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ZIRCONIUM TO STAINLESS STEEL CONNECTION

Filed June 10, 1959

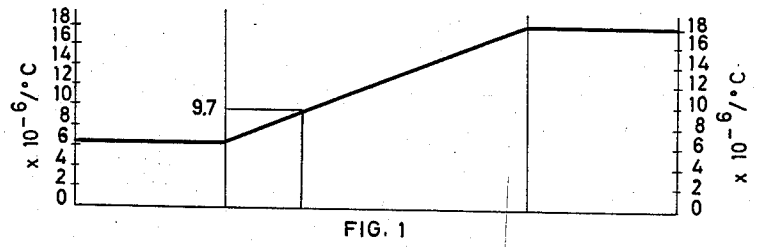


FIG. 1

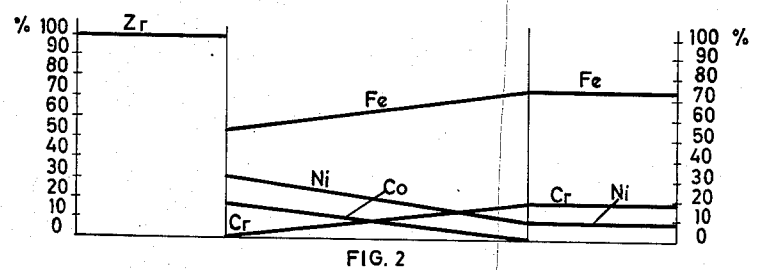


FIG. 2

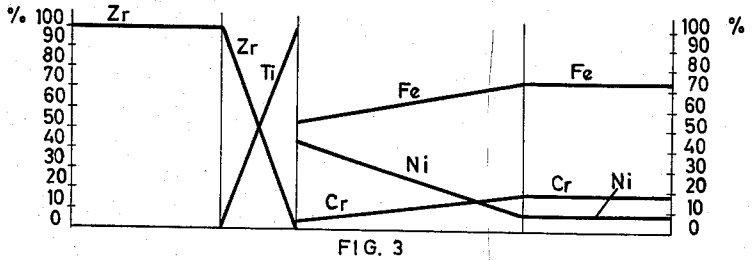


FIG. 3

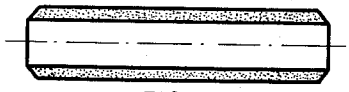


FIG. 4

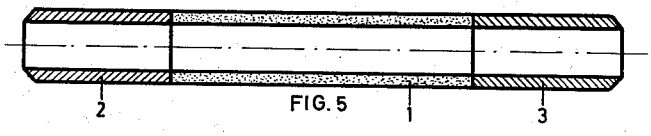


FIG. 5

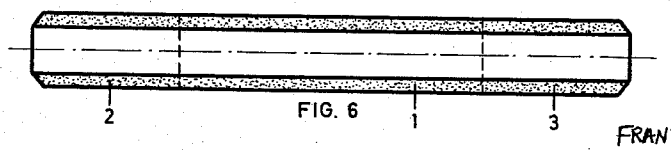


FIG. 6

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ZIRCONIUM TO STAINLESS STEEL CONNECTION

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1 Claim. (Cl. 29—196)

This invention relates to improvements in the methods of welding together different heat-resisting metals or alloys, and more particularly to the welding together of different metals or alloys which have very different expansion coefficients. Such metals or alloys are more particularly employed in thermal or nuclear stations and also in the chemical industry.

It is known that the thermal efficiency of such stations depends to a large extent on the maximum temperature of the fluid which is employed in the stations. Such a temperature is limited by the characteristics at high temperature of the materials used in the construction of the apparatus of the said stations. Among the metals or alloys having favourable mechanical and chemical characteristics at high temperatures, the following may be mentioned in the increasing order of their resistance to high temperature:

Ferritic steel slightly alloyed with Cr—Mo, Cr—Mo—V;
Stainless ferritic steel with 12% Cr, improved by additions of Mo, V, Nb, W;
Austenitic steels of the type 18Cr/8Ni;
Refractory alloys Fe—Cr—Ni; Co—Ni—Cr—Fe; Ni—Cr; Co—Cr—Ni;
Metals with a high melting point: Be, Ti, Zr, V, Nb, Mo, Ta, W;
"Cermets" (i.e. combinations of metallic powders and powders of oxides, carbides, silicates and nitrides);
Hard intermediary compounds, for instance Cr_2Ti, $MoSi_2$.

