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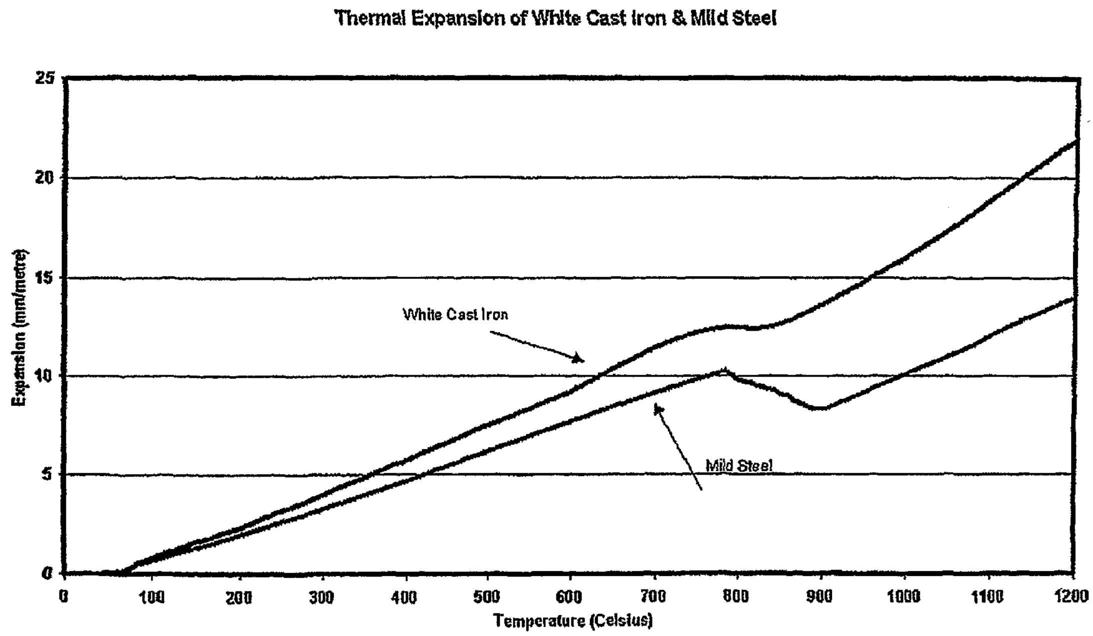
(54) Title: METHOD OF JOINING MATERIALS



(57) Abstract: A process for joining together two components is disclosed. One component is an outer component made from a first material having a first coefficient of thermal expansion. The second component is an inner component made from a second material having a second coefficient of thermal expansion. The process relies on differences in thermal expansion of the materials to bring mating surfaces of the components into close contact with a metallurgical bonding material so that the bonding material is shielded from contact with the atmosphere. Consequently, the bonding process is not affected adversely by reactions between the bonding material and oxygen.

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METHOD OF JOINING MATERIALS

The present invention relates to joining together components made from different metals and/or alloys.

In particular, although by no means exclusively, the present invention relates to joining together components made from white cast iron alloys and components made from steels.

The components of most mining and processing equipment that are subject to wear (eg slurry pumps, cyclones, and crushers) are produced from wear resistant white cast iron alloys.

Some of the composition specifications for white cast iron alloys are AS 2027, BS 4844 and ASTM A532. Basically, these standards cover 3 families of white cast iron alloy compositions, namely high chromium alloys (27 wt% Cr), nickel/chromium alloys (NiHard alloys), and chromium/molybdenum alloys (15 wt%Cr-3 wt% Mo).

Castings of these white cast iron alloys have high wear resistance and provide good service life for process equipment that is subject to erosion and abrasion wear.

These wear resistant white cast iron alloy castings can weigh up to 10 tonnes or more and consist of two distinct parts, namely: (a) areas that are subject to erosion or abrasion wear; and (b) regions that are structural components of the casting and not subject to abrasion wear.

During manufacture some of the structural components of these castings are subjected to drilling, milling and turning to facilitate subsequent fastening of the white cast iron components to processing equipment that is made from other alloys, typically steel.

Such machining operations on these very hard wear resistant white cast iron alloys are extremely difficult and costly to carry out. Furthermore, fabrication and assembly of white cast iron alloy components by welding processes is not practical since these materials readily crack during welding.

US patent 3,355,264 discloses that such difficulties with fabrication of white cast iron alloy components by machining and welding can be overcome in relatively small castings (nominally 0.5 to 50 kg in weight) by vacuum brazing procedures.

