STRESS DISTRIBUTION ANALYSIS IN ZIRCONIUM DIBORIDE AND SILICON CARBIDE (ZrB_2-SiC) BASED THERMAL PROTECTION SYSTEM UNDER HYPERSONIC FLIGHT CONDITIONS USING MACHINE LEARNING DRIVEN APPROACH

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Established methods and extensive previous research showed that it could be possible to fly outside the Earth's atmosphere and re-enter reaching speeds that could go above the speed of sound by 5 folds. Ultra-high temperature ceramics (UHTCs) materials have shown to be a good candidate that can be used as a non-ablative thermal protection system (TPS) for a space vehicle due to the low volatility, high melting points and high heat-flux resistance. Deployment of such material in such condition requires extensive testing for safety and vehicle manoeuvrability and, in current days and times, hypersonic wind tunnel is very expensive and provide experimental tests for limited amount of time.

This study evaluates a non-discrete stress distribution analysis in a partially ablative TPS made by ZrB_2/SiC composite. The design is assumed to be utilised as a shield for a space vehicle with sharp leading edge that would fly under hypersonic conditions. Thermo-fluid analysis using a surrogate Computational Fluid Dynamic (CFD) model was performed quickly and accurately to approximate the data that can help with the optimal design process. This particular model tries to re-create a hypersonic wind tunnel condition on computer screen to look on behaviour of fundamental parameters such as temperature and heat flux at high speed. Such surrogate model has been developed using two different types of CFD approaches - Reynolds Average Navier Stoke Equations solver and Neural Network, Gradient Boosting and Random Forest. Such approaches generated a maximum temperature of 5000 K and a Pressure Distribution across the boundary layer separation that reaches values of up to 205 MPa.

Previous studies on similar TPSs have resulted in temperature and pressure field of maximum Von-Mises Stress - 35 MPa and Principal Stress of 166 MPa which were obtained using traditional finite element modelling approaches. In this study, a different approach based on machine learning driven methodology has been tried with a combination of a clustering methodology using TensorFlow in the Keras library. The results showed that high thermal stress within occurs circa ¾ down the boundary layer separation points where is believed flow is highly stochastic and oxygen ionisation takes place. The stress reaches peak of 500 MPa meaning that re-usability of such shield could not be guaranteed, however the use of deep learning lowered the computational time required for the simulation and showed that accuracy can be improved.