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METHOD FOR IMPROVING A METAL CASTING

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ABSTRACT OF THE DISCLOSURE

A metal casting of an alloy based on an element selected from the group consisting of Ni, Co, Fe and Ti and having internal discontinuities, such as porosity, microfissures and internal tears, is improved by applying pressure to an outer surface of the casting surrounding the discontinuities while at the same time heating the casting, at least in its portion including the discontinuities, at a temperature less than that which will cause substantial degradation of the mechanical properties of the metal. The casting outer surface is coated with a coating of sufficient thickness to bridge the surface openings of the surface-connected discontinuities and to prevent penetration of the pressurizing fluid into such surface discontinuities. The combined amount of and time of application of pressure and the heating is sufficient to press together and to diffusion bond walls of the discontinuity.

BACKGROUND OF THE INVENTION

Generally, metal castings include porosity, microfissures and internal tears. Porosity and microfissures in castings can be caused by the molding to which the metal was cast being colder than the metal. As a consequence, surfaces adjacent the mold walls, and adjacent to the surfaces of any cores which might be included in the mold, solidify first. Then the metal between such surfaces solidifies. The result is that the central area of the casting between such surfaces is less dense than the metal at such surfaces and can include porosity and microfissures.

Some discontinuities can be tolerated in some castings from which cast articles are made. However, in castings from which are made certain jet engine components, such as turbine blades and vanes which experience relatively severe operating conditions, discontinuities can be cause for rejection of such castings. Any discontinuities will cause less than optimum mechanical properties.

SUMMARY OF THE INVENTION

It is a principal object of the present invention to provide a method for improving a metal casting by eliminating from its internal structure such discontinuities as porosity, hot tears and microfissures.

It is another object of the present invention to eliminate such discontinuities from the internal structure of a casting while at the same time improving its mechanical properties.

These and other objects and advantages will be more clearly understood from the following detailed description and specific examples which are meant to be typical of rather than limiting on the scope of the present invention.

Briefly, the method of the present invention for improving the structural integrity and mechanical properties of the metal casting having discontinuities in its internal structure comprises applying pressure to the outer surfaces of the casting surrounding the discontinuity while at th esame time heating the casting at least in that portion including the discontinuities. The temperature at which heating occurs is less than that which will cause substantial degradation in mechanical properties of the metal. However, the combination of the applied pressure and the heating, for the time of such application is sufficient to press together and to diffusion bond walls of the discontinuities.

In a more specific form, the present invention is particularly useful in connection with the stronger alloys, such as those sometimes referred to as the superalloys based on the transition triad elements Ni, Co and Fe, as well as on Ti. The broad treatment temperature range for such materials is from about 1300–2250° F., depending upon the alloy being treated. The temperature is selected so that, at the pressure for example about 1–30,000 p.s.i. and for the time of application for example about ½ to 16 hours, there will be no substantial degradation in mechanical properties of the metal after treatment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As has been stated, the type of metals with which the present invention is particularly useful are the higher strength alloys based on the elements Ni, Co, Fe and Ti. During evaluation of the present invention, a variety of alloys, including the types the nominal compositions of which are shown in the following Table I, were considered. Where the alloy names are used in the examples which follow, they refer to the nominal compositions shown in Table I.

TABLE I

	Nominal composition (weight percent)															
Alloy	C	Cr	Ti	B	Al	W	Mo	Co	Zr	Ni	V	Si	Cb/TA	Cu	Fe	Mn
Rene' 80	.17	14	5	.015	3	4	4	9.5	.03	Bal.						
Rene' 100	.17	9.5	4.2	.015	5.5		3	15	.06	Bal.	1					
Ti 6-4			Bal.		6						4					
X-40	.5	25.5				7.5		Bal.		10.5						
17-4 PH		16.1								4.1		.75	.27	3.1	Bal.	
AISI 403	.1	12										.4			Bal.	.5

EXAMPLE 1

A study of cast René 80 alloy stress rupture test bars showed that the cast metal had microfissures and internal hot tears. Using a microprobe, it was learned that the microfissures in such castings were in areas rich in titanium and aluminum. Therefore, the porosity in such a superalloy casting appears to be a hot tear in the eutectics that have lower melting temperatures than the balance of the metal matrix.