The US patent discloses a process that is based on using a copper filler metal at elevated temperatures in a vacuum furnace as a means of metallurgically bonding together white cast iron alloy components and steel backing plates to form composite wear resistant plates.

In a practical form of the process disclosed in the US patent, the process includes positioning a copper shim between the white cast iron alloy and steel components. The assembly of the components and the shim is then heated to a temperature above the melting point of copper. At this temperature, carbides migrate from the white cast iron alloy component to the steel component, with the result that a metallurgical bond forms between the components. In order to avoid oxidation of copper, which is undesirable, it is essential that the assembly be heated in a vacuum furnace.

However, the process disclosed in the US patent is unsuitable for bonding steel plates to large white cast iron alloy castings since vacuum furnaces of the required size are either unavailable or extremely costly to build.

The present invention is a means for producing similar brazed bonds between large white cast iron alloy components and steel components using conventional furnaces and without the need to use vacuum furnaces.

The above-mentioned bonding process disclosed in the US patent occurs by a mechanism known as "constitutional undercooling" which occurs at elevated temperatures (above the melting point of the copper filler metal, namely 1083°C). The vacuum component of the furnace plays a secondary role in the bonding process by excluding the presence of oxygen in the atmosphere from the white cast iron alloy/steel mating surfaces to prevent undesirable oxidation of copper. Thus, the role of the vacuum component in the vacuum furnace is to exclude oxygen and eliminate high temperature oxidation that destroys the bonding process.

In the particular context of white cast iron alloy and steel components, the present invention provides another means of excluding oxygen from the mating surfaces and allowing the same metallurgical bonding process to occur at elevated temperatures in conventional furnaces open to the atmosphere.

In the particular context of white cast iron alloy and steel components, the present invention takes advantage of the differences in thermal expansion of white cast iron alloys and steels to exclude oxygen in the atmosphere from the mating surfaces.

Figure 1 illustrates the thermal expansion curves for a high chromium white cast iron alloy and a mild steel on heating from room temperature to 1200°C. These curves demonstrate that the mild steel has a lower coefficient of thermal expansion than the high chromium white cast iron alloy tested.

In the particular context of white cast iron alloy and steel components, the present invention is based on the realisation that the differences in thermal expansion of white cast iron alloys and steels makes it possible to bring the mating surfaces of an outer steel component and an inner white cast iron alloy component into close contact with a metallurgical bonding metal or alloy, as described herein (such as copper), sandwiched between the white cast iron alloy and the steel of the components with the result that the metallurgical bonding metal or alloy is thereby shielded from contact with the atmosphere.

As a consequence, the assembly can be heated thereafter in an open atmosphere to a temperature above the melting point of the metallurgical bonding metal or alloy to facilitate the above-described bonding process and thereby join together the outer steel component and the inner white cast iron alloy component without concern that the metallurgical bonding metal or alloy will come into contact with oxygen in the atmosphere and be oxidised.

The required thermal expansion to bring the mating surfaces of an outer steel component and an inner white cast iron alloy component into close contact may be achieved by heating the outer steel component and/or by cooling the inner white cast iron alloy component.

The metallurgical bonding metal or alloy may be formed as a coating on one or both of the mating surfaces of the components.

The metallurgical bonding metal or alloy may also be provided in a separate solid form, such as a shim, that is positioned between the mating surfaces prior to thermal expansion and/or contraction of the components bringing the mating surfaces into close contact.

In the particular context of white cast iron alloy and steel components, the term "metallurgical bonding metal or alloy" as described herein is understood to mean a metal or alloy that has a lower melting point than the white cast iron alloy and the steel in the components and is capable of forming a metallurgical bond between the components.

In the broader context of the present invention, namely in the general application of the invention to joining together metallurgically components made from different metals and/or alloys, the term "metallurgical bonding metal or alloy" as described herein is understood to mean a metal or alloy that has a lower melting point than the metals and/or alloys from which the components are made and is capable of forming a high strength metallurgical bond between the components.

