Aluminium alloys for engine components working at elevated temperatures

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Improvement in performance of the internal combustion (IC) engine for reduction of fuel consumption and CO_2 emissions is highly competitive, and requires an increase in the combustion pressure and temperature within the engines.

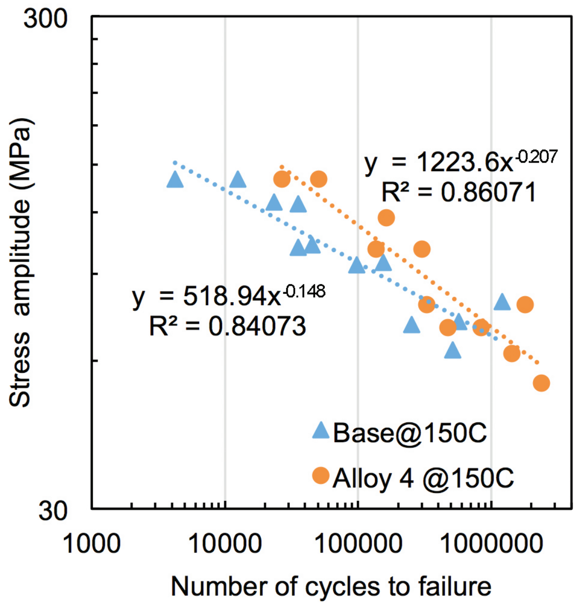

FIGURE 1. Stress amplitude versus the number of cycles to failure obtained from the fatigue tests of the alloy 4 and baseline alloy at 150 °C.

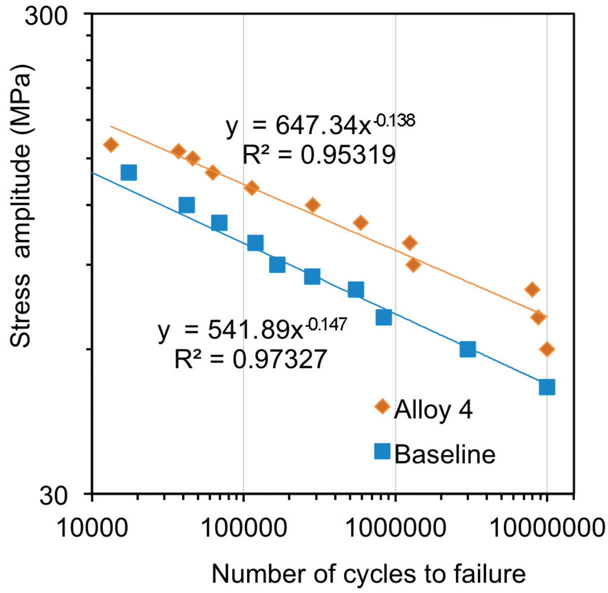

FIGURE 2. Stress amplitude versus the number of cycles to failure for the alloy 4 and baseline alloy conducted at 200 °C.

Therefore, the development of aluminium alloys for improved mechanical performance at elevated temperatures is essential for manufacturing future IC engine parts.

The present project aims to increase the working temperature of aluminium alloys by matching the mechanical properties of the baseline alloy (EN-AC-42000) at 150 °C, with the new alloy at 200 °C. To achieve the defined targets, minor elements including Zr, Mo, Nb, Ni, Hf, Si, Mn, Fe Sc, Cu, V, Ti, RE and others were studied and the new alloy has been developed for industrial applications. For the EN AC-42000 alloy, the yield strength and ultimate tensile strength are 218 and 272 MPa respectively and elongation is 4.86 % at ambient temperature. The yield strength and ultimate tensile strength are 160 and 173 MPa respectively, after exposing the alloy at 200 °C for 40 minutes whilst elongation is increased to 6.6 %. For the newly developed alloy, the yield and ultimate tensile strength and elongation at ambient temperature are 293 MPa, 374 MPa and 5.31 % respectively. The yield and ultimate tensile strength decrease to 232 and 256 MPa and the elongation increases to 6.15 % at 200 °C. More importantly, the fatigue properties at 150 °C and 200 °C are tested and the results are shown in Figures 1 and 2. Clearly, the improvement in tensile strength and fatigue properties for the newly developed alloy are significant. At 200 °C, the fatigue property of the new alloy is 10 times better than the baseline alloy when the stress is fixed at the same level. Meanwhile, for the given cycles, the stress level of the new alloy is 30 MPa higher than the baseline alloy.

The investigation on the strengthening mechanism has shown that the new phases formed at the elevated temperature exhibit minimal coarsening and provide an effective strengthening behaviour to resist deformation at elevated temperatures.

The developed materials have been validated in the small scale testing from the tensile and fatigue properties at room temperature and at elevated temperatures. The demonstration components will then be made and tested in line with industrial partners for application to the cylinder heads of internal combustion engines. The plan for future work will include testing of the alloys for other applications at elevated temperatures.