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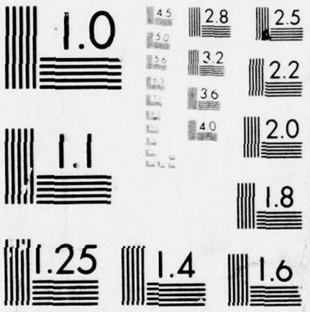

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PRESUMABLE MECHANISM OF THE FORMATION OF A DIFFUSION JOINT OF BONDED METALS OF A HIGH AFFINITY TO OXYGEN

by

W. Karlinski

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PRESUMABLE MECHANISM OF THE FORMATION OF A DIFFUSION JOINT OF BONDED METALS OF A HIGH AFFINITY TO OXYGEN

Wlodzimierz Karlinski

SUMMARY

The article advances the hypothesis that in the case of bonding a diffusion metal and alloys having a high affinity to oxygen, a joint is formed as the result of the chemical reaction of oxides which are found on the surface of the bonded metals or through the formation of solid oxide solutions. Tests were conducted to support the hypothesis, as well as a thermodynamic analysis of interoxide reactions which could take place during the bonding of acid-resisting steels and a heat-resisting alloy.

1. INTRODUCTION

In publications devoted to diffusion bonding the view is often expressed that the fundamental condition in achieving a joint is to have a metallicly pure surface of the joined elements. On account of the considerable affinity of many metals to oxygen, the vacuum used during bonding is often inadequate for the complete removal of oxides from the surface of the metals. For example, dissociation of nickel, chromium, and aluminum oxides at 1273°K occurs respectively under pressures of 10^{-7}, 10^{-18} and 10^{-31} Tr (1). In the opinion of many authors the impossibility of obtaining joints during diffusion bonding of austentitic steels and heat-resisting alloys should be explained. The bonding of these materials requires the use of intermediate layers made of another metal, for example, nickel (2-3), Ni-Be alloy (4), and eventually cobalt or cobalt alloys (5).

However, as a result of the low pressure of oxide pairs and the great speed of oxidation, the metal of the interlayer also probably oxidizes under these conditions. Thus, according to research data (6), at room temperature a monomolecular layer of oxides and adsorbed oxygen forms on steel within $2.4 \cdot 10^{-9}$s under atmospheric pressure or within 0.18s under 10^{-5} Tr, and so is lower than in the majority of cases of diffusion bonding. Bartle (20) admits that the formation mechanism of an intermetallic bond in a case when a vacuum which is used or protective atmosphere are not sufficient in dissociating oxides, is not clear. A test to explain this problem is undertaken in the present research.

2. TESTS

In order to test the formation mechanism of a diffusion joint tests were conducted in bonding rust-proof martensitic steel of the 2H13 type, rust-proof austentitic steel of the type 1H18N9T, the alloy EI437B and Armco iron. The joints were executed on a SD-1 type device manufactured by the Aeronautics Institute at temperatures of 1173-1423°K within 10 minutes. The following bonding variants were used:

a) without an interlayer, the specimens were etched and after washing were immediately placed in a vacuum chamber;

b) without an interlayer, the specimens were degreased after which they were stored in the air for 1-4 weeks and then placed in the chamber;

c) with an interlayer of nickel in the form of a galvanic layer or of foil, the specimens were etched and after washing were immediately placed in the chamber;

d) with an interlayer of nickel, the specimens were degreased after which they were stored in the air for 1-4 weeks and then placed in a chamber.

