Material retains springiness at 1,100°C

Dean Palmer reports on a new material for piston rings that manages to retain its springiness properties at temperatures of 1,100°C, leading to potential applications in high temperature turbines and aircraft engines

A UK company has developed the use of a new powder metallurgy alloy, Incolloy MA956, which offers 'springiness' even at temperatures as high as 1,100°C for long periods with good corrosion resistance in hot air. But these same 'springy' properties that hold a piston ring against a bore could also be used to make leaf springs.

The company behind the breakthrough is Cross Manufacturing, which makes piston rings, the majority of these being used, not on piston engines, but as near-to-static seals to contain hot gases on gas turbines. The firm is a major supplier of sealing rings to the aeronautical, automotive and power generation industries.

Rodney Cross, MD of the company told Eureka: "Engine designers are now being forced to work at higher temperatures and piston ring seals are now being used for long periods at or above 700°C. Nickel and cobalt alloys are normally used for these rings, including Nimonic, but above 750°C for long periods they begin to collapse and do not perform properly, which can cause high downtime costs."

So the company decided to look for a new grade of material that could retain its springiness at high temperatures. After consulting with materials experts Cross hired a metallurgy design engineer who began to investigate alternative materials.

MA956 is produced by a mechanical alloying process, which allows the introduction of ceramic materials such as yttria (Y_2O_3) without the use of extreme temperatures. The alloying process has several stages, the first of which is the creation of the individual powders. MA956 uses three powders: an elemental iron powder, a pre-alloyed metallic powder and an yttria powder. The next stage is a dry, high-energy milling process that not only mixes the powders but also alloys them. The final alloyed powder then undergoes hot consolidation and hot extrusion to produce a very fine microstructure.

After re-crystallisation at 1,300°C, MA956 adopts a structure that consists of extremely large grains that are elongated in the direction the material has been worked. And it was primarily this large grain structure, which gives the alloy excellent creep resistance at elevated temperatures, that led to interest in MA956 at Cross.

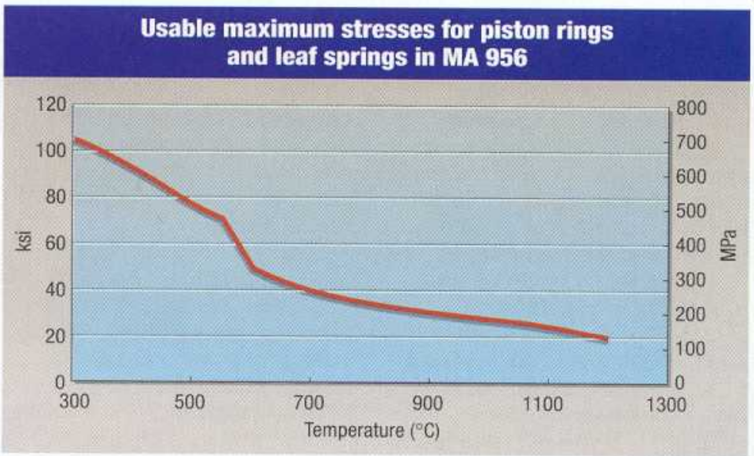
Reliable microstructure

Rodney Cross said that early tests involved using a cold rolling process but difficulties were found in consistently achieving the desired large grain structure in the alloy after it was processed to form rings. More recently, tests using a 'warm' rolling process achieved a better microstructure and produced it reliably.

Cross then produced example rings and leaf springs using MA956. The rings produced were out-springing sealing rings (they seal against the bore rather than the piston). Each ring was designed with a maximum working stress of 80,000lbs/in² when placed in the bore.

The rings were compressed into test bores and subjected to a heat relaxation test. Starting at 300°C the rings were heated for 18 hours and then allowed to cool to room temperature, after which they were removed from the bores and measured. The maximum stress in each ring was then calculated using the free gap measurements – any reduction in working stress (and therefore loss of sealing ability) is shown as a reduction in the free gap of each ring. The rings were then re-compressed and placed back into the oven, which was pre-heated to 350°C, for a further 18 hours. The temperature was increased in this way by 50°C increments up to 1,200°C.

The decrease in stress during the tests (pictured) shows that the rings maintained a degree of their initial working stress even after 18 hours at 1,200°C (around 80% of the melting point of MA956). The total test time was 342 hours, 18 hours at 19 different temperatures. The best performing rings maintained 25% of their initial radial pressure after testing was complete. □



Tests at Cross showed that MA 956 piston rings consistently retained their springiness at extreme temperatures

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- Research suggests that MA956 will outperform its close rivals, materials such as Waspaloy and Haynes 25, that are currently used by Cross in high temperature, high performance sealing applications
- The aerospace industry is already using Cross' MA956 piston rings on high temperature helicopter engines, but other potential applications for the material might include fighter aircraft engines, brazing furnaces for heat exchangers and heat treatment jigs
- MA956 also has excellent oxidation and corrosion resistance due to its aluminium and chromium content