SENSITIVITY OF CORE DETECTION IN TURBINE BLADES

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ABSTRACT

Neutron radiography has proven to be a valuable tool for
the detection of residual core material in cast turbine
blades. A series of experiments was designed to determine the
detection sensitivity for various combinations of core and
alloy thickness. The core material samples were of three
types; untreated, doped with gadolinium oxide and tagged with
gadolinium nitrate solution.

The untreated core is not readily imaged in thicknesses
expected to simulate residual core material. The detection
sensitivity for the doped and tagged core samples is fifty
micrograms, equivalent to a sphere of 0.033 cm diameter.
These results can be used to estimate the sensitivity for
residual core detection in other alloys with approximately
similar compositions.

INTRODUCTION

One of the more salient uses of thermal neutron radiography is
the detection of residual core material in turbine blades
fabricated by the investment casting technique. Whereas the
presence of residual core material in the internal passages of gas­
cooled turbine blades was not as critical in the past because of
simpler passages, the extremely high temperature environment in
current engines pushes the turbine blade material mechanical
properties to their limit. Without cooling, the turbine blades would be subjected to overheating and severe loss of durability, which would lead to shortened engine life.

Modern-day turbine engines have blades with convoluted or serpentine coolant passages which provide for greater heat transfer and, therefore, better engine efficiency. In these state-of-the-art engines, residual core material in the coolant passages is not tolerable. Use of borescopes and X-radiography have been ineffective in detecting residual core material, particularly in the newer cores which are mostly silicon dioxide based. The nickel-based superalloys mask the silica from the X-radiographer.

The value of neutron radiography is exemplified by the ability of the technique to highlight the residual core material within the turbine blades. However there is one requirement before the neutron radiographer can pinpoint the offending residue. The core residue must contain a neutron opaque material.

In the early sixties, Watt (1) improved neutron radiographic contrast in turbine blade internal passages by filling the passages with cadmium nitrate solution. Since this solution-filling method was not readily adaptable to production techniques, Mallon (2) experimented with the "doping" of the core bodies with one to ten weight percent of gadolinium oxide in the early seventies. Mallon concluded that this addition of gadolinium oxide is more than sufficient to permit detection of residual core material as small as 1000 micrograms or 0.090 cm in diameter.

Doping is defined as the process whereby neutron absorbing material, such as gadolinium oxide, is added to the core material before the core body is formed. This method, first used as a production process prior to 1976 (3), is the method of choice in terms of ease of use and detection sensitivity, particularly at the 3% doping level.

An alternative method, a proprietary technique for tagging residual core material after the core-leaching (autoclaving) process, has been developed at Aerotest Operations. The tagging technique, adapted for neutron application, had its roots in early 1971 when gadolinium tagging solutions were used to detect cracks in the internal surfaces of hollow metal bodies where borescopes could not probe. After a variety of uses, especially for containers and tubes, the method was applied, in 1974, to the inspection of turbine blades.

The current experimental program was conducted to determine the sensitivity for residual core detection during neutron radiography for both the doped core and tagging processes.