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PROCESSING OF GAS TURBINE ENGINE SHAFTING

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4 Claims

ABSTRACT OF THE DISCLOSURE

Bi-metal gas turbine engine shafting, formed at one end from a high fatigue strength, creep limited low alloy steel such as AMS 6340, and at the other end from a high creep strength age-hardenable nickel base alloy such as Inconel 718, is heat treated in an unconventional cycle to attain and preserve the advantageous mechanical properties at both ends of the shafting.

The invention herein described was made in the course of or under a contract or subcontract thereunder with the Department of the Air Force.

BACKGROUND OF THE INVENTION

The present invention relates in general to bi-metal shafting for gas turbine engines and, more particularly, to the fabrication and processing of such materials.

A number of the advanced gas turbine engines require shafting characterized by high torsional strength at one end and at the other end by high temperature creep resistance. Typical is the shaft interconnecting the low compressor with its driving element at the low turbine end of the engines where shaft temperatures may reach 1100° F. Since alloys having the torsional fatigue strength of steels combined with the high temperature properties of the age-hardenable nickel base alloys simply do not exist, a bi-metal shaft has been developed which incorporates a low alloy steel in the cold section and an austenitic alloy in the hot section. Typically, the respective alloys are metallurgically rather than mechanically joined.

SUMMARY OF THE INVENTION

It is a primary object of the present invention to provide a bi-metal shaft for gas turbine engines, characterized by high torsional strength at one end and by high elevated temperature creep resistance at the other end. In furtherance of the above object, the invention contemplates providing a bi-metal shaft formed at one end from a high fatigue strength, low alloy steel, and at the other end from an age-hardenable, nickel-base alloy of high creep strength; and heat treating the bi-metal shaft in a sequence including the step of simultaneously aging the nickel-base alloy while maintaining the steel in a solutioned condition.

In a particular preferred embodiment, a composite shaft formed at one end from an alloy having a nominal composition of, by weight, about 1% chromium, ½% molybdenum, ½% manganese, ¼% vanadium, ½% carbon, balance iron, and at the other end from an alloy having a composition comprising 18.5% chromium, 18% iron, 5% columbium and/or tantalum, 3% molybdenum, 1% titanium, ½% aluminum, .1% carbon, balance nickel; is solution heat treated at about 1775° F.; air cooled to 1400° F. and held for several hours; water quenched from 1400° F.; and subsequently aged at about 1125° F.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As previously mentioned, there is provided a bi-metal shaft formed at one end from a high fatigue strength,

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low alloy steel and at the other from an age-hardenable high creep strength nickel-base alloy. In order to provide the desired properties, the two alloys which comprise the bi-metal shaft must be heat treated. However, the conventional heat treatments for the low alloy steels and the age-hardenable nickel-base alloys generally differ significantly.

The conventional heat treatment for a low alloy steel, such as AMS 6304 at a nominal composition of, by weight, about 1% chromium, about ½ percent of each of molybdenum, manganese, and carbon, about ¼ percent vanadium, balance iron, is as follows: 1750° F. for 1 hour; water quench; 1125° F. for 6 hours; air cool and 1100° F. and 4 hours; and air cool.

The conventional heat treatment for an age-hardenable nickel-base alloy such as Inconel 718 at a nominal composition of, by weight, about 18.5% chromium, 18% iron, 5% columbium and/or tantalum, 3% molybdenum, .9% iron, .6% aluminum, .1% carbon, balance nickel, is as follows: 1750° F. for 1 hour; air cool or faster; 1325° F. for 8 hours; furnace cool to and hold at 1150° F. for 8 hours; and air cool.

The nature of the joining processes utilized in fabricating the bi-metal shaft usually does not allow conventional heat treatment of the individual alloys prior to joining and the application of two differing heat treatments to separate sections of a joined shaft is not practical. In order to take advantage of the bi-metal concept, therefore, it was necessary to appropriately select materials and devise a single heat treatment cycle which would preserve the yield and fatigue strength of the low alloy steel without compromise of the creep strength of the nickel-base alloy, as provided by the conventional heat treatments for the respective alloys. The processing must also be such as to provide adequate yield and fatigue strength in the nickel alloy.

