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(54) **METHOD OF STRIPPING A COATING FROM A ROTARY SEAL OF AN AIRCRAFT ENGINE**

VERFAHREN ZUM ENTFERNEN EINER BESCHICHTUNG EINER ROTIERENDEN DICHTUNG EINES FLUGZEUGMOTORS

PROCEDE PERMETTANT DE DECAPER UN REVETEMENT D'UN JOINT ROTATIF D'UN MOTEUR D'AVION

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(56) References cited:

EP-A- 0 165 104	**EP-A- 0 713 957**
DE-C- 4 120 305	**FR-A- 2 281 439**
FR-A- 2 300 142	**GB-A- 2 115 013**
GB-A- 2 220 678	**GB-A- 2 307 427**
US-A- 3 622 391	**US-A- 4 274 908**
US-A- 4 282 041	**US-A- 4 302 246**
US-A- 4 327 134	**US-A- 4 339 282**

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to a method of stripping a coating from an aircraft engine part, in particular, a method of stripping a nickel-aluminum coating from a rotary seal.

BACKGROUND OF THE INVENTION

[0002] A rotary seal controls the passage of air through the core of the aircraft jet engine. Such seals can rotate at a speed of approximately 10,000 to 15,000 rpm, and thus the parts of the seal which interact with stationary parts of the engine will be subject to wear. Accordingly, those parts of the seal, such as seal teeth, are commonly coated with one or more coatings. For instance, the teeth of the seal which interact with the stationary part of the engine can be coated with a nickel aluminum bond coat, and an outer wear-resistant, abrasive coating. The outer coating can be a fused alumina coating. To ensure continued protection of the seal and to provide for inspection of the seal teeth, the coatings must periodically be removed, and replaced with a fresh coating.

[0003] In a known technique for removing coatings from certain parts (the technique referred to hereinafter as ultrasonic stripping), the part is immersed in a stripping solution, and subjected to ultrasonic vibrations. The ultrasonic vibrations cause the surfaces of the immersed part to vibrate, thereby dislodging parts of the coating that have already reacted with the stripping solution, and exposing fresh coating, which can then react with the stripping solution.

[0004] It is known, however, that ultrasonic treatment can potentially reduce the operational life of the part being treated. For instance, vibration of the part induced by the ultrasonic treatment can potentially reduce the high cycle fatigue life of the part.

[0005] In the case of some parts, the reduction in the fatigue life of the part may not be particularly significant. For instance, some parts, such as combustion chamber linings, are stationary, and will typically not experience the dynamic stresses that a moving part will experience during engine operation. It has been proposed to use an ultrasonic treatment in the removal of a heat-resistant coating from a combustion chamber (GB 2 115 013).

[0006] Additionally, it has been proposed to treat certain moving parts with ultrasonic methods. For instance, it is known to use an ultrasonic treatment in the cleaning of a turbine blade (GB 2 220 678).

[0007] A rotary seal is a rotating part, and can be subject to significant dynamic stress during flight. It is desirable to take precautions to ensure that rotary seals do not fail during flight. Accordingly, ultrasonic treatments have not been used on rotary seals. Other methods have been used, in particular, a manual scrubbing process. The manual scrubbing has proved effective for removing parts of the coating that have reacted and exposing fresh coating. However, during one complete stripping process the manual scrubbing may have to be carried out several times, which can be time-consuming and therefore expensive.

SUMMARY OF THE INVENTION

[0008] According to the present invention there is provided a method of stripping a nickel-aluminum coating from a rotary seal, the method comprising immersing the coated seal in a nitric acid stripping solution, and subjecting the immersed seal to ultrasonic vibrations.

[0009] The method may be used on various rotary seals, including but not limited to CDP (compressor discharge pressure) seals and forward outer seals.

[0010] The seal may comprise any suitable metal and/or metal alloy, and may be sintered.

[0011] The nickel-aluminum coating may contain components other than nickel and aluminum. Preferably, the nickel-aluminum coating contains approximately from 90 to 98 wt % nickel and from 10 to 2 wt % aluminum.

[0012] The stripping solution may contain components other than nitric acid. Preferably, the stripping solution contains approximately from 30 to 45 wt % nitric acid, advantageously, approximately from 35 to 40 wt % nitric acid.

