論 文 の 内 容 の 要 旨

論文題目　Meso-Mechanics of Aluminum Die Cast for Fatigue Life Prediction
(疲労寿命予測のためのアルミダイカスト材料のメゾメカニクス)

氏　　名　ビダハール　スジット　クマール

High pressure die casting of aluminum makes it possible to attain complex, multifunctional components which are increasingly used in automobile parts owing to its high specific strength. The use of aluminum casting alloys is widespread in different fields of applications such as automobile, aerospace etc. However such casting process induces various defects such as porosity and cold flake which affect the strength of material. The fatigue performance of these alloys is strongly influenced by the presence of such defects. So it is important to know how pore content, its distribution, location and geometry of individual gas pores will affect fatigue failure of the component. The purpose of this research is to develop a prediction model for fatigue crack initiation and to quantify threshold values for the various parameters. Since there are many parameters like defect size, geometry, location, notch radius etc., which affects fatigue life, it is necessary to carry out a systematic study of each of these parameter for a casting defect and incorporate them into a single simple model. It is proposed that local stress concentration factor can be used to predict fatigue life correctly and can even be used to identify fatigue crack prone gas pores. Although the concept is not new but it has not been applied to real component. In this research attempt is made to apply this methodology of local stress concentration to the test pieces made directly from the car engine block. Fatigue tests are carried these test pieces containing various level of porosity. Fatigue life shows wide spread which makes it difficult to predict the fatigue life of such components by conventional S-N curve. X-ray CT image is taken to get three dimensional geometry reconstruction of actual gas pores which is then used in image based finite element analysis in meso scale, to find out the local stress concentration factors which is then used to get a modified S-N curve to get a better prediction of fatigue lives.

To understand the fatigue crack propagation mechanism in this material scanning electron microscopy and energy dispersion spectroscopy are carried out on fractured surface. It is found that gas pores are the dominating fatigue crack initiators. The crack initially incubated at the region of highly stressed/strain localized region and proceeds with fine striation mark. But at a later stage as the crack grows, crack is attracted towards the pores which offers weaker path which is formed by intensified local cyclic plastic zones in the matrix due to pore geometry,

pore configurations, pore-pore separations. After this, the crack grows by a sequence of successive pore encounters in mode I.

After having understood the role of stress concentration in fatigue crack propagation, it is required to understand how the stress concentration is affected by porosity, pore configuration and pore geometry. To start with, pair of ideal spherical cavities are considered and the interaction between them is studied using finite element analysis calculation. An empirical formula is developed to show the variation of stress concentration factor with different sizes of pores, inter-pore distance and orientation of pores to loading direction. This model is then applied to multi-pore system and subsequently to actual gas pores in die cast test piece. At this stage, gas pores are considered to be ideal spheres of radii equivalent to the actual volume. Subsequently, the complicated curvatures of the gas pores are also studied. Then this is compared with proposed empirical model. There is a good agreement between the two, implying usefulness and effectiveness of predictive model.