The results obtained are presented in Tables 1 and 2. From the comparison if follows that good joints were obtained for all the materials

Table 1

Results of Diffusion Bonding of Oxidized Specimens

Material	1H18N9T	2H13	EI437B	Armco Iron	Galvanic Nickel or Foil
1H18N9T	—	+	+	+	+
2H13	+	—	—	+	+
EI437B	+	—	—	0	+
Galvanic nickel or foil	+	+	+	0	—
Armco Iron	+	+	+	0	0

\+ good joint
— no joint
0 bonding not tried

Table 2

Results of Diffusion Bonding of Oxidized Specimens with Etched Specimens

Etched Material	Oxidized Material			
	1H18N9T	2H13	EI437B	Galvanic Nickel or Foil
1H18N9T	—	+	+	+
2H13	+	—	—	+
EI437B	+	—	—	+
Galvanic nickel or foil	+	+	+	—

Fig. 1. Joint 1H18N9T - 2H13 with galvanic nickel interlayer; diffusion bonding parameters: temp. 1223°K, pressure 1.0 kG/mm^2, bonding time 10 min. (x 500)

Fig. 2. Joint 1H18N9T - 2H13 without interlayer; bonding parameters as in Fig. 1 (x 500)

Fig. 3. Joint EI437B - 1H18N9T with galvanic nickel interlayer; diffusion bonding parameters: temp. 1323°K, pressure 1.25 kG/mm^2, bonding time 10 min. (x 500)

Fig. 4. Joint EI437B - 1H18N9T without interlayer; diffusion bonding parameters as in Fig. 3 (x 500)

tested when interlayers were used (in the Tables this is treated as the joining of nickel with several alloys), while without an interlayer--for specimens from various materials with the exception of the pair 2H13-EI437B. The joint was rated on the basis of the result of a tension test.

Fig. 5. Joint EI437B - EI437B with galvanic nickel interlayer. Diffusion bonding parameters as in Fig. 3. (x 500)

Fig. 6. Armco iron - 2H13 joint without interlayer; diffusion bonding parameters: temp. 1123°K, pressure 1.5 kG/mm^2, bonding time 10 min. (x 500)

Joints were considered to be good if the specimens broke up beyond the plane of the joint. In the case of joining identical metals or the 2H13 - EI437B pair the specimens separated when hit by a hammer. (Results of the endurance tests will be published at a later time). It is worthwhile to note that the microstructure and mechanical properties of the joints executed on etched or oxidized specimens were identical.

Examples of good joints are shown in photomicrographs (Figs. 1-6).

3. DISCUSSION OF THE RESULTS

The results obtained confirm the supposition that during diffusion bonding of oxidized metals the process of joint formation occurs (or does not occur) in oxidized layers and not at the distribution limit of the metals. The bonding mechanism of oxides can be twofold, either chemical reactions between the oxides occur, or as the result of dissolution of the oxides, solid oxide solutions form. A third eventuality, namely, the sintering of the oxides was excluded as a result of the following experiment. Degreased specimens of 20 steel before bonding were kept in the air for 10 minutes for the purpose of forming oxides on the surface of the layer. As known (7) at room temperature a Fe_2O_3 type oxide forms on common steel. The specimens were bonded at a temperature of $1173^{\circ}K$ under 2.5 kG/mm^2 pressure. The specimens did not join, because the temperature at the beginning of the sintering of this oxide totals $1113^{\circ}K$ (8) (the temperature regarded as the temperature for the beginning of sintering is that at which spontaneous sintering of the particles begins without external pressure).[1]

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[1] To be sure, the author of the study (9) obtained diffusion joints in common steels during bonding in air, but he used 10 kG/mm^2 pressure, under which the oxide layers crumbled and at the contact points of the specimens a metallic bond was formed.

Let us examine the thermodynamic possibility of a reaction between oxides of the alloying components under diffusion bonding conditions. Oxide formation and interoxide reactions of a given alloying component will be analized during discussion of the individual alloys. In the instance of the appearance of those same oxides in other alloys examined in further considerations only the reactions reckoned to be the most likely will be taken under consideration.