[0013] The rotary seal may have a further coating which is an outer coating, in which case, the outer coating is removed prior to immersing the seal in the stripping solution. The outer coating may comprise aluminum oxide. The outer coating can be removed by any suitable method, including but not limited to a dry blasting process or an autoclave process.

[0014] The present invention further provides a method of repairing a rotary seal, the method including stripping a nickel-aluminum coating from the seal by a method according to the invention, and then applying a fresh coating to the seal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015]

Fig. 1 is a cross-sectional, schematic illustration of a rotary seal mounted with a turbine shaft of an aircraft engine, and

Fig. 2 is a schematic diagram of equipment being used to strip a coating from the seal.

DETAILED DESCRIPTION OF THE INVENTION

[0016] A rotary seal which can be stripped of its coating according to the present invention is a CDP (compressor discharge pressure) seal of a gas turbine engine, such as a CFM56 series or GE90 series gas turbine engine. A CDP seal is illustrated schematically in Figure 1.

[0017] The seal 1 comprises a disc 2 having a central aperture 3 and a number of seal teeth 4. The seal 1 is shown mounted with the turbine shaft 5 of an aircraft engine. In use, the turbine shaft 5 rotates, and so rotates the seal 1. The seal teeth 4 interact with a stationary portion of the engine, such as a honeycomb seal land 6 of the engine, to thereby form a labyrinth seal 7 which controls the passage of air through the engine. The seal 1 is made of a nickel-based superalloy. The seal teeth 4 are coated with a thermally-sprayed, double-layer coating comprising a nickel-aluminum bond coat and an aluminum oxide top coat. The nickel-aluminum bond coat contains 95 wt % nickel and 5 wt % aluminum. Each layer of the coating has a thickness of about 0.002 to 0.006 inches (about 0.05 to 0.15mm), although the thickness of the aluminum oxide coating on the tips of the teeth 4 may be greater.

[0018] Figure 2 shows an ultrasonic tank 8 having a number of ultrasonic generators 9 (for example, six, with only two shown for simplicity in Figure 2), a power supply cabinet 10 and a control unit 11. The tank 8 measures about 1.5m length x 1.5m breadth, and is filled with water 12. The tank further contains a liner 13 filled with a nitric acid stripping solution 14 to a depth of about 200mm. The stripping solution 14 is made by mixing equal parts by volume of commercial 70% nitric acid and water.

[0019] Parts of the seal 1 which are not coated are masked, and the aluminum oxide top coat is removed by dry blasting with alumina 220 mesh at 75 to 90 psi (about 0.5MPa to 0.62MPa). It is ensured that no base metal is exposed during blasting.

[0020] The ultrasonic generators 9 are set to 25kHz, and the temperature of the acid is maintained at 25°C. The tank 8 is allowed to run for a minimum of 10 minutes in order to achieve temperature stability and de-aeration of the stripping solution 14 before the seal 1 is placed in the tank 8. The seal 1, mounted on a holder 15, is then lowered into the stripping solution 14, and left for 3.5 to 4 hours. It is ensured that the ultrasonic generators 9 are not turned on or off while the seal 1 is immersed in the stripping solution 14. The seal 1 is then removed from the tank 8. All the nickel-aluminum coating is stripped away. No manual scrubbing is required.

[0021] During the ultrasonic treatment, cavitation bubbles are produced in the nitric acid stripping solution and impact on the seal dislodging the products of reaction with the nitric acid from the seal. It is known that such bubbles form and collapse very rapidly and as a result can create high pressure forces and high temperatures in very limited areas. At Applicants' request, tests were carried out by the National Physical Laboratory (NPL) to assess whether or not the ultrasonic treatment would damage rotary seals. The rotary seals assessed were:

a) GE90 engine series CDP seal, and
b) CFM56 engine series CDP seal.

[0022] The series of fundamental frequencies and harmonics for various modes of vibration of the seals were determined by an impulse excitation technique using a "Grindosonic" Mk V instrument manufactured by Lemmens Elektronika BV of Leuven, Belgium. This instrument is specifically designed to analyze the signal generated from a microphone or piezoelectric transducer to determine the fundamental frequency. This normally corresponds to the strongest signal after all other frequencies have decayed. The signal was passed to a Hewlett Packard Dynamic Frequency Analyser 35665A. This enabled the frequency spectrum to be displayed at a series of triggered time intervals after impact. The measurements were carried out while the rotary seal was suspended in air (i.e., damping was negligible).