Some of the cast test bars were treated, according to the present invention, by placing them in an autoclave, evacuating air from the autoclave and then applying pressure to the test bars within the autoclave through an inert gas, in this example argon. At the same time as pressure was applied, the bars within the autoclave were heated to about 2225° F. at which point a pressure of about 10,000 p.s.i. was being applied. The bars were held in the autoclave under these conditions for about 8 hours before cooling and removing.

Microstudies after treatment in the autoclave showed that the walls of the discontinuities, i.e., the microfissures and the internal hot tears, were pressed together and diffusion bonded. Because there was evidence of incipient melting in the material, it is believed the part of the healing of the voids is by incipient melting under pressure to make an integral mass. Therefore, as used herein, the term "diffusion bond" is intended to include within its meaning such incipient melting of the lower melting eutectics in the base metal matrix.

The cast test bars treated as described above were tested in stress rupture along with untreated specimens. Data resulting from such testing is shown in the following Table II.

TABLE II.—STRESS RUPTURE DATA

		1,600° F./45,000 p.s.i.		
Specimen	Condition	Life (hrs.)	El, percent	R.A., percent
1	Untreated René 80 castings	19	2	1
2	do	64	3	4
3	Treated René 80 castings	138	14	24
4	do	134	9	15
5	do	150	14	13
6	do	140	11	17
7	do	147	12	20
8	do	138	9	14

In the above table, the term "El" means "Elongation" and the term "R.A." means "Reduction of Area." Both the untreated and treated specimens were given the same heat treatment of solutioning at 2225° F. for 2 hours in a vacuum then inert gas quenching to room temperature followed by 2000° F. for 4 hours in a vacuum and then inert gas quenching to room temperature. These specimens were aged at 1925° F. for 4 hours then furnace cooled to 1200° F. where they were held for 1 hour prior to air cooling to room temperature. Then they were heated at 1550° F. for 16 hours in argon and then cooled to room temperature.

The data of Table II shows the dramatic increase in stress rupture properties, both in life and ductility, which results from the practice of the method of the present invention on Specimens 3 through 8.

EXAMPLE 2

A cast turbine bucket of René 80 alloy was found through eddy current tests to have subsurface defects which, through fluorescent penetrant tests, were found to be surface connected. These were in amounts sufficient to cause rejection of the casting. Prior to treatment of such casting according to the present invention, the surface of the casting was nickel electroplated to a thickness of about 0.001" to bridge the openings of surface connected defects and thus to prevent pressurizing fluid penetration within such surface defects. Then the casting was treated as in Example 1.

After treatment, no defects were located. The casting was sectioned at a location which had shown subsurface voids prior to treatment. No discontinuities were located by microinspection. Stress rupture testing of specimens from this casting and from companion untreated castings showed the same type of improvement as that shown in Table II.

EXAMPLE 3

A casting of René 100 alloy with internal discontinuities was treated in accordance with Example 1 except that the treatment temperature was 2000° F. Examination of the casting after treatment showed that the voids in the casting did not close.

Subsequent treatment of additional defective castings at the temperature of 2225° F. showed that such internal defects did fully close. Therefore, in respect to this type of nickel base superalloy, it is preferred that the temperature of treatment according to the method of the present invention be greater than 2000° F.

EXAMPLE 4

A titanium base alloy having the composition of Ti 6–4 and with internal discontinuities was treated in accordance with the method of Example 1. Although the discontinuities were healed in accordance with the method of the present invention, it was found that such a temperature was too high and resulted in degradation of the properties of the alloy. Heating of such titanium base alloys should not exceed the beta transus temperature of such alloy and should be maintained in the range of about 1300–1850° F. Normally, diffusion bonding of such titanium alloys as Ti 6–4 can be accomplished at about 1750° F. under pressure of about 1000 p.s.i. for 1 hour to complete bonding.

EXAMPLE 5

An iron base alloy of the composition identified by 17–4 PH and having internal discontinuities was treated in accordance with the conditions of Example 1. Although the discontinuities were healed in accordance with the method of the present invention, it was found that the temperature of 2225° F. resulted in degradation of the mechanical properties. Therefore, treatment of such alloys should be conducted at about 2000° F. or less. For example, an undesirable delta ferrite will form in alloys such as AISI 403 stainless steel, at about 2100° R. or above. Therefore, it is believed that these alloys should be treated at about 2000° F. or less, for example at about 5000 p.s.i. for about 1 hour.

Treatment according to the present invention of the various types of metal castings described above and which included internal discontinuities such as pores, microfissures and internal tears resulted in the production of sound metal castings. In addition, the treatment produced significant improvement in mechanical properties compared with ordinary castings. Such treatment did not substantially affect the external configuration of the casting but merely resulted in a densification of the metal.

Although the present invention has been described in connection with the above specific examples, it will be understood that the application of heat and pressure and the combination of the two can vary over relatively wide limits so long as the applied temperature is less than that which will cause substantial degradation in mechanical properties of the metal and that the pressure applied to the outer surface is sufficient to cause for example, creep in the metal at the selected temperature. If it is desired to seal surface connected voids, the method of the present invention contemplates first coating the surface of the casting to bridge surface openings of such voids.

What is claimed is:

1. A method for improving the structural integrity and mechanical properties of a metal casting of an alloy based on an element selected from the group consisting of Ni, Co, Fe and Ti and having in its internal structure surface-connected discontinuities, defined by discontinuity walls, and having surface openings through a casting outer surface, comprising the steps of:

coating the casting outer surface with a coating of sufficient thickness to bridge the surface openings of the surface-connected discontinuities and to prevent pressurizing fluid penetration within such surface-connected discontinuities;

heating the casting at least in its portion including the discontinuities at a temperature less than that which will cause substantial degradation of mechanical properties of the metal; while at the same time,

applying pressure through a fluid uniformly to the casting outer surface sufficient to cause creep in the metal at the temperature; and then

holding the casting at the temperature and pressure for a time until discontinuity walls are pressed together and diffusion bonded.

2. A method as in claim **1** in which:

(a) the temperature of heating is

(i) no greater than the incipient melting point of the alloy and up to about 2,250° F. when the element selected is Ni or Co,

(ii) less than 2,100° F. and the temperature at which delta ferrite would form when the element selected is Fe, and

(iii) up to about 1,850° F. and less than the beta transis temperature when the element selected is Ti;

(b) the pressure is applied through a fluid and is at least about 1,000 p.s.i.;

(c) the time of applied pressure and temperature is at least about ½ hour.

3. A method as in claim **2** in which:

the alloy is a nickel base alloy;

the temperature of heating is in the range of greater than 2000° F. up to about 2250° F.;

the pressure is applied through a gas and is in the range of about 1000–30,000 p.s.i.; and

the time of holding the casting at such temperature and pressure is about ½–16 hours.

4. A method as in claim **2** in which:

the alloy is an iron base alloy;

the temperature of heating is in the range of about 1500° F. up to less than 2100° F.;

the pressure is applied through a gas and is in the range of about 1000–30,000 p.s.i.; and

the time of holding the casting at such temperature and pressure is about ½–16 hours.

5. A method as in claim **2** in which:

the alloy is a titanium base alloy;

the temperature of heating is in the range of about 1300–1850° F.;

the pressure is applied through a gas and is in the range of about 1000–30,000 p.s.i.; and

the time of holding the casting at such temperature and pressure is about ½–16 hours.

6. The method as in claim **5** in which the temperature of heating is in the range of about 1450–1750° F.

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