3.1 Oxide Formation on the EI437B Alloy

The alloy EI437B contains 19-22% Cr, 2.4-2.8% Ti, 0.6-1.0% Al, and nickel comprises the rest. According to data of study (10) with respect to oxidation this alloy can be considered a double Ni-Cr 80-20 type alloy, since titanium and aluminum in given quantities do not take part in the formation of oxides. The authors of this study confirmed that the following oxides are formed on an 80-20 alloy oxidized in air: below 673°K --NiO, in the range 773-873°K -- α--Cr_2O_3, higher than 973°K -- the mixture $\alpha-Cr_2O_3 + NiCr_2O_4$ which signifies that a selective chromium oxidation occurs. Using this data it is possible to describe the processes occurring on the surfaces of the EI437B specimens during bonding. Before the specimens are placed in the chamber device their oxidation occurs, which, after the required vacuum has been obtained, becomes partially restrained. The density of the NiO layer on the surface of the specimens will increase during heating up to the moment that 773^{O}K is attained, higher than which the process of selective chromium oxidation and reduction of the nickel oxide NiO begins according to the reaction

$$3NiO+2Cr=Cr_2O_3+Ni \tag{1}$$

or rather with respect to the small oxide content in the vacuum chamber

$$NiO+2Cr+O_2=Cr_2O_3+Ni \tag{2}$$

or

$$2NiO+2Cr+0{,}5O_2=Cr_2O_3+2Ni \tag{3}$$

When examining the probability of the occurrence of the reaction we must take into account the possibility of the formation of a complex spinel type of oxide

$$NiO+Cr_2O_3=NiCr_2O_4 \tag{4}$$

Reaction (1) can be presented as the difference of the auxiliary reactions in the formation of individual oxides from the elements (11):

$$\begin{array}{cr} 2Cr+1{,}5O_2=Cr_2O_3 & \text{(i)} \\ 3Ni+1{,}5O_2=3NiO & \text{(k)} \\ \hline 3NiO+2Cr=Cr_2O_3+3Ni & \text{(1)} \end{array}$$

The thermodynamic potential of reaction (1) ΔG_1° yields

$$\Delta G_1^{\circ}=\Delta G^{\circ}+3\Delta G^{\circ}+2\Delta G_{Cr}-3\Delta G_{Ni} \tag{A}$$

Since the bonding was carried out in a vacuum of $2\cdot 10^{-4}$ Tr, the oxygen pressure equals $pO_2 = 8\cdot 10^{-9}$ atm, which is taken into account in the formula

Table 3. Thermodynamic Potentials of Reactions able to Occur During Diffusion Bonding.

Reaction Symbols in Text	Reaction	Thermodynamic Potential of Reactions		
		pressure 1 atm		vacuum $2\cdot10^{-4}$ Tr
		ΔG_T° cal/mol	source	ΔG_T cal/mol
i	$2Cr+1,5O_2 = Cr_2O_3$	—267750+62,1T	11	—267750+146,7T dla 2H13 * —267750+147,9T dla 1H18N9T *
k	$Ni+0,5O_2 = NiO$	—58450+23,55T	11	—58450+37,2T
l	$Ni+2Cr+2O_2 = NiCr_2O_4$	—342000+83,4T	13	—342000+219,8T
1	$3NiO+2Cr = Cr_2O_3+3Ni$			—92400+23,9T
2	$NiO+2Cr+O_2 = Cr_2O_3+Ni$			—209300+111,0T
3	$2NiO+2Cr+0,5O_2 = Cr_2O_3+2Ni$			—150850+65,4T
4	$NiO+Cr_2O_3 = NiCr_2O_4$	—12930+1,91T	13	—12930+38,9T
5	$NiO+2Cr+1,5O_2 = NiCr_2O_4$			—281000+183,6T
6	$4NiO+2Cr = NiCr_2O_4+3Ni$			—105700+84,8T
7	$FeO+Cr_2O_3 = FeCr_2O_4$	—13750+3,93T	14	—13750+41,0T
8	$3FeO+2Cr = Cr_2O_3+3Fe$			—81600+56,9T
9	$2FeO+2Cr+0,5O_2 = Cr_2O_3+2Fe$			—143650+90,4T
10	$FeO+2Cr+O_2 = Cr_2O_3+Fe$			—205700+123,9T
11	$Fe+0,5O_2 = FeO$	—62050+14,95T	11	—62050+32,2T
12	$2Fe+1,5O_2 = Fe_2O_3$			—199580+157,2T
13	$3Fe+2O_2 = Fe_3O_4$	—265660+76,81T	14	—265660+224,0T
14	$Fe+2Cr+2O_2 = FeCr_2O_4$			—333550+211,8T dla 2H13 * —333550+190,4T dla 1H18N9T *
15	$Fe+Cr_2O_3+0,5O_2 = FeCr_2O_4$	—65800+12,1T	11	—65800+42,5T
16	$Ni+Cr_2O_3+0,5O_2 = NiCr_2O_4$	—68500+22,0T	13	—68500+74,1T
17	$2FeO+NiO+1,5O_2 = NiCr_2O_4$	—47000+1,0T	14	—47000+93,5T
18	$Ni+2Fe+2O_2 = NiFe_2O_4$	—259500+88,0T	14	—259500+230,0T
19	$Ni+2FeO+O_2 = NiFe_2O_4$			—105450+151,7T