The alloys were selected on the following basis: a compatible solutioning temperature range; and an overlap between the solutioning temperature range of the steel and the aging temperature range of the nickel alloy. Additionally, a tolerance on the part of the nickel-base alloy to a water quench was indicated.

The above-mentioned alloys, Inconel 718 and alloy AMS 6304, were found to meet the established criteria. They exhibit a compatible conventional solutioning temperature range of 1750°–1800° F. and the water quench from the solution temperature required to develop maximum strength in AMS 6304 can be tolerated in Inconel 718. However, the conventional aging temperature range of 1325°–1375° F. for Inconel 718 is not compatible with the tempering range of 1100° F.–1150° F. for AMS 6304. Furthermore, extensive evaluation has indicated that there is no compromise temperature between 1150° F. and 1325° F. which can reliably provide the required Inconel 718 properties without severely compromising those of AMS 6304 and vice-versa.

A unique heat treatment was devised which for the above alloys employs a 1775° F. solutioning step; air cool to 1400° F. and hold for several hours; water quenching from 1400° F.; and a subsequent tempering at 1125° F. For the AMS 6304-Inconel 718 combination the exact heat treatment was as follows: 1775° F. for 1 hour; air cool to 1400° F., hold for 3 hours; water quench; 1125° F. for 6 hours; and air cool.

The initial solutioning at 1775° F. is in the temperature range wherein the solutioning of the respective alloys overlap. The hold at 1400° F. alloys aging of the Inconel 718 at a somewhat higher than conventional temperature while still maintaining the ASM 6304 austenitic structure formed at the 1775° F. solution temperature. Water quenching from 1400° F. results in the strength inducing

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martensitic transformation in the AMS 6304 while not adversely affecting the Inconel 718. The subsequent 1125° F. treatment tempers the quenched AMS 6304 while the Inconel 718 undergoes some additional aging.

Evaluation of the tensile, fatigue and creep properties of the respective alloys after the above heat treatment indicated that the properties were generally comparable with those provided by the conventional heat treatments for these particular alloys with the exception of the 0.2% yield strength of the Inconel 718 alloy which was somewhat lower than the conventionally heat treated material, but nevertheless more than adequate for the purpose intended.

Of course, the particular times and temperatures for optimum results in the heat treatment sequence will vary depending upon the particular combination of steel and nickel-base alloy being treated. However, the existence of a common solutioning temperature and an ability to simultaneously age the nickel alloy while maintaining the low alloy steel in the solutioned condition will still govern the selection of materials.

While the invention has been described in detail in connection with particular preferred examples and embodiments, these will be understood to be illustrative only. The invention in its broader aspects is not limited to the exact details described, for obvious modifications will occur to those skilled in the art.

What is claimed is:

1. The method of fabricating gas turbine engine shafting which comprises:
 - providing the shafting as a composite structure formed at one end from a low alloy steel and at the other from an age-hardenable nickel-base alloy;
 - heat treating the shafting at a solutioning temperature common to both alloys;
 - aging the nickel-base alloy at a temperature sufficiently high to maintain the steel in the solutioned condition;
 - quenching the shafting;
 - and heat treating the shafting to temper the steel.

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2. The method of fabricating gas turbine engine shafting which comprises:

- providing the shaft as a composite structure formed at one end from a low alloy steel of high fatigue and torsional strength, and at the other from an age-hardenable nickel-base alloy having good high temperature creep resistance;

- heat treating the shaft at a solutioning temperature common to both alloys;

- heat treating the shaft at a temperature within the aging temperature range of the nickel-base alloy but above the austenite-martensite transformation temperature of the steel;

- water quenching;

- and heat treating the shaft to simultaneously temper the steel and further age the nickel-base alloy.

3. The method according to claim 2 wherein the nickel-base alloy consists essentially of, by weight, about 18 percent chromium, 18 percent iron, 3 percent molybdenum, 5 percent columbium/tantalum, 1 percent titanium, ½ percent aluminum, 0.1 percent carbon, balance nickel.

4. The method according to claim 3 wherein:

- the solutioning heat treatment is conducted at a temperature of about 1750–1800° F.;

- the aging heat treatment is conducted at a temperature of about 1400° F.;

- and the tempering heat treatment is conducted at a temperature of about 1100°–1150° F.

References Cited

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