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Passive Thermal Management & Thermal Protection Systems

During my internship in the Thermal Design Branch (ES3), I contributed to two main projects: **i)** novel passive thermal management system for future human exploration, **ii)** AVCOAT undercut thermal analysis.

i) As NASA prepares to further expand human and robotic presence in space, it is well known that spacecraft architectures will be challenged with unprecedented thermal environments. Future exploration activities will have the need of thermal management systems that can provide higher reliability, mass and power reduction and increased performance. In an effort to start addressing the current technical gaps the NASA Johnson Space Center Passive Thermal Discipline has engaged in technology development activities. One of these activities was done through an in-house Passive Thermal Management System (PTMS) design for a lunar lander. The proposed PTMS, functional in both microgravity and gravity environments, consists of three main components: a heat spreader, a novel hybrid wick Variable Conductance Heat Pipe (VCHP), and a radiator. The aim of this PTMS is to keep electronics on a vehicle within their temperature limits (0 and 50°C for the current design) during all mission phases including multiple lunar day/night cycles. The VCHP was tested to verify its thermal performance. I created a thermal math model using Thermal Desktop (TD) and analyzed it to predict the PTMS performance. After testing, the test data provided a means to correlate the thermal math model. This correlation took into account conduction and convection heat transfer, representing the actual benchtop test. Since this PTMS is proposed for space missions, a vacuum test will be taking place to provide confidence that the system is functional in space environments. Therefore, the model was modified to include a vacuum chamber with a liquid nitrogen shroud while taking into account conduction and radiation heat transfer. Infrared Lamps were modelled and introduced into the model to simulate the sun's rays directly impinging on the system. Heating rate of the lamps were calculated by knowing fraction of emitted energy in a wavelength interval and the filament temperature. This version of the model can be used to predict performance of the system under vacuum with extreme cold or hot conditions. Initial testing of the PTMS showed promise, and the thermal math model predicts even better performance in thermal vacuum testing.

ii) Thermal Protection Systems (TPS) are required for vehicles which enter earth's atmosphere to protect from aerodynamic heating caused by the friction between the vehicle and atmospheric gases. Orion's heat shield design has two aspects which needed to be analyzed thermally: i) a small excess of adhesive used to bond the outer AVCOAT layer to the inner composite structure tends to seep from under the AVCOAT and form a small bead in between two bricks of AVCOAT, ii) a silicone rubber with different thermophysical properties than AVCOAT fills the gap between two bricks of AVCOAT. I created a thermal model using TD to determine temperature differences that are caused by these two features. To prevent false results, all TD models must be verified against something known. In this case, the TD model was correlated to CHAR, an ablation modelling software used to analyze TPS. Analyzing a node far from the concerning features, we saw that the TD model data match CHAR data, verifying the TD model. Next, the temperature of the silicone rubber as well as the bead of adhesive were analyzed to determine if they exceeded allowable temperatures. It was determined that these two features do not have a significant effect on the max temperature of the heat shield. This model can be modified to check temperatures at various locations of the heat shield where the composite thickness varies.

Following my experience at NASA JSC working in the passive thermal discipline, I was able to confirm my career and academic goals. This rotation gave me an opportunity to gain knowledge in the area of thermal fluids science and I will be able to leverage this knowledge and experience to pursue graduate studies in the area of interfacial phenomena. I am now certain that NASA JSC is one of the best places to work if you enjoy technical problems and challenges. I am sure that JSC is not unique in this regard, and that any NASA center would appeal to someone with an engineering/science background.