising reusability [4]. This material has been recently used in European MARS EXPRESS mission by Astrium [4], the tests results performed were really convincing.

The module was mounted at the top of multistage solid rocket motor [5]. The module was built according to the dimensions as in [5]. Reentry in case of Apollo modules is blunt body reentry, tests performed by Allen and Eggers 1958 [6] reveled that heat load experienced by reentry vehicle was inversely proportional to the drag coefficient. The detached shockwave formed in blunt body reentry prevent it from excessive heating, but still a considerable heating is occurred not only to the reentry face but also to the walls of the module [7]. In the proposed model, the detached shockwave is relatively far from module's main body (discussed later on) causing relatively less heating of the module.

Design and Methodology

The proposed design of new module is a slight variation in conventional one. It has incorporated a deployment mechanism which is housed in the increased extra length of the module. The mechanism will deploy the portion of the skin panels present at the periphery of the base of the module changing its shape just before the process for reentry starts. This will change the geometry of the module from conventional one to extended base shaped module.

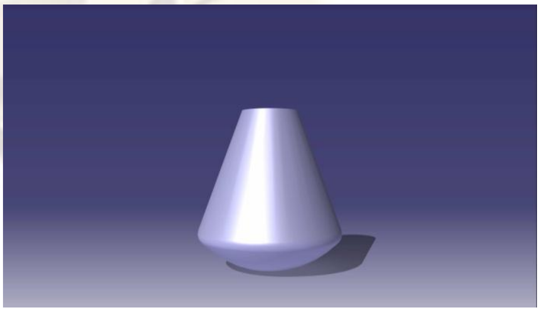


Fig. 1: Solid model of Module (Panels Retracted) prepared in Catia V5R20

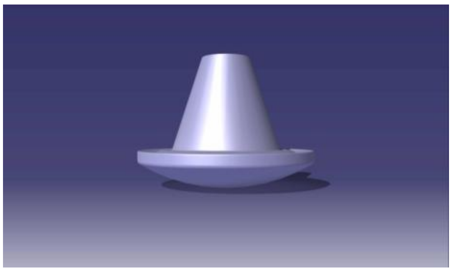


Fig. 2: Solid model of Module (Panels deployed) prepared in Catia V5 R20

The scaled model of Apollo Command Module was developed in Catia V5 as per the dimensions given as in [5] with some increase in total height of the module so as to make appropriate room for new mechanisms and other vital systems. The simulations for both the models were run by enabling the energy equation and setting flow to viscous–realizable k-epsilon with standard wall function. Simulation results and comparisons will be discussed later on.

Skin panels around the periphery of the base of the module are of considerable thickness and strength so that they can bear extreme temperature and various forces during reentry. The base and skin panels are coated with Norcoat-Liège, and the characteristic values according to the requirement are substituted for running Simulations.

The change in shape i.e. deploying skin panels outwards is achieved by a mechanism that will be explained in the following section.

Panel Deploying Mechanism

The deployable skin panels are folded inside the main body of module during launch. This extra panel portion will be deployed just before starting the reentry process. Panels are made of sheet of required thickness, a circular rack which is moved with help of a pinion to move it forward to required position.

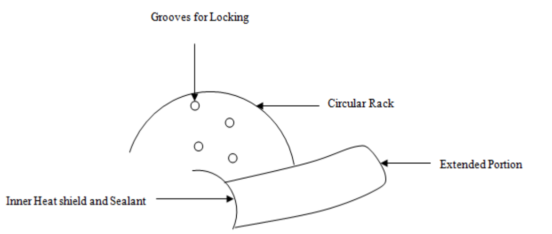


Fig. 3: Extended skin panel portion

On the solid circular rack circular grooves are present in which locking pins will be fixed, hence locking the panel firmly. At the end of the circular rack, a similar plate of comparatively less thickness is present that will replace the position of initial panel in the outer skin of the module. The inner layer of the panel near the hinges is coated with heat shield and required sealants to ensure heat locking of the system as well. These heat shields and locking pins make the extended panel portion of the skin strong, both mechanically and thermally.

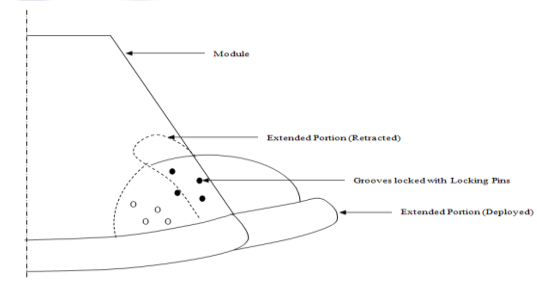


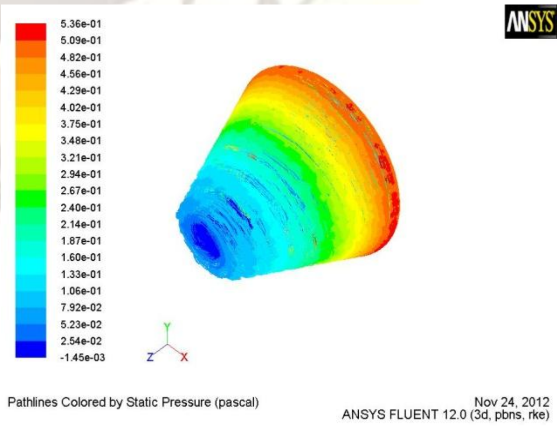
Fig 4 : Extra portion of Skin panel (retraction and deployment)