[0023] It was found that all fundamental frequencies and almost all the significant harmonics for the GE90 CDP seal, and for the CFM56 CDP seal were below 15 and 18 kHz, respectively.

[0024] Similar results were obtained on the CFM56 CDP seal when immersed in water.

[0025] An FE (finite element) analysis was carried out using a simplified model of the GE90 CDP seal to calculate the seal's natural frequencies for comparison with the results obtained by measurement.

[0026] The frequency distribution in the ultrasonic tank was measured using a calibrated, hand-held frequency meter. It was found that when the frequency was set nominally to 25kHz, the frequency varied throughout the tank from 16

to 23 kHz with the lowest frequency at the center of the tank. It was noted that the bottom of the tank was not flat and the depth of the water at the center was 130mm compared to 210mm at the edges. When an engine part was placed at the center of the tank, the frequency readings taken at this location increased from 16 to 18 kHz. It was therefore concluded that the operative frequency range of the tank is 18 to 23 kHz, and thus that the fundamental frequencies and the associated harmonics of the two rotary seals fall outside the operative range of the tank.

[0027] Each of the two rotary seals was fitted with six strain gauges (3 in the radial direction and 3 in the tangential direction) in order to measure local surface strains during a simulated stripping operation. The test set-up was identical in every aspect to an actual stripping operation except that water was used instead of a stripping solution.

[0028] The locations where the strain gauges were to be bonded were prepared using 320 grade SiC polishing paper followed by chemical cleaning. The strain gauges were glued in place and coated with silicon rubber to make them waterproof. Thermocouples were attached to the rotary seals close to the strain gauge, to measure the surface temperatures during the test.

[0029] The strain gauges had the following specification:

Manufacturer	Tokyo Sokki Kenkyujo Co Ltd
Gauge Type	FLA-6-11
Gauge resistance	120 ± 0.3
Gauge factor	2.12 ± 1%.

[0030] The strain gauges were connected to a System 5000 data acquisition system manufactured by Vishay Measurements Group. This system scans at a rate of 1 ms per scan. Input channels are scanned sequentially at a rate of 25,000 samples per sec and stored in random access memory within a 1 ms window.

[0031] The temperatures of the rotary seals were measured by Type K thermocouples that were calibrated to an accuracy of ± 1°C at a mean temperature of 22°C. The rotary seals temperatures were always in the range 25 to 27°C. The tank temperature was always in the range 23 to 24°C (the notional temperature setting of the tank being 25°C).

[0032] Measurements were taken on both rotary seals in different positions within the tank, in various orientations and sometimes turned upside down. A statistical summary of the strain gauge radings is given in Table 1 where:

G1 Inner -	Radial Strain,
G2 Middle -	Radial Strain,
G3 Outer -	Radial Strain,
G4 Inner -	Hoop Strain,
G5 Middle -	Hoop Strain, and
G6 Outer -	Hoop Strain.

Table 1

Component		G1	G2	G3	G4	G5	G6
GE90 CDP Seal	Max	6	8	6	9	8	7
	Min	-9	-9	-51	-40	-19	-61
CFM56 CDP Seal	Max	11	20	2	71	19	17
	Min	-30	-6	-107	-4	-2	0

[0033] It can be seen from Table 1 that for both rotary seals the strain readings were very small and typically less than 100 microstrain in tension or compression. This corresponds to induced tensile or compressive stresses of 22 MPa (3200 psi) for IN718 material (Inconel 718 - a nickel-based superalloy). Such induced stresses were not considered to be significant.

[0034] In view of the test results given above, it can be seen that the system tested would not in itself cause damage to a non-damaged rotary seal.

[0035] Whilst detailed tests have been described above for checking that two particular rotary seals can be treated in accordance with a particular example of the invention, it should be understood that similar tests could be carried out on other rotary seals to show that they too can be treated in accordance with the invention.

Claims

1. A method of stripping a nickel-aluminum coating from a rotary seal, the method comprising immersing the coated seal in a nitric acid stripping solution containing approximately from 30 to 45 wt % nitric acid, and subjecting the stripping solution to ultrasonic vibrations.