In general terms, the present invention provides a process for joining together an outer component made from a first material having a first coefficient of thermal expansion that has a mating surface and an inner component made from a second material having a second coefficient of thermal expansion that has a complementary mating surface that comprises the following steps:

(a) forming a coating of a metallurgical bonding metal or alloy, as described herein, on the mating surface of the outer component and/or the mating surface of the inner component;

(b) heating the outer component and expanding the outer component and/or cooling the inner component and contracting the inner component a sufficient extent so that the outer component can be fitted over the inner component so that the mating surfaces are aligned;

(c) fitting the outer component over the component so that the mating surfaces of the components are aligned;

(d) cooling the outer component and thereby contracting the outer component and/or heating the inner component and thereby expanding the inner component so that the mating surfaces of the components (with the metallurgical bonding metal or alloy on one or both surfaces) come into close contact and thereby form a seal that excludes contact between the atmosphere and the metallurgical bonding metal or alloy, and

(e) heating the assembly formed in step (d) to a temperature above the melting point of the metallurgical bonding metal or alloy and thereby facilitating the above-described metallurgical bonding process and thereby joining together the outer component and the inner component.

The present invention also provides a process for joining together an outer component made from a first material having a first coefficient of thermal expansion that has a mating surface and an inner component made from a second material having a second coefficient of thermal expansion that has a complementary mating surface that comprises the following steps:

(a) heating the outer component and expanding the component and/or cooling the inner component and contracting the component a sufficient extent so that the outer component can be fitted over the inner component so that the mating surfaces of the components are aligned and there is a clearance between the mating surfaces;

(b) fitting the outer component over the inner component so that the mating surfaces of the components are aligned and thereafter fitting a shim of a metallurgical bonding metal or alloy, as described herein, between the mating surfaces;

(c) cooling the outer component and thereby contracting the outer component and/or heating the inner component and thereby expanding the inner component so that the mating surfaces of the components come into close contact with the metallurgical bonding metal or alloy and thereby form a seal that excludes contact between the atmosphere and the metallurgical bonding metal or alloy, and

(d) heating the assembly formed in step (c) to a temperature above the melting point of the metallurgical bonding metal or alloy and facilitating the above-described metallurgical bonding process and thereby joining together the outer component and the inner component.

The coating of the metallurgical bonding metal or alloy may be a continuous or a discontinuous coating on the mating surface of the outer component. It is preferred that the coating be continuous.

The outer and inner components may be any components that are formed from different metals and/or alloys. In addition, the mating surfaces may be any suitable complementary surfaces of the components.

In particular embodiments the mating surface of the outer component is an inwardly facing cylindrical surface.

In these embodiments the mating surface of the inner component is an outwardly facing cylindrical surface.

With the above arrangement of cylindrical surfaces, preferably the outer diameter of the mating surface of the inner component is (a) greater than the inner diameter of the mating surface of the outer component when both components are at room temperature and (b) less than the inner diameter of the mating surface of the outer component when the inner component is at room temperature.

The heating steps (d) and (e) may be carried out in an open atmosphere.

In particular embodiments of the present invention the first material having the first coefficient of thermal expansion is a steel and the second material having the second coefficient of thermal expansion is a white cast iron alloy.

With the above arrangement, preferably the metallurgical bonding metal or alloy is copper or a copper alloy.

Preferably the white cast iron alloy is a high chromium white cast iron alloy having at least 15 wt% chromium.

Preferably the steel is a mild steel.

According to the present invention there is also provided an assembly of two components made from materials having different coefficients of thermal expansion that are joined together at mating surfaces of the components in accordance with the method described above.

The method is described further with reference to the accompanying drawings of which:

Figure 1 is the above-described thermal expansion curves for a high chromium white cast iron alloy and a mild steel on heating from room temperature to 1200°C;

Figure 2 is a perspective view of an assembly of a pump volute made from a white cast iron alloy and a flange made from a steel that are joined together at mating surfaces in accordance with one embodiment of a method in accordance with the present invention;

Figure 3 is a perspective view of part of one half of the volute/flange assembly shown in Figure 2 after sectioning the assembly transversely that illustrates in detail the interconnection of the flange and the volute;

Figure 4 is a perspective view of an assembly of an outer steel ring and an inner white cast iron alloy ring joined together metallurgically in accordance with one embodiment of a method in accordance with the present invention; and

Figure 5 is a photomicrograph of a section through the assembly shown in Figure 4 that shows the microstructure of the metallurgical bond between the outer and inner rings.

The following description of the present invention is in the context of joining together metallurgically a first material, namely a steel, having a first coefficient of thermal expansion and a second material, namely a white cast iron alloy, having a second coefficient of thermal expansion.