*"dla" = for

$$\Delta G_T = \Delta G_T^\circ + 4{,}575 T \Sigma n \lg pO_2 \qquad (B)$$

where Σ n is the algebraic total of the number of moles of the agents in the reaction, whereby for the starting materials "n" has the sign -, while for the products of the reactions, a + .

Assuming that the EI437B alloy is a true solution, or fulfills Raoult's Law, we can write

$$\left.\begin{aligned} \Delta G_{Cr}^\circ &= 4{,}575 \lg C_{Cr} \\ \Delta G_{Ni}^\circ &= 4{,}575 \lg C_{Ni} \end{aligned}\right\} \qquad (C)$$

where G_{Cr} and G_{Ni} are the molar concentrations of chromium and nickel in the alloy.

And so, the final formula for the thermodynamic potential of reaction (1) will take the form

$$\Delta G_1 = G_i^\circ - 3\Delta G_k^\circ + 2\Delta G_{Cr}^\circ - 3\Delta G_{Ni}^\circ + 4{,}575 T \Sigma n \lg pO_2 \qquad (D)$$

and after substitution of the value ΔG_i° and ΔG_k° from Table 2 and the value ΔG_{Cr}° and ΔG_{Ni}° we get

$$\Delta G_1 = -92400 + 23{,}9 \text{ T cal/mol} \qquad (E)$$

The thermodynamic potentials of the remaining reactions were calculated analogously. The starting and calculated data is set forth in Table 3. The values obtained of the thermodynamic potentials of reactions (1) to

(4) are also presented graphically in Fig. 7.

In comparing the thermodynamic potentials of the reactions it can be concluded that at temperatures higher than $973^{\circ}K$, and thus in the range of bonding temperatures, reaction (2) is the most probable, as a result of which a layer of Cr_2O_3 oxide is formed on the surface of the alloy. This is in agreement with the experimental data cited in study (10), where, in the Ni-Cr alloy of the type 90-10, oxidized with a limited access to the air, the appearance of exactly this oxide was stated.

3.2 Bonding the EI437B Alloy with Nickel

During diffusion bonding of the EI437B alloy with nickel on the contacting surfaces Cr_2O_3 is found on EI437B and NiO on the nickel. After applying pressure strict adherence of the joined surfaces is found, which brings about an interruption in the flow of oxygen to the surfaces of the specimens. With regard to the tendency of the structure to attain a state of thermodynamic equilibrium, there occurs a leveling out of oxygen content in the surface layers of the metal and in the oxides as the result of the diffusion of cations. At $1073-1373^{\circ}K$ the diffusion speed of chromium ions in Cr_2O_3 is two times greater than the diffusion speed of nickel ions in NiO (the energy of the activation of Ni diffusion in NiO equals 44 000 cal/mol (15), while for the Cr diffusion in $\alpha - Cr_2O_3$ this quantity equals 22 300

