A New Decoupled CFD and FEM Methodology for the Fatigue Strength Assessment of an Engine Head

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A 2200 cc engine head for marine applications has been analysed and optimized by means of decoupled CFD and FEM simulations in order to assess the fatigue strength of the component. The fluid distribution within the cooling jacket was extensively analysed and improved in previous works, in order to enhance the performance of the coolant galleries. A simplified methodology was then proposed in order to estimate the thermo-mechanical behaviour of the head under actual engine operation. As a consequence of the many complex phenomena involved, an improved approach is presented in this paper, capable of a better characterization of the fatigue strength of the engine head under both high-cycle and low-cycle fatigue loadings. The improved methodology is once again based on a decoupled CFD and FEM analysis, with relevant improvements added to both simulation realms. From the CFD side, a new generation polyhedral grid is employed to combine high resolution surface spacing, computational demand, and numerical stability of the CFD simulations, with particular emphasis on the boundary layer representation. The local heat flux distribution is calculated by means of CFD analyses of the coolant galleries, now including the engine block portion, plus the engine head metal cast. In order to tune and improve the accuracy of the numerical forecasts, comparisons are carried out with experiments in terms of local metal cast temperature distribution for steady operation of the cooling circuit. Once again, particular care is devoted to the CFD representation of the boundary layer, both fluid and thermal. At the same time, great attention is paid to the thermal boundary conditions, i.e. the distribution of the heat fluxes among the many components facing the combustion process. In order to improve the accuracy of the CFD forecasts, effects of coolant boiling on the heat transfer forecast are investigated and included in the procedure. As a result, a pointwise heat transfer distribution on the fluid/solid interface is transferred as a boundary condition to a thermo-structural analysis for the evaluation of the fatigue strength of the component. An ad-hoc routine is used to map the CFD computed pointwise distribution of the heat flux on a FEM-optimized grid. From the FEM side, an energy based fatigue strength criterion is now implemented in order to create a design tool capable of predicting the fatigue strength of automotive parts subjected to different thermo-mechanical loadings. Both high-cycle fatigue and low-cycle fatigue regions are analysed, and the proposed methodology is successfully applied to predict the site of crack nucleation on an actual engine head and to improve the cooling jacket behaviour.

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