Figures 2 and 3 illustrate one practical application of the method of the present invention. The application is to join together a pump volute 3 made from white cast iron alloy and a flange 5 made from steel. Such assemblies are commonly used as parts of slurry pumps for the mining industry. The flange 5 is in the form of a ring that has outer and inner cylindrical surfaces and flat upper and lower surfaces and a series of holes extending through the flange from the upper to the lower surfaces. The inner cylindrical surface forms a mating surface of the flange 5. The flange 5 is formed to fit around a cylindrical end section of an outlet arm 7 of the volute 3. The end section forms a mating surface of the volute 3.

The method of joining the flange 5 and the volute arm 3 includes the following steps.

1. Machining the inner surface of the flange 5 and electroplating or otherwise forming a copper coating to a thickness of 0.01 - 0.1 mm on the surface.

2. Machining the end section of the volute arm 7 to a dimension that is nominally 0.1 - 1.0 mm greater than the diameter of the inner surface of the flange 5 at room temperature.

3. Heating the flange 5 to a temperature of 100 - 400°C in a non-oxidising atmosphere furnace. According to the thermal expansion curves of Figure 1, a 1000 mm I.D. steel ring expands 3.3 mm on heating from 20°C to 300°C and thus the diameter of inner surface of the flange 5 will be greater than the diameter of the room temperature end section of the volute arm 7 and can be fitted over the end section.

4. Removing the heated flange 5 from the oven and immediately placing the heated flange 5 around the end section of the volute arm 7 that is maintained at room temperature. As the heated flange 5 cools it contracts around the end section of the volute arm 7 and forms a tight interference fit at room temperature. Thus, oxygen in the air is excluded from the mating surfaces and, more particularly, from direct contact with the copper.

5. Heating the white cast iron alloy/steel assembly in a conventional furnace to approximately 1120°C and permitting the required bonding process, described earlier as constitutional undercooling, involving migration of carbides from the volute arm 7 into the flange 5 to form a metallurgical bond between the components.

The different thermal expansion coefficients of the white cast iron alloy and the steel of the components means that the volute arm 7 expands more than the flange 5. The relative expansion promotes a tighter fit between the components and thereby reinforces the exclusion of oxygen from contact with copper at all temperatures, ie the interference fit between the two components increases with temperature, thus ensuring that oxygen is excluded at all times from the mating bond surfaces.

Since the strength of the metallurgical bond achieved by this process is greater than the tensile strength of steel, the integrity of the metallurgical bond is maintained on subsequent cooling to room temperature.

The above-described method is a very effective method of joining together white cast iron alloy and steel components and is particularly, although not exclusively suited to joining together large components, ie white cast iron alloy components that are larger than 50 kg.

In order to evaluate the above-described process the applicant joined together an outer ring formed from a mild steel (E02) and an inner ring formed from a white cast alloy (A02) using copper as a metallurgical bonding metal. The resultant assembly of the outer and inner rings is shown in Figure 4.

In the assembly shown in Figure 4 the mating surfaces are the outer cylindrical surface of the inner ring and the inner cylindrical surface of the outer ring. The outer ring has an outer diameter of 250mm. The inner and outer rings each have a radial width of 25mm and an axial width of 40mm.

In order to form the assembly, a coating of copper was formed on the inner cylindrical surface of the outer ring. Thereafter, the two rings were shrink fitted together as shown in Figure 4 and the assembly of the rings was heated in an open atmosphere furnace to a temperature above the melting point of copper and held at that temperature for a sufficient time to allow the formation of a metallurgical bond. Thereafter, the assembly was allowed to cool to an ambient temperature.

Figure 5 is a micrograph of a section through the assembly. The micrograph shows that the bond between the outer ring and inner ring comprises a layer of copper and fingers of carbides extending from the inner ring (of white cast iron alloy) into the copper layer. The microstructure of the illustrated metallurgical bond achieved according to the invention is identical with the microstructure of the metallurgical bond obtained by vacuum brazing techniques described in the prior art.

Many modifications may be made to the preferred embodiment of the present invention described above without departing from the spirit and scope of the invention.

By way of example, the process described above in relation to Figures 2 and 3 includes forming a copper coating on the mating surface of the steel flange 5. The present invention is not so limited and also extends to embodiments in which a copper coating is formed on the mating surface of the volute 3 and to arrangements in which copper coatings are formed on both mating surfaces. Moreover, the present invention also extends to alternative embodiments in which the metallurgical bonding metal or alloy is provided as a separate component, such as a shim formed from copper, that is positioned between the mating surfaces of the outer and inner components.

