ON THE DESIGN AND FEASIBILITY OF REFRACTORY METAL-BASE SUPERALLOYS

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Over the last 60 years, the evolution of nickel-base superalloys has enabled successive generations of gas turbine engines to operate at progressively higher temperatures. However, despite continued research activity, capability enhancement has become incremental and it seems unlikely that nickel-base superalloys will be able to support the requirements of future engine designs. Therefore, to enable a step change in operating temperatures, it is necessary to identify and develop new alloy systems, which, in addition to higher temperature capability, also have the correct balance of mechanical and environmental properties. Here, we outline an alloy design philosophy and report on the initial characterisation of one of the potential alloy systems.

High temperature properties are dominated by the melting temperature and crystal structure of the principal element. Thus, only 11 elements offer capability above that of nickel-base alloys. However, if terrestrial abundance and cost are also considered, then only the bcc refractory metals remain as viable options. Intrinsic environmental resistance above 1000˚C can be afforded only by the formation of protective silica or alumina scales, requiring the incorporation of at least one of these elements in reasonable concentrations. In addition the required balance of mechanical properties is only likely to be achieved by the production of a microstructure containing a fine dispersion of small intermetallic precipitates, which have a coherent superlattice structure of solid solution matrix.

The simplest materials identified by this approach are ternary refractory metal-base alloys, e.g. Ta-Al-Co. However, the phase equilibria of these systems, particularly in the refractory rich corners, are poorly defined. To address this issue and explore the potential of these materials, a series of alloys in the Ta-rich corner of the Ta-Al-Co system have been created and characterised following 500 hour heat treatments at temperatures between 1000 and 1300℃. As part of this work the first conclusive evidence of a large-unit-celled Ta_2AlCo phase was obtained, which may give potential for refractory metal-base superalloys.