2. A method as claimed in claim 1, wherein the rotary seal is a CDP (compressor discharge pressure) seal.

3. A method as claimed in claim 1, wherein the rotary seal comprises a disc having an aperture, and wherein the rotary seal further comprises a plurality of seal teeth.

4. A method as claimed in Claim 1, wherein the coating contains approximately from 90 to 98 wt % nickel and from 10 to 2 wt % aluminum.

5. A method as claimed in Claim 1, wherein the stripping solution contains approximately from 35 to 40 wt % nitric acid.

6. A method as claimed in Claim 1, wherein the rotary seal has a further coating which is an outer coating and the outer coating is removed prior to immersing the seal in the stripping solution.

7. A method as claimed in Claim 6, wherein the outer coating comprises aluminum oxide.

8. A method as claimed in Claim 7, wherein the outer coating is removed by a dry blasting process.

9. A method as claimed in any one of claims 1 to 8 wherein the rotary seal comprises a plurality of sealing teeth, and the rotary seal having a fundamental frequency; including
   directing said ultrasonic energy to the stripping solution to provide an operative frequency range, wherein the fundamental frequency of the rotary seal is outside the operative frequency range.

10. A method of repairing a rotary seal, the method including stripping a nickel-aluminum coating from the seal by a method according to any one of Claims 1 to 9, and then applying a fresh coating to the seal.

Patentansprüche

1. Verfahren zum Abziehen einer Nickel-Aluminium-Beschichtung von einer Drehdichtung, wobei das Verfahren enthält, dass die beschichtete Dichtung in eine Salpetersäure-Abziehlösung eingetaucht wird, die etwa von 30 bis 45 Gew.% Salpetersäure enthält, und die Abziehlösung Ultraschall-Schwingungen ausgesetzt wird.

2. Verfahren nach Anspruch 1, wobei die Drehdichtung eine CDP (Verdichter-Ausgangsdruck) Dichtung ist.

3. Verfahren nach Anspruch 1, wobei die Drehdichtung eine Scheibe mit einer Öffnung aufweist und wobei die Drehdichtung ferner mehrere Dichtungszähne aufweist.

4. Verfahren nach Anspruch 1, wobei die Beschichtung etwa von 90 bis 98 Gew.% Nickel und von 10 bis 2 Gew.% Aluminium enthält.

5. Verfahren nach Anspruch 1, wobei die Abziehlösung etwa von 35 bis 40 Gew.% Salpetersäure enthält.

6. Verfahren nach Anspruch 1, wobei die Drehdichtung eine weitere Beschichtung aufweist, die eine äussere Beschichtung ist, und die äussere Beschichtung entfernt wird, bevor die Dichtung in die Abziehlösung eingetaucht wird.

7. Verfahren nach Anspruch 6, wobei die äussere Beschichtung Aluminiumoxid aufweist.

8. Verfahren nach Anspruch 7, wobei die äussere Beschichtung durch ein trockenes Blasverfahren entfernt wird.

9. Verfahren nach einem der Ansprüche 1 bis 8, wobei die Drehdichtung mehrere Dichtungszähne aufweist und die Drehdichtung eine Grundfrequenz hat, und wobei

die Ultraschallenergie auf die Abziehlösung gerichtet wird, um für einen Betriebsfrequenzbereich zu sorgen, wobei die Grundfrequenz der Drehdichtung ausserhalb des Betriebsfrequenzbereiches ist.

10. Verfahren zum Reparieren einer Drehdichtung, wobei das Verfahren enthält, dass eine Nickel-Aluminium-Beschichtung von der Dichtung abgezogen wird durch ein Verfahren nach einem der Ansprüche 1 bis 9, und dann eine frische Beschichtung auf die Dichtung aufgebracht wird.

Revendications

1. Procédé pour ôter un revêtement de nickel-aluminium d'un joint rotatif, qui comprend l'immersion du joint revêtu dans une solution de décapage à base d'acide nitrique, contenant d'environ 30 % à environ 45 % en poids d'acide nitrique, et la soumission de la solution de décapage à l'action d'ultrasons.

2. Procédé selon la revendication 1, dans lequel le joint rotatif est un joint de pression de décharge de compresseur (PDC).