In a situation in which the outer and inner components are the flange 5 and the volute 3, one such alternative embodiment includes the following steps. The first step is to heat the flange 5 and/or cool the end section of the volute arm 7 to a sufficient extent so that the heated and/or cooled components can be positioned with the mating surfaces of the components aligned and a clearance between the mating surfaces. Thereafter, a copper shim is positioned in the clearance and the flange 5 is cooled and/or the volute 3 is heated so that the mating surfaces come into close contact and form a seal that excludes oxygen from contacting the copper shim. Finally, the assembly of the volute 3, the shim, and the flange 5 is heated to a temperature above the melting point of the copper and thereby facilitates the above-described metallurgical bonding process and joins together assembly.

CLAIMS:

1. A process for joining together an outer component made from a first material having a first coefficient of thermal expansion that has a mating surface and an inner component made from a second material having a second coefficient of thermal expansion that has a complementary mating surface that comprises the following steps:

(a) forming a coating of a metallurgical bonding metal or alloy, as described herein, on the mating surface of the outer component and/or the mating surface of the inner component;

(b) heating the outer component and expanding the outer component and/or cooling the inner component and contracting the inner component a sufficient extent so that the outer component can be fitted over the inner component so that the mating surfaces are aligned;

(c) fitting the outer component over the inner component so that the mating surfaces of the components are aligned;

(d) cooling the outer component and thereby contracting the outer component and/or heating the inner component and thereby expanding the inner component so that the mating surfaces of the components (with the metallurgical bonding metal or alloy on one or both surfaces) come into close contact and thereby form a seal that excludes contact between the atmosphere and the metallurgical bonding metal or alloy, and

(e) heating the assembly formed in step (d) to a temperature above the melting point of the metallurgical bonding metal or alloy and thereby facilitating the above-described metallurgical bonding process and thereby joining together the outer component and the inner component.

2. A process for joining together an outer component made from a first material having a first coefficient of thermal expansion that has a mating surface and an inner component made from a second material having a second coefficient of thermal expansion that has a complementary mating surface that comprises the following steps:

(a) heating the outer component and expanding the component and/or cooling the inner component and contracting the component a sufficient extent so that the outer component can be fitted over the inner component so that the mating surfaces of the components are aligned and there is a clearance between the mating surfaces;

(b) fitting the outer component over the inner component so that the mating surfaces of the components are aligned and thereafter fitting a shim of a metallurgical bonding metal or alloy, as described herein, between the mating surfaces;

(c) cooling the outer component and thereby contracting the outer component and/or heating the inner component and thereby expanding the inner component so that the mating surfaces of the components come into close contact with the metallurgical bonding metal or alloy and thereby form a seal that excludes contact between the atmosphere and the metallurgical bonding metal or alloy, and

(d) heating the assembly formed in step (c) to a temperature above the melting point of the metallurgical bonding metal or alloy and facilitating the above-described metallurgical bonding process and thereby joining together the outer component and the inner component.

3. The process defined in claim 1 wherein the coating of the metallurgical bonding metal or alloy is a continuous coating on the mating internal surface of the outer component.

4. The process defined in any one of the preceding claims wherein the mating surface of the outer component is an inwardly facing cylindrical surface.

5. The process defined in claim 4 wherein the mating surface of the inner component is an outwardly facing cylindrical surface.

6. The process defined in claim 5 wherein the outer diameter of the inner component is (a) greater than the inner diameter of the outer component when both components are at room temperature and (b) less than the inner diameter of the outer component when the inner component is at room temperature.

7. The process defined in any one of the preceding claims wherein the heating steps (d) and (e) are carried out in an open atmosphere.

8. The process defined in any one of the preceding claims wherein the first material having the first coefficient of thermal expansion is a steel and the second material having the second coefficient of thermal expansion is a white cast iron alloy.

