Thermal stresses in the charge air coolers generated during the validation process

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ABSTRACT

This work is devoted to research on improving the strength of the charge air cooler design in regards to thermal stress generated during the thermal cycle test. The design of the charge air cooler being the subject of this thesis was created based on a standard concept of design of heat exchangers for limited space in the car for its engine cooling module. However, in this case it was required to have significantly larger dimensions to achieve an adequate level of heat transfer. This had a significant impact on increasing valuesof forces and moments acting on the tubes of the charge air cooler. This, together with the new more demanding parameters of the thermal cycle test, resulted that the charge air cooler cannot meet the new specification requirements. At 50 % of the required number of cycles, tubes are cracking resulting in leaks. Previous test specifications did not assume such a rapid change in the temperature of air flowing through the charge air cooler system, as well as its maximum value which were required by the new test specification.

To solve the problem of cracking tubes, it was decided to develop a computer model simulating the thermal cycle test and to perform parallel experimental tests providing information on the behavior of the charge air cooler tubes during the test. The developed computer model of the charge air cooler has indicated the most heavily loaded areas are the external tubes on the inlet pipe side, which was in line with the failure mode locations on the charge air cooler during testing. Due to the assumptions adopted in the first simulation about an even temperature distribution in the tubes of the inlet side of the charge air cooler, the results of the analysis indicated the greatest stresses on all four external tubes of the inlet side. Measurement data from the experimental tests showed the actual temperature distribution in the tubes not being uniform. The boundary conditions of the computer model were updated with these temperatures, resulting in a correct outcome indicating the maximum stress on the external tubes on the inlet side. Locations of the greatest stresses indicated by the simulation coincided with the locations of cracks in the charge air cooler during the thermal cycles test. This confirms the validity of the computer model. In turn, the experimental tests made it possible not only to determine the impact of a given test parameter on tube deformation, but also created a database defining the relationship between the design of the charge air cooler and the specific conditions of the thermal cycles test. The experimental tests showed how the deformation level of charge air cooler tubes is influenced by a given parameter of the thermal cycles test.

Based on experimental testing and simulation the result of the thermal cycle test can be predicted for a given test specification. Finally, a series of simulations, physical and experimental tests, complemented with measurement data from prototype cars, allowed not to make any design changes in the analyzed charge air cooler. According to the new established time for the change of the charge air temperature to 30 seconds, the charge air cooler positively passed 8 000 test cycles and was approved for series production. The work done has also contributed to the development of new concepts for the design of the charge air cooler improving its strength to thermal stresses.