Annexure-B

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
Cleveland, Ohio
U.S.A.

Research Memorandum

Turbojet-Engine Evaluation of AISI-321 and AISI 347 Stainless Steels as Nozzle-Blade Materials

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Summary

As investigation was conducted to evaluate the engine service performance of nozzle-diaphragm of AISI 321 (titanium modified) and of AISI 347 (Columbium modified) stainless steels. Data were obtained from three nozzle diaphragms alternately bladed with each of the two materials. In order to simulate conditions of normal service, the nozzle diaphragms were subjected to 20-minute cycles of engine operation consisting of 5 minutes at idle and 15 minutes at rates speed of the aircraft.

Cracks started as early as 80 cycles (26 hours, 40 minutes) in one diaphragm and as late as 240 cycles (80 hours) in another. After one diaphragm had been operated 319 cycles (106 hours, 20 minutes), 21 of 24 AISI 321 blades and 19 of 24 AISI 347 blades were cracked, but in no case did a complete rupture occurred. The blade cracks, which occurred principally at the edges of the blades, were attributed to thermal stresses and to oxidation by the turbine gas. The cracks progressed and propagated through the material along the grain boundaries. Cracks were also observed in unsound zones of scale in the wells of both alloys on the inner-spacer ring after 80 hours of operation.

Introduction

Stainless steels of the 18% chromium, 8% nickel type have desirable high-temperature properties. One of the disadvantages of these corrosion resistant stainless steels, however, is susceptibility to inter-granular corrosion after exposure to the temperature range between 750°F and 1650°F. The formation at these temperatures of carbide in the grain boundaries of he steel is responsible for the poor resistance to inter-granular corrosion.

The formation of the grain boundary carbides can be reduced by

1. Lowering of carbon content of the steel to the solubility limit of the alloy, or

2. Stabilizing the steel to reduce the carbon available for precipitation.

The first method is self-explanatory; the second method consists in adding elements that have a strong carbide-forming tendency, and will, with the proper heat treatment, form carbides that precipitate in the matrix of the steel. This precipitation reduces the free-carbon content of the matrix and reduces the formation of inter-granular carbides. The stabilization method is more practicable because of the high cost, high rejections and difficulty in producing low-carbon stainless steel turbine blade and nozzle materials.

Titanium and columbium are the elements most commonly used as stabilizers of stainless steels. Investigators and metallurgists have determined that a certain ratio of stabilizing element to carbon is necessary to prevent inter-granular corrosion (reference 2).

Columbium has been widely used in preference to titanium as a stabilizing element because of greater ease of welding during fabrication. Columbium, however, is a critical alloying material and high purity columbium was insufficient in supply for industrial use, whereas titanium is readily available, and therefore, more desirable.

As part of a general evaluation of various heat-resisting alloys for jet-engine and gas-turbine applications, investigations were conducted at the NACA Lewis Laboratory on three turbine-nozzle diaphragms fabricated with alternate blades of AISI 321 and of AISI 347 stainless steel to compare the performance of the two steels under service conditions. The AISI stainless steel was in use as blade material at the time of time of investigation was conducted. Both steels contain approximately 18% chromium and 10% nickel. The AISI 321 and the AISI 347 steels are stabilized with titanium and columbium, respectively. In order to avoid the difficult welding techniques necessary with titanium-stabilized welding rods, the AISI 321 blades were welded with molybdenum steel welding rods containing 19% chromium and 9% nickel. The AISI 347 blades were welded with AISI 347 welding rods.

A cyclic-type engine operation was chosen to simulate the starting and shut down conditions in service conditions in service operation. Each nozzle diaphragm was subjected to the same cyclic conditions. After completing the cycle engine operation, the nozzle diaphragms were metallurgically examined in an attempt to identify the mechanism of failure.

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