Simulation Results

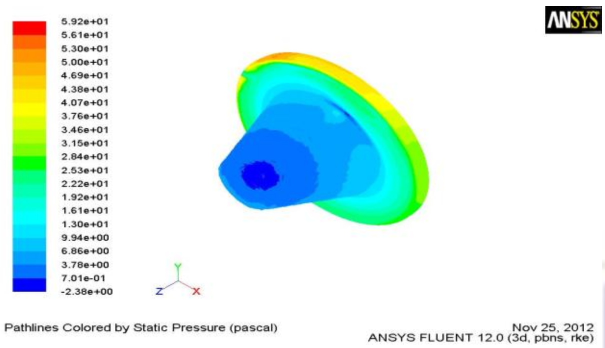
1) Pressure Distribution :

Using ANSYS12 around 1000 iterations has been done for conventional Apollo module and proposed design and comparison has been shown:

a) Conventional Module



b) Module with proposed changes

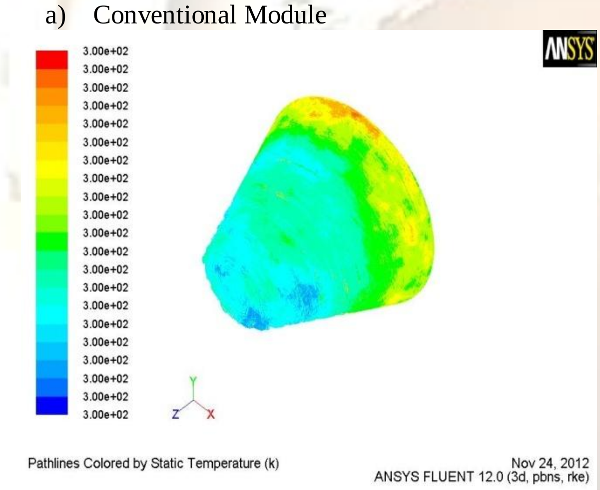


As it is clear from the figure, there has been a decrease in pressure around new proposed design as compared to pressure distribution implies there will be less structural loads on proposed change in design of module.

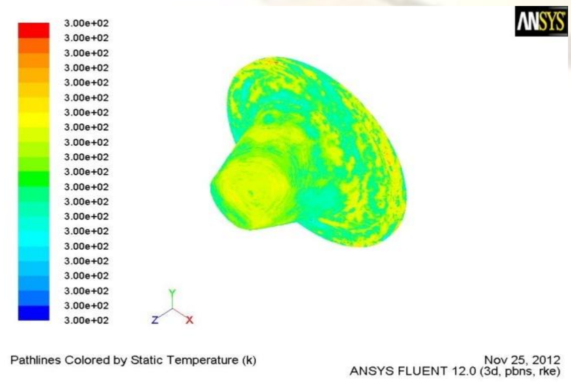
2) Temperature

Using ANSYS12 approximately 1000 iterations are done and comparison of temperature distribution has been shown,

a) Conventional Module



a) Module with proposed changes

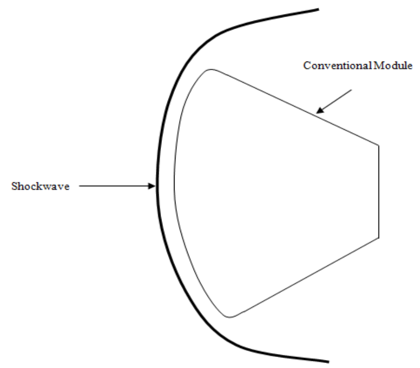


It can be observe that in new module, there is reduction in temperature with uniform distribution while in case of conventional module high temperature distribution is there along boundaries.

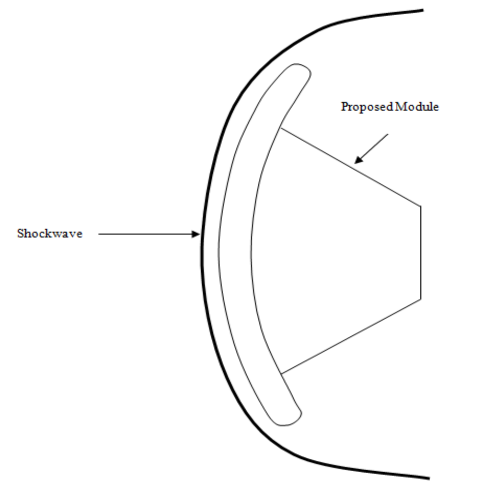
3) Shock Wave Pattern

Shock wave pattern generated around module during reentry is compared between two different modules,

a) Conventional Module



b) Module with proposed changes



It is expected that in new module, relative distance between shock waves and module will be larger in comparison to conventional module. Thus, it reveals a structure with less structural loads.

Advantages

1) Reduction in temperature and its uniform distribution around module, thus making it much safer and enhancing its reusability.
2) There is less chance of structural disintegration as pressure distribution around new module has decreased.
3) Reusability of module is enhanced as due to increase in structure size, there is less chance of

salty water to get into electronics of module at time of sea landing.

Disadvantages

Due to structural change, there is need of more material implying increase in cost.

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