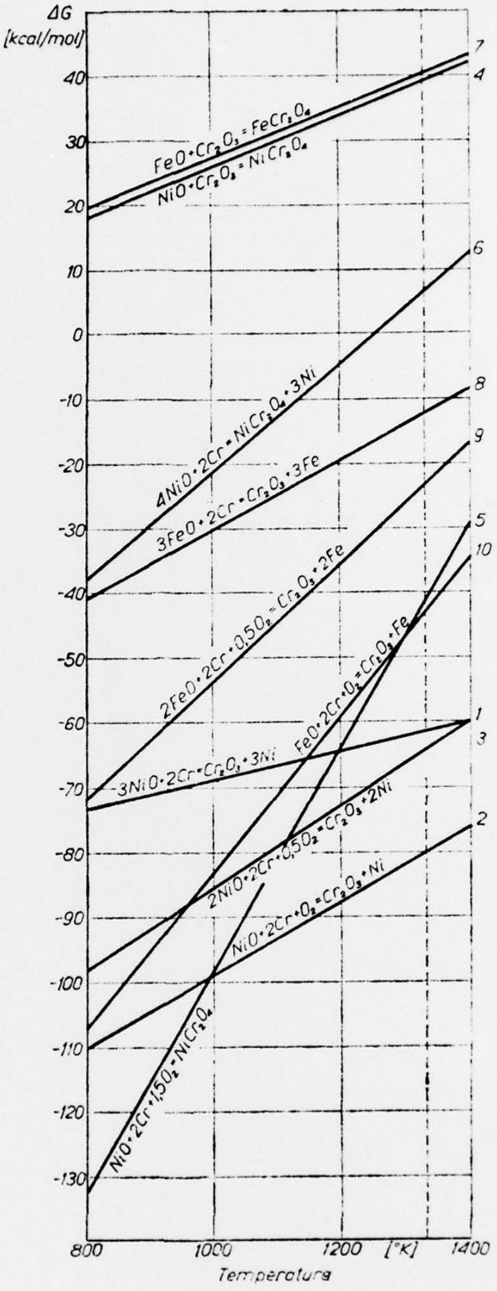

Fig. 7. Thermodynamic potentials of reactions able to take place during diffusion bonding of the EI437B alloy and 2H13 steel with nickel and Armco iron; the broken line indicates diffusion bonding temperature.

cal/mol (10) and consequently, with an equal density of oxide layers, the Cr_2O_3 reduction will run twice as fast. In the case discussed most likely the NiO layer will be thicker than the Cr_2O_3 layer, since the energies of the activation of the oxidation of nickel and the EI437B alloy at 1273-1373^{O} equal 72 800 cal/mol for the alloy (10) and 38 400 cal/mol for nickel (16). After a certain amount of time, when the diffusion process leads to the reduction of the Cr_2O_3 oxide, NiO contact on the nickel with the chromium occurs in the EI437B alloy. In like manner the conditions necessary to begin the chemical reaction between the chromium and the nickel oxide are fulfilled. This can be one of the reactions already discussed (1) - (3) or the reaction of the spinel $NiCr_2O_4$ formation

$$NiO + 2Cr + 1{,}5O_2 = NiCr_2O_4 \quad (5)$$
$$4NiO + 2Cr = NiCr_2O_4 + 3Ni \quad (6)$$

The thermodynamic potentials of reactions (5) and (6), calculated in the same way as for reactions (1) - (4), are presented in Table 3. In the calculations the thermodynamic potentials of the previously presented reaction (II) and the reaction of the $NiCr_2O_4$ formation were used

$$Ni + 2Cr + 2O_2 = NiCr_2O_4 \quad (1)$$

At 1323^{O}K reaction (2) is the most probable, since its thermodynamic potential is the most negative.

D. V. Ignatov and R. D. Samgunova (10) confirmed experimentally, that in the arrangement of NiO -- Cr_2O_3 equilibrium only one $NiCr_2O_4$ compound appears, which is formed at temperatures of 993-1373°K, while at a temperature higher than that, it disintegrates. Since diffusion bonding takes place in a vacuum the disintegration process of the $NiCr_2O_4$ spinel shifted toward the side of the lower temperatures.

