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BAYESIAN HIERARCHICAL MODELING BASED MICROMECHANICS COMPUTATIONAL FRAMEWORK FOR INTEGRATED MATERIAL AND PROCESS DESIGN OF FAILURE CRITICAL COMPONENTS

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With increased societal reliance on complex engineered systems, their performance and failure involves significant human and environmental risk, and life cycle costs. The higher the complexity of the product and the larger the number of associated components, the higher is their probability of failure or malfunction. The material state and its processing play critical role in the failure of critical parts, and in turn the failure of engineered system, Fig 1 [1].

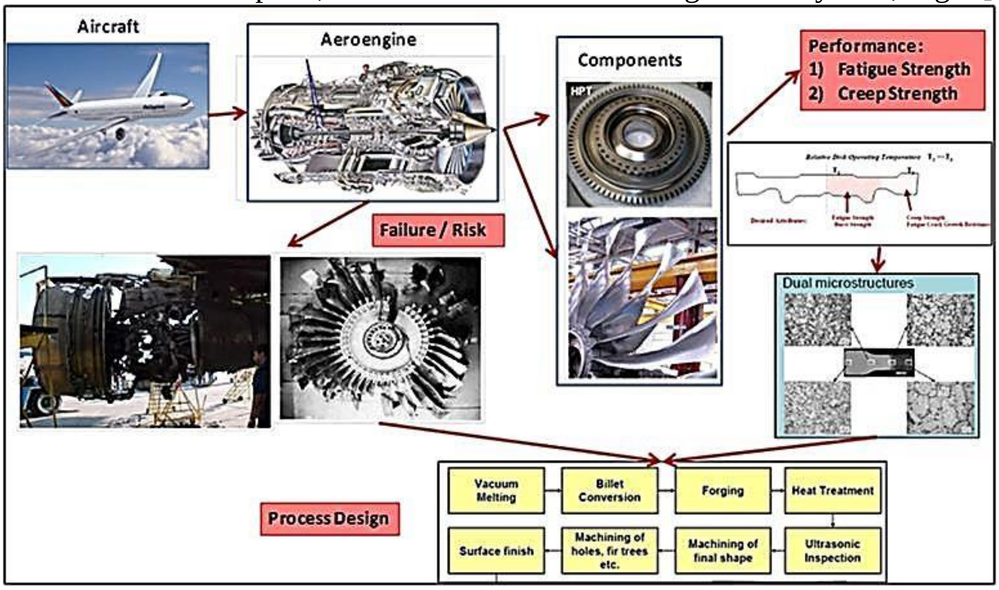

Fig 1: Role of material and process design in the performance of complex engineered system.

Due to the reactive nature of titanium to oxygen and nitrogen in the atmosphere, several defects or anomalies are generated during the melt processing of titanium alloys into ingots. These include macrosegregation of oxygen, beta stabilizing elements, nitrogen-stabilized hard alpha particles (LDIs) and high-density inclusions (HDIs). In addition to these melt related defects, microstructural, textural and damage-type (cracks, pores etc) defects may form during ingot to billet conversion process in alpha/beta titanium alloys [2]. The so-called low-density inclusions (LDI) - hard-alpha inclusions- are characterized by substantially higher hardness and low ductility than the material from the surrounding region. In the micromechanics of heterogeneous media, the deformation of hard alpha inclusion in titanium alloy during hot forging has been modelled using the multi-body algorithm available in the commercial software, FORGE3 [3,4]. The complicated contact behavior between hard alpha inclusions and matrix material is modelled using the penalty based contact approach.

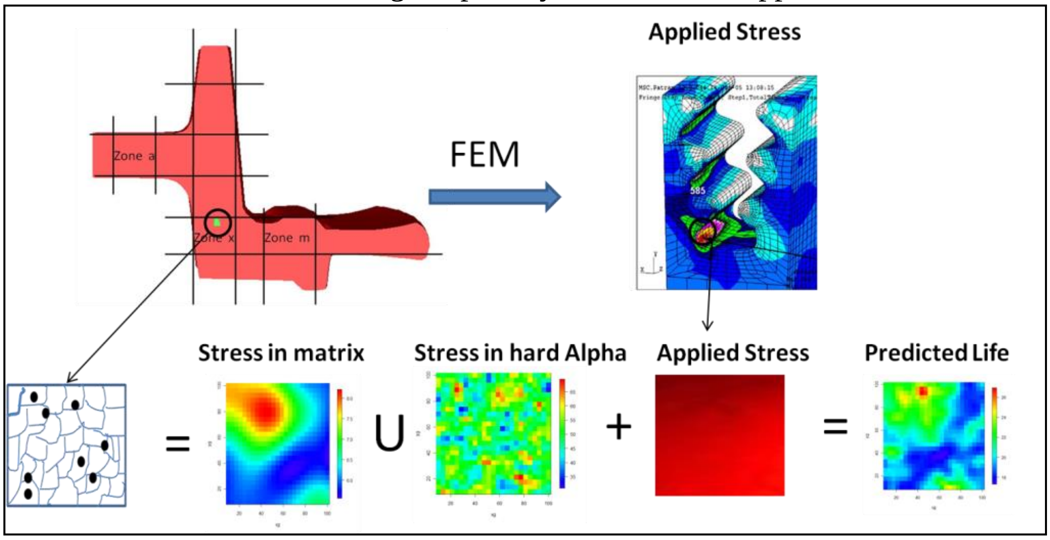

Fig 2: Multibody micromechanics based hierarchical approach to the prediction of failure.[5]

In this paper, the ICME systems approach is extended to the material and processing based design of engineered system. As an alternative to the deterministic design approach, a hybrid approach consisting of probabilistic Bayesian hierarchical decomposition together with multi body computational model to assess the risk associated with an embedded discrete anomaly, Fig 2. To determine the life of the system we first decompose the life of the disk into the multi-level description consisting of processes, processing design parameters, material and stress states and the multifunctional requirements. The linking between the scales is obtained through acyclic Bayesian network of the decomposed state. The process design parameters (such as temperatures, velocities, preform design etc.) and the material state (anomaly motion and rotation during forge processing) is linked to the failure state via multibody computational modeling of the embedded inhomogeneity in a self-consistent titanium matrix. The location, orientation and morphology of this anomaly with respect to the imposed stress state determine the failure risk associated with processing of heterogeneous material [6].

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