From the point of the welding itself, the said metals and alloys have the following drawback: their expansion coefficients vary within very wide limits, as shown by the following examples giving the average expansion coefficient between 20° and 500° C.:

Tungsten	4.6×10^{-6}
Molybdenum	6×10^{-6}
Zirconium	6.4×10^{-6}
Titanium	9.7×10^{-6}
Steel with 12% Cr	12×10^{-6}
"Nimonic 80" (registered trademark)	13.7×10^{-6}
Ferritic steel	14×10^{-6}
Beryllium	16×10^{-6}
Steel 18/8	18×10^{-6}

Owing to the said large difference between the expansion coefficients, a heterogeneous welding between two metals, such as zirconium and austenitic steel for instance, is the seat of very severe mechanical stresses.

When the welding is periodically heated and cooled, it is subjected to repeated stresses and to plastic deformations which produce microfissures with consequent destruction of the welded joint.

It has previously been proposed by the present applicant to produce a welded joint between ferritic steel and austenitic steel, by using a "transition" piece of variable composition, the expansion coefficient of which increases in a progressive and continuous manner from one end (that of ferritic steel) from 14.10^{-6} (coefficient of expansion of ferritic steel) to 18.10^{-6} (coefficient of expansion of austenitic steel) to the other end of the said transition piece.

According to the said prior method, it is also known to use a pre-fabricated transition piece made by the metallurgy of powders, consisting of three parts, namely a ferritic part, a transition part of variable composition, and an austenitic part.

It has now been found that a welding may be made between two metals or alloys, other than ferritic steel, with use of a transition piece the expansion coefficient of which varies progressively and continuously from that one of the metals or alloys to that of the other metal or alloys.

When the differences between the expansion coefficients of the two metals or alloys of the above types to be welded is great, use is preferably made according to the present invention of a transition piece made by the metallurgy of powders.

The transition piece may preferably be made of alloys Fer-Nickel (ferronickels) of variable composition with suitable additions of chromium and cobalt.

The chromium increases the expansion coefficient, the cobalt reduces it.

The said alloys allow of obtaining all intermediary coefficients between the extreme values of 6×10^{-6} and 18×10^{-6}. The alloys possessing the smallest coefficients contain about 30% of nickel and up to 17% of cobalt, the rest being iron.

The pure ferronickels, without any cobalt addition, with 36 to 48% Ni, have expansion coefficients of the order of 8×10^{-6}.

Coefficients higher than 8×10^{-6} are obtained by lowering the percentage of nickel and increasing the percentage of chromium.

It is possible to obtain a given expansion coefficient by using different compositions, in which the percentages of nickel, chromium and cobalt is varied.

It is possible to obtain a given expansion coefficient by using different compositions, in which the percentages of nickel, chromium and cobalt is varied.

Since the chromium generally increases the resistance to oxidation at high temperature and the cobalt increases the mechanical resistance in a hot state, it is possible to prepare a composition for a given expansion coefficient, with the purpose of increasing either the mechanical resistance, or the resistance to corrosion, or both.

The mechanical resistance in the hot state may be increased by means of small additions of C and elements such as Mo, V, W, Ti, Nb, which form carbides and intermetallic compounds, or by means of additions of oxides, silicates, nitrides.

Elements such as Si and Al may be added in order to increase the resistance to oxidation in a hot state.

Cobalt is an element the presence of which is undesirable in the alloys intended to be used in nuclear stations, owing to the danger of its induced radioactivity; it may be avoided by using for the expansion coefficients lower than 8×10^{-6} (minimum expansion coefficient of the pure ferronickels) an alloy such as zirconium-titanium, the extreme expansion coefficients of which are 6.4×10^{-6} and 9.7×10^{-6}.

Other characteristic features of the invention will appear from the following description of a joint zirconium-austenitic steel, with reference to the accompanying drawings.

In the drawings,

FIG. 1 is a diagram illustrating the expansion coefficient varying from that of zirconium (6.4×10^{-6}) to that of the austenitic steel (18×10^{-6});

FIG. 2 is a diagram showing the variations of the composition from the left end of a transition portion of an alloy 53% Fe–30% Ni–17% Co (coefficient 6.4×10^{-6}) to the composition of austenitic steel (18% Cr–8% Ni) reached at the right end (coefficient 18×10^{-6}) of the said transition portion.

FIG. 3 shows as a modification, the variation of the composition in a transition piece comprising two types of alloys, namely:

(1) An alloy zirconium-titanium occupying the sector of the expansion coefficients from 6.4×10^{-6} (that of zirconium) to 9.7×10^{-6} (that of titanium);

(2) An alloy varying from a composition 54% Fe–42% Ni–4% Cr having an expansion coefficient of 9.7×10^{-6} to a composition of 18% Cr and 8% Ni having a coefficient of expansion of 18×10^{-6}.

FIGURES 4, 5 and 6 show three forms of transition pieces used according to the present invention.

It should be noted that by the use of the metallurgy of powders, it is possible to obtain the desired variable composition of the transition piece, either by using powders of the individual metals, which powders are mixed in the required proportions, or by employing alloys reduced to powder form by atomization and mixed in a suitable manner.

It is also possible to form by the metallurgy of powders, materials the characteristic features of which, both in a cold and in a hot state, are the same as those obtained by the old metallurgy, and it is possible to avoid undesirable elements in an alloy, such as manganese for instance, owing to the large efficient section of capture (12 barns), or to avoid cobalt owing to the danger of its induced radioactivity (half-life 5.3 years), or to avoid solid or gaseous impurities (P, S, O, N).

The metallurgy of powders also allows of introducing special elements into the alloy, of the amount required for obtaining special physical and metallurgical characteristics, such as expansion coefficient, mechanical and chemical resistance, etc., thus affording a facility which the old metallurgy does not offer owing to the serious drawbacks which may follow from such massive additions (segregation, faulty ingots, difficult forging operation).

The transition pieces shown in FIGURES 4, 5 and 6 may all be obtained by the metallurgy of powders.

The piece shown in FIGURE 4 is a monoblock; that of FIGURE 5 comprises a central portion 1, welded by flash welding between a short tube 2 of zirconium made by ordinary methods and a short tube 3 of austenitic steel made also by ordinary methods. The transition piece shown in FIGURE 6 is a monoblock comprising a part 2 of zirconium, a transition part 1, and a part 3 made of austenitic steel, the entire pre-fabricated piece being made by the metallurgy of powders.

Both methods of FIG. 2 and FIG. 3 allow of forming the transition piece, the expansion coefficient of which varies in a continuous manner from the very low value

(6.4×10^{-6}) of the zirconium to the very high value (18×10^{-6}) of the austenitic steel 18/8.

Under such conditions, the difference between the expansion coefficients of two neighboring sections is so small that the stresses produced in the said sections by variations of temperature, are practically suppressed. The danger of crevices or of a rupture of the joint is entirely avoided.

The powder metallurgy lends itself very satisfactorily to the manufacture of such a joint since zirconium, titanium and their alloys, and also austenitic alloys are metals most satisfactorily used in such a technique.

It should be noted that alloys Zr—Ti have a very good mechanical and chemical resistance at high temperature, which resistance may still be increased by small additions of elements such as Cr, Mo, W, Ta, Nb, Sn, V.

The weldings effected with transition pieces according to the present invention radically avoid the danger of deterioration when in service. That is of considerable advantage from the point of view of safety, namely in the case of weldings employed in nuclear reactors.

Another method consists in employing as an alloy in contact with Zr, a ferronickel having 42% Ni the expansion coefficient of which is 7.6×10^{-6}, that is a coefficient near to that of the Zr (6.4×10^{-6}).

The percentage of Ni in certain cases may reach 90% or more.

What I claim is:

A zirconium member connected to an 18–8 chrome-nickel steel member by means of a transition piece which is an alloy which varies continuously and progressively so that the iron varies from 53% at the first end to 74% at a point substantially two-thirds the length of the piece, the nickel varies from 30% at the first end to 8% at said point, the chromium varies from 0% at said first end to 18% at said point and the cobalt varies from 17% at said first end to 0% at said point and the remaining one-third of said piece consisting of an alloy consisting of 74% iron, 8% nickel and 18% chromium which extends from said point to the second end of said piece, said first end being fused to the zirconium member and the second end being fused to said steel member.

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