A thermodynamic analysis of the diffusion bonding of the EI437B alloy with nickel showed then, that diffusion joints occur as the result of reactions of the reduction of the oxide of nickel by the chromium contained in the EI437B alloy. Warming the specimens after joint formation causes diffusion of chromium to the oxide so that after a lapse of a certain amount of time a complete reduction of the oxide in the joint occurs, while the developing chromium oxide dissolves in the alloy forming a solid solution.

3.3 Bonding of the EI437B Alloy with Armco Iron

Three kinds of oxides FeO, Fe_3O_4 and Fe_2O_3 can be formed on Armco iron and common steels, depending on the temperature. At low temperatures as the result of oxidation Fe_2O_3 is produced, at temperatures higher than 500°K Fe_3O_4 is formed simultaneously with Fe_2O_3. Wustite (FeO) appears in a wide range of temperatures higher than 843°K (8).

Diffusion bonding of the EI437B alloy with Armco iron was carried out when wustite appeared, and consequently the following reactions can take place:

$$FeO + Cr_2O_3 = FeCr_2O_4 \quad (7)$$

$$FeO + 2Cr = Cr_2O_3 + 2Fe \quad (8)$$

$$2FeO + 2Cr + 0{,}5O_2 = Cr_2O_3 + 2Fe \quad (9)$$

$$FeO + 2Cr + O_2 = Cr_2O_3 + Fe \quad (10)$$

From the presentation of thermodynamic potentials of reactions (Table 3 and Fig. 7) it is disclosed that reaction (10) will most probably occur. The reduction mechanism of Cr_2O_3 on the surface of the EI437B alloy to pure chromium will be analogous with the explanation in point 3. 2 in that, instead of NiO in contact with chromium oxide FeO is found. The activation energy of the iron oxidation within the range 773-1373^{O}K equals 33 000 cal/mol (16) while the activation energy of Fe diffusion in FeO is 30 000 cal/mol (15).

3. 4 Oxide Formation on 2H13 Steel

The equilibrium arrangement Fe-Cr-O discloses that a negligible addition of chromium prevents FeO formation. According to F. F. Chimusina (8) Cr_2O_3 oxide or $FeCr_2O_4$ spinel is first formed on steel containing 13% chromium, depending on oxidation conditions.

Let us examine the reactions which can take place in the oxidation process of 2H13 steel in a $2 \cdot 10^{-4}$ vacuum. These reactions will be similar to those discussed particularly for the EI437B alloy

$$2Cr + 1{,}5O_2 = Cr_2O_3 \quad (1)$$

$$Fe + 0{,}5O_2 = FeO \quad (11)$$

$$2Fe + 1{,}5O_2 = Fe_2O_3 \quad (12)$$

$$3Fe + 2O_2 = Fe_3O_4 \quad (13)$$

$$Fe + 2Cr + 2O_2 = FeCr_2O_4 \quad (14)$$

$$Fe + Cr_2O_3 + 0{,}5O_2 = FeCr_2O_4 \quad (15)$$

In reaction (11) instead of FeO, $Fe_{0.95}O$ (11), (14), should be written, but on account of the estimative character of the calculations for reasons of simplification the wustite formula can be taken to be FeO.

As in the case of EI437B we can assume that 2H13 steel is a true solution and fulfills Raoult's Law. The calculated values of thermodynamic potentials of the above named reactions are assembled in Table 3 and graphically presented in Fig. 8. Comparing this data it can be concluded that at temperatures lower than $1164^{o}K$ spinel $FeCr_2O_4$ is formed on 2H13 steel, while at higher temperatures Cr_2O_3 oxide is produced. And so, the mechanism of the formation of diffusion joints of 2H13 steel with other metals will be analogous with the diffusion bonding of the EI437B alloy. The appearance of identical oxides on 2H13 steel and EI437B explains the reason for the negative result of the bonding tests of those materials without an interlayer (Tables 1 and 2).

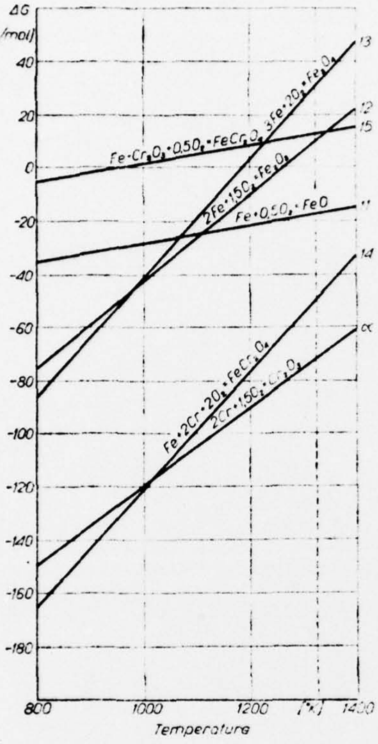

Fig. 8. Thermodynamic potentials of reactions which can take place during bonding of 2H13 steel; the broken line indicates the diffusion bonding temperature.

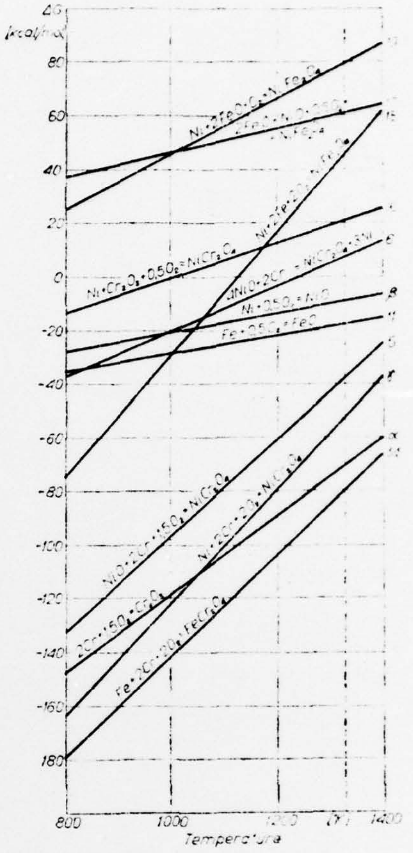

Fig. 9. Thermodynamic potentials of reactions which can take place during oxidation and diffusion bonding of 1H18N9T steel; the broken line indicates diffusion bonding temperature.

3.5 Oxide Formation on 1H18N9T Steel

During oxidation of 1H18N9T steel in a $2 \cdot 10^{-4}$ vacuum oxidation processes of individual steel components can occur according to reactions (i), (k), (l), (5), (6) and (14) already discussed. Moreover, spinel formation reactions can take place

$$Ni + Cr_2O_3 + 0{,}5O_2 = NiCr_2O_4 \tag{16}$$

$$2FeO + NiO + 0{,}5O_2 = NiFe_2O_4 \tag{17}$$

$$Ni + 2Fe + 2O_2 = NiFe_2O_4 \tag{18}$$

$$Ni + 2FeO + O_2 = NiFe_2O_4 \tag{19}$$

Reactions (4), (7), (12), (13) are not examined since they have positive values of thermodynamic potential, and thus cannot take place.

The calculated thermodynamic potentials are assembled in Fig. 9 and given in Table 3. Certainly in this case as well it is presumed that we have to deal with a true solution. Moreover, the possibility of the development of oxides of components appearing in small amounts such as carbon, titanium, manganese and silicon was omitted. The layer of oxides on steel will be composed of $FeCr_2O_4$ and, eventually, of the mixture $FeCr_2O_4$ with Cr_2O_3. This is in accordance with the data cited by O. Kubaschevski and B. E. Hopkins (16), who say that on the surface of 18-8 type steel the spinel $FeO \cdot Cr_2O_3$ is formed. On the other hand, other authors (12, 17) note that a layer of oxides contains nickel ions as well, and consequently, the spinel formula is written (Fe, Ni) O · (Fe, Cr)$_2$O$_3$. This is only an apparent contradiction, since the FeO wustite in iron alloys containing nickel is in actuality the solid solution NiO and Fe_2O_3 in FeO (18), in which the concentration of NiO in the solution depends on the nickel concentration in the alloy and at 1273°K can total from 0 to 1.3%.

3.6 Bonding of 1H18N9T Steel with 2H13 Steel, the EI437B Alloy or Armco Iron

With regard to the lack of thermodynamic data on Fe-Ni-Cr-O alloys making an analysis of reactions occurring during the diffusion bonding of those alloys is impossible. It can only be assumed that joints are produced as the result of disintegration of FeO, which is found on the surface of Armco iron or Cr_2O_3 on chromium steel and the EI437B alloy in the spinel layer on 1H18N9T steel. As the studies of V. F. Balakireva (19) showed, the spinel $FeCr_2O_4$ is in actuality a solid solution of the FeO, Fe_2O_3 and Cr_2O_3 oxides, which (solution) can be presented as $FeCr_{2-x}Fe_xO_4$, where $0 \leqslant x \leqslant 2$. Consequently, during bonding of the oxidized specimens of the above named materials, there will take place an enrichment or reduction of the $FeCr_{2-x}Fe_xO_4$ spinel into chromium, and thus a change in the value of "x" takes place. Nickel wustite (Fe, Ni)O, entering into the composition of the oxide layer on 1H18N9T steel, probably does not take part in joint formation, since in contrast to FeO it does not form solid solutions with $FeCr_2O_4$ (18).

4. CONCLUSIONS

The tests conducted on the diffusion bonding of 1H18N9T and 2H13 steels, alloy EI437B and Armco iron in an oxidized state, as well as the thermodynamic analysis of the interoxide reactions taking place showed that a diffusion joint forms either as the result of the chemical reactions between oxides, or on account of the mutual disintegration of the oxides and the production of solid oxidizing solutions in the zone of joining.

The proposed hypothesis explains why a joint cannot be obtained during diffusion bonding of austentitic steels and nimonic type of alloys without an interlayer, explains the mechanism of joint development by using an interlayer of material having a great affinity to oxygen, for example nickel or cobalt, and gives a new criterium for selecting metal for the interlayer.

In light of this hypothesis it appears that the use of a high vacuum in bonding oxidizing alloys is pointless, since a vacuum or protective atmosphere can only prevent further oxidation of the distribution surface of bonded metals at the time of their joining, so that interoxide reactions could take place. This affords the possibility of simplifying the technology in the majority of the uses of diffusion bonding with the exception of vacuum-tight joints or the joining of oxygen-free metals since this introduction of oxides or a solid solution of oxygen into a joint is inadmissable. In these cases bonded surfaces should be metallicly pure.

Published October, 1972

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Presumable Mechanism of Formation of a Joint in Diffusion Bonded Metals of High Affinity to Oxygen

Summary

In order to analyse the mechanism of formation of a diffusion-bonded joint in alloys of high affinity to oxygen bonding tests have been carried out for the 2H13 (420) and 1H18N9T (18-8) type steels, the EI437B (Nimonic 80A) type alloy and the Armco iron. Some of the specimens were first subjected to oxidation and the remainder to etching in order to remove the oxides. A number of specimens were bonded with an intermediate layer of nickel. All the samples with the intermediate layer and the EI437B — 1H18N9T and 2H13 — 1H18N9T specimens failed in parent metal.

On the basis of the results obtained it is supposed that the specimens undergo oxidation before they are placed into the vacuum chamber and in the course of the heating process before bonding, because the vacuum does not seem to be sufficient for dissociating the oxides. In view of this fact the diffusion joint is not produced as a result of formation of a metallic link but a reaction between oxides or, if such a reaction is impossible, by the formation of a solid oxide solution, as is the case, for instance, of welding Armco iron with 1H18N9T type steel. The impossibility of diffusion welding 2H13 type steel with the EI437B alloy can be explained by the presence of the same oxide (Cr_2O_3) on both surfaces.

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