3. Procédé selon la revendication 1, dans lequel le joint rotatif est un joint comprenant un disque présentant une ouverture, et comprenant en outre plusieurs dents de joint.

4. Procédé selon la revendication 1, dans lequel le revêtement est un revêtement contenant d'environ 90 à environ 98 % en poids de nickel et d'environ 10 à environ 2 % en poids d'aluminium.

5. Procédé selon la revendication 1, dans lequel la solution de décapage est une solution contenant d'environ 35 à environ 40 % en poids d'acide nitrique.

6. Procédé selon la revendication 1, dans lequel le joint rotatif est un joint possédant un autre revêtement qui est un revêtement externe, et le revêtement externe est ôté avant l'immersion du joint dans la solution de décapage.

7. Procédé selon la revendication 6, dans lequel le revêtement externe est un revêtement comprenant de l'oxyde d'aluminium.

8. Procédé selon la revendication 7, dans lequel le revêtement externe est ôté par un procédé de sablage à sec.

9. Procédé selon l'une quelconque des revendications 1 à 8, dans lequel le joint rotatif est un joint comprenant plusieurs dents de joint et ayant une fréquence fondamentale, ledit procédé comprenant l'apport de ladite énergie ultrasonore à la solution de décapage de manière à fournir un domaine de fréquences de travail tel que la fréquence fondamentale du joint rotatif soit à l'extérieur de ce domaine.

10. Procédé de réparation d'un joint rotatif, qui comprend l'élimination d'un revêtement de nickel-aluminium du joint par un procédé selon l'une quelconque des revendications 1 à 9, puis l'application d'un revêtement frais sur le joint.

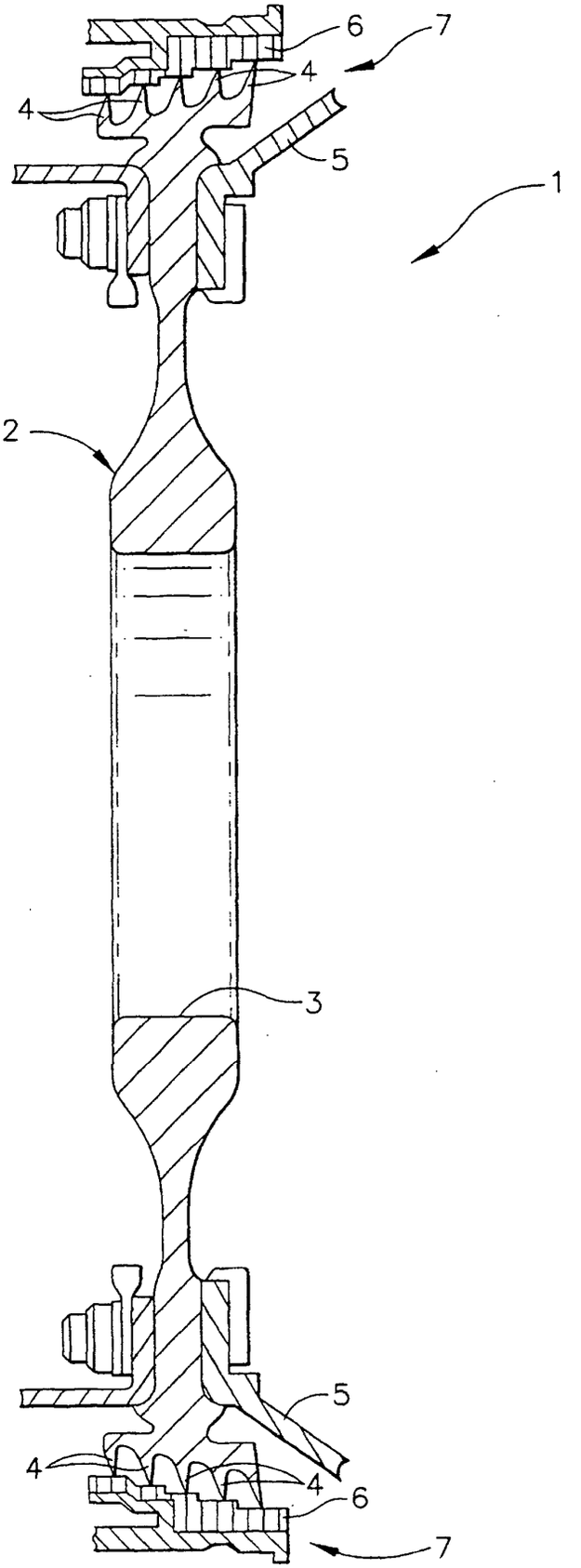


FIG. 1

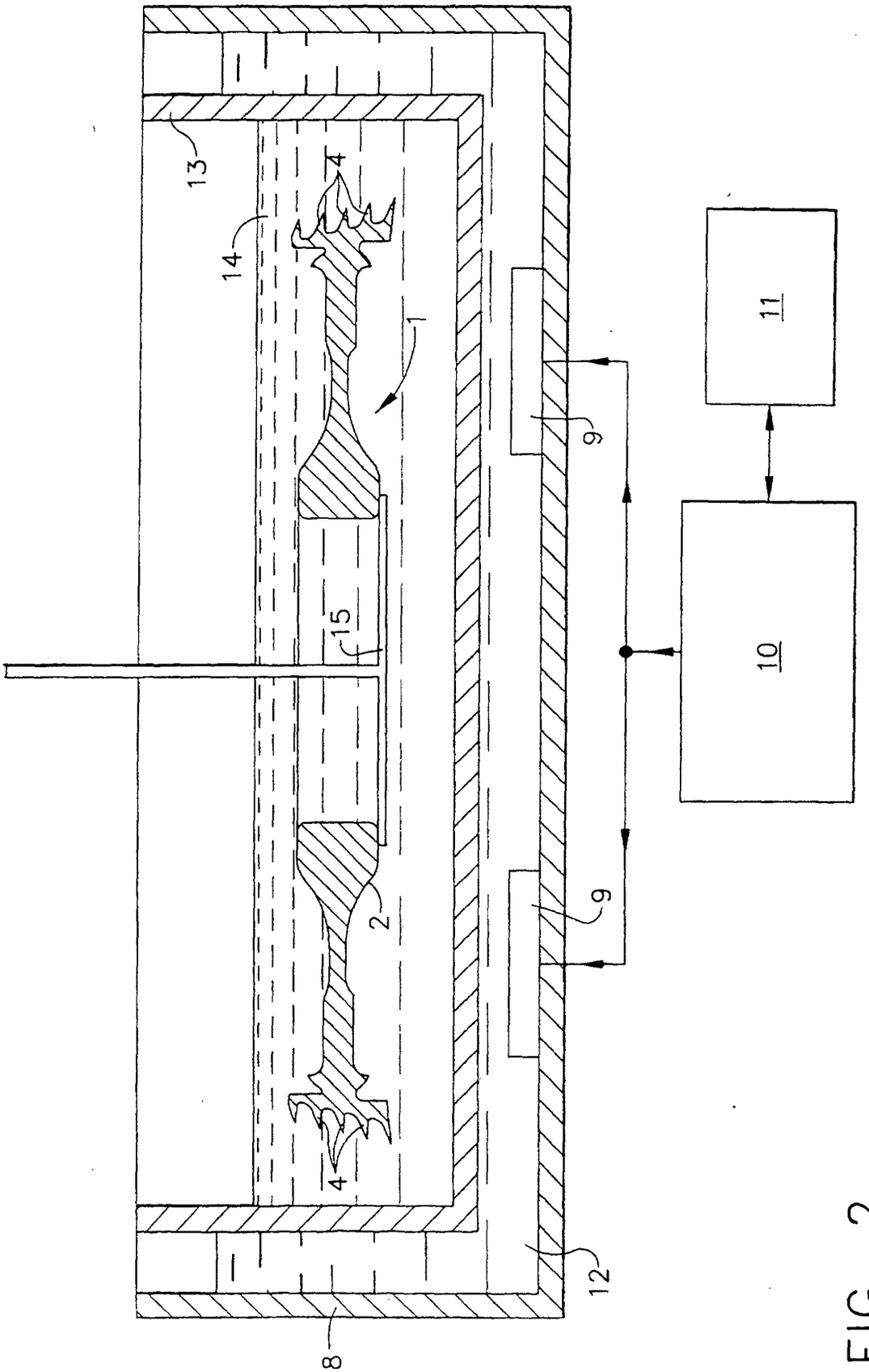


FIG. 2