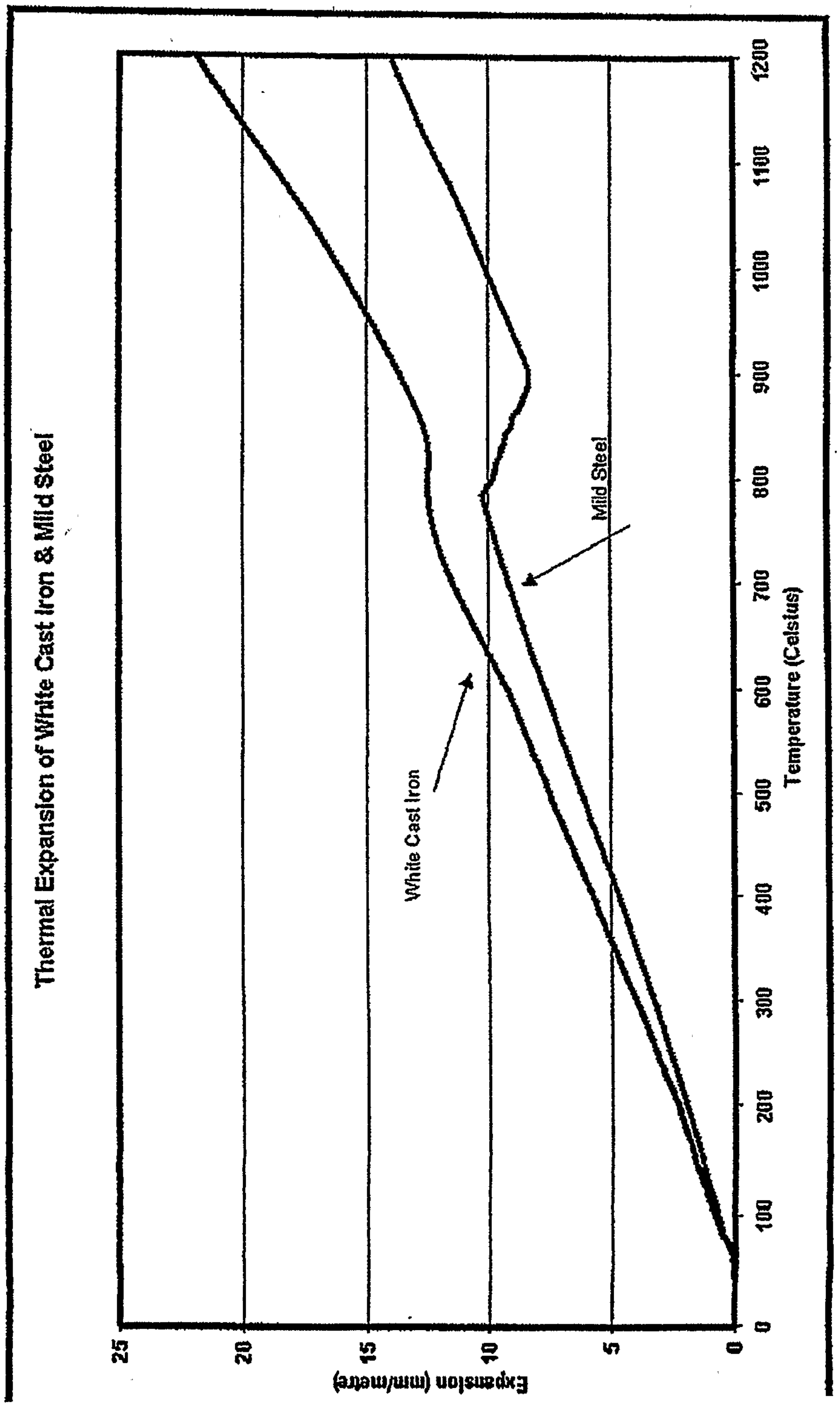
9. The process defined in claim 8 wherein the metallurgical bonding metal or alloy is copper or a copper alloy.

10. The process defined in claim 9 wherein the white

cast iron alloy is a high chromium white cast iron alloy having at least 12 wt% chromium.

11. An assembly of two components made from materials having different coefficients of thermal expansion that are joined together at mating surfaces in accordance with the method defined in any one of the preceding claims.

FIGURE 1


Thermal Expansion of White Cast Iron & Mild Steel
White Cast Iron
Mild Steel
Expansion (mm/metre)
25
20
15
10
5
0
Temperature (Celsius)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200

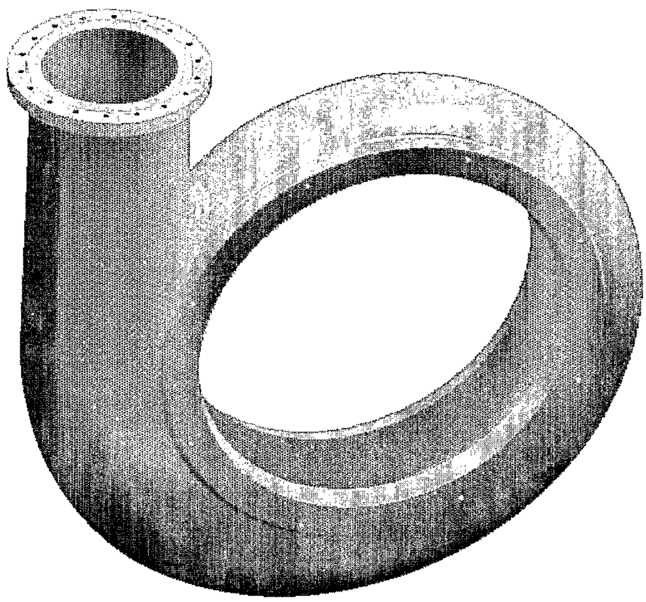


Figure 2

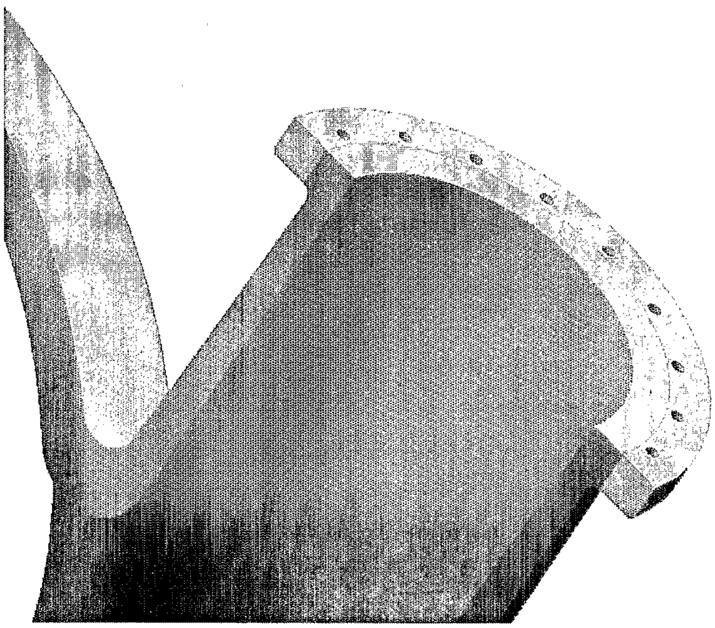


Figure 3

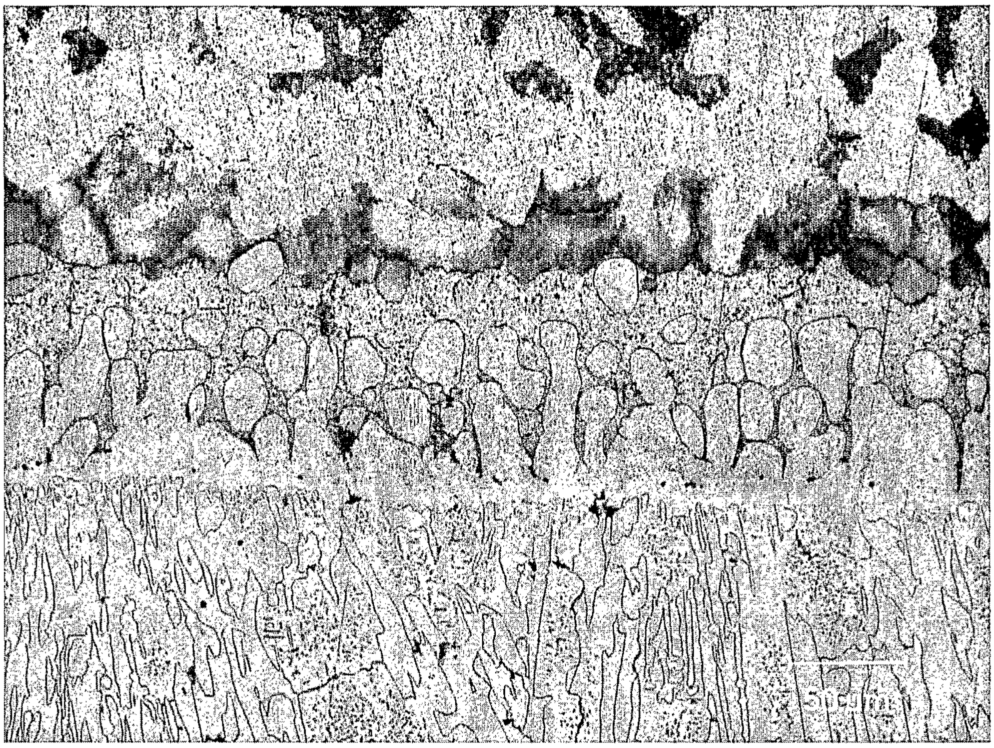


Figure 4

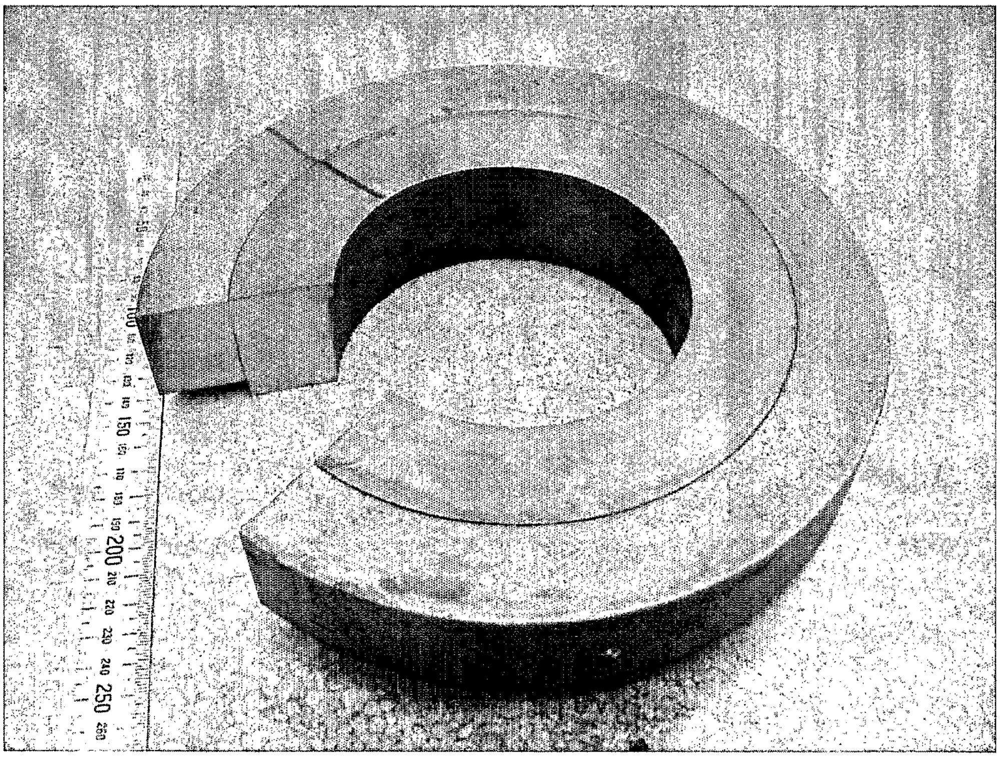


Figure 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2004/000679

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. 7: B23K 1/008, 1/19

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DWPI, JAPIO IPC as above + keywords *braz+, shrink, interfer+, wear, abrasion, ring, collar, flange* and similar other terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Derwent Abstract Accession No. 70133A/39, Class M23, P55 SU 579110 A (ZABOLOTSKII, VM) 23 November 1977 See abstract	1-5,11
X	FR 2638382 A (GEC ALSTHOM SA) 4 May 1990 See abstract	1-5,11
X	Patent Abstracts of Japan JP 64-053765 A (NKK CORP et al) 1 March 1989 See abstract	1-5,11
A	EP 206048 B1 (KAWASAKI JUKOGYO KK) 10 December 1986 See abstract	

[X] Further documents are listed in the continuation of Box C   [X] See patent family annex

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
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- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
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Date of the actual completion of the international search	Date of mailing of the international search report
13 July 2004	27 JUL 2004
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized officer **N. STOJADINOVIC** Telephone No : (02) 6283 2124

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2004/000679

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 568058 A2 (BAUGERAETE-UNION GMBH & CO et al) 3 November 1993 See abstract	
A	DE 4444572 A1 (KUBOTA CORP) 14 June 1995 See abstract	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/AU2004/000679

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
SU	579110						
FR	2638382	CH	681214				
JP	64053765						
EP	0206048	AU	58423/86	CA	1260551	CN	86103742
		JP	61283416	JP	62061721	JP	62061722
		JP	62061733	JP	62062078	US	4727641
EP	0568058	DE	4214298				
DE	4444572	FR	2713740	GB	2295568	JP	7155937
		US	5513794				

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX