A New Method of Pack Aluminization

T. Werber, L. Levin, A. Ginzburg, L. Klinger and A. Katsman

*Department of Materials Engineering, Technion –
Israel Institute of Technology, Haifa, 32000, Israel*

ABSTRACT

Aluminium diffusion coatings are often prepared by using a pack aluminization technique, which is a specific variety of the CVD method. The coating process takes place in a bed containing a master alloy (MA) that serves as a source of the coating forming element (CFE). The phase composition of the diffusion layer obtained depends on the activity of the CFE during the pack aluminization processing. One of the methods to control the activity is a variation in the chemical composition of the MA. In this method the MA of the needed CFE concentration is also prepared by using the pack aluminization technique. So the pack aluminization technique is used twice during the processing cycle: once for MA preparation and once for coating. The method was applied to coating of iron with a layer of FeAl.

INTRODUCTION

Iron aluminides are signalized by an excellent corrosion resistance at elevated temperatures in aggressive atmospheres /1-4/. This enables steels and alloys to be protected by means of Fe-Al intermetallic coatings.

In this work iron aluminide coatings were deposited on Iron Armko by pack aluminization. This technique is a specific variant of the CVD method. The coating process takes place in a bed containing a master alloy, which serves as the source of the element providing the coating. Master alloys are usually prepared by melting followed by homogenization and grinding into powder /5-8/. In this process some chemical and phase inhomogeneity arises, so that the effective activity of the bed differs from that originally intended.

In the present work a new method of master alloy preparation was elaborated, which consisted of producing the master alloy itself, too, by the pack aluminization technique, which is thus used twice during the processing cycle, viz. for the preparation of the master alloy and for coating. In this method, prior calculation permits regulation of the activity of the bed: a) using Al powder, which provides a high-activity bed; b) using Fe_2Al_3 or other intermetallics providing a low-activity bed. The actual composition of the bed is selected on the basis of the Fe-Al phase diagram. In this manner the composition of the protective coating can be planned ahead.

EXPERIMENTAL

In the authors' experiments the intermetallic master alloy was produced from Al and Fe powders, following prior blending for 60 mins, at a temperature of 700°C, the powders being of quantities sufficient for yielding Fe_2Al_3 , NH_4Cl serving as activator and alumina as filler.

Pack aluminization of the Iron Armko was applied at 700°C and at 900°C in a high-activity bed (Al powder delivering the coating, NH_4Cl serving as the activator, alumina as filler), as well as in a low-activity bed at 900°C (Fe_2Al_3 as the source of the coating, activator and filler, as before). Some samples, pack-aluminized at 700°C in the high-activity bed, were heat-treated at 900°C with subsequent air-cooling.

The iron aluminide coatings were examined with the aid of optical microscopy, scanning electron microscopy with EDS, and X-ray analysis. X-ray and EDS analysis data match well in all the variants of the pack aluminization process studied as well as in those

Table 1
Pack aluminization of Iron Armko

Temperature and exposure at Pack Aluminization	Composition of the bed	Composition of the the coating	Thickness of each layer, μm
700°C, 1.5h	Al+Al ₂ O ₃ +NH ₄ Cl (high-activity bed)	Fe ₂ Al ₅	40
900°C, 2.5h	Al+Al ₂ O ₃ +NH ₄ Cl (high-activity bed)	Fe ₂ Al ₅	a few microns
		FeAl ₂	250
		FeAl	50
900°C, 2.0h	Fe ₂ Al ₅ +Al ₂ O ₃ +NH ₄ Cl (low-activity bed)	FeAl ₂	8-10
		FeAl	5-7
		Solid Solution	12-15
Pack Aluminization at 700°C, 1.5h and heat treatment at 900°C, 2.5h	—	Fe ₂ Al ₅	a few microns
		FeAl ₂	10-15
		FeAl	10-15
		Fe ₃ Al	5
		Solid Solution	13-14

specimens that were heat-treated. The results of the study are presented in Table 1 and in Figs. 1 - 3.

DISCUSSION AND CONCLUSION

In a high-activity bed at 700°C, a 64 μm -thick Fe₂Al₅ intermetallic layer was formed on the surface of the specimen (see Fig. 1a). When the processing temperature was increased to 900°C, a three-layered coating was observed on the surface of the specimen: the Fe₂Al₅ layer (a few microns thick), beneath this a ~30 μm -thick layer of FeAl₂, and a third layer, consisting of FeAl intermetallic 20 μm , thick (see Fig. 1b).

In the low-activity bed at 900°C (Fe₂Al₅ used as MA), a three-layered coating was again obtained, the following sequence of layers being observed (from the

surface to the matrix): FeAl₂ (8-10 μm), FeAl (5-7 μm), solid solution Al in Fe (12-15 μm) (see Fig. 2a).

After heat treatment at 900°C for 2.5 hours, the one-layered Fe₂Al₅ coating (obtained at 700°C in a high-activity bed) was changed by diffusion into a poly-layered coating, as follows (the layer positions shown from surface to matrix): FeAl₂ (10-15 μm), FeAl (10-15 μm), Fe₃Al (~5 μm), solid solution Al in Fe (13-14 μm) (see Fig. 2b).

It is noteworthy that the sequence of the inter-metallic layers corresponds to the sequence of phases given in the Fe-Al equilibrium diagram: Fe₂Al₅ - FeAl₂ - FeAl - Fe₃Al - solid solution.

To conclude, by using an intermetallic of a certain composition as master alloy, the phase composition of the intermetallic coating on the surface of the coated alloy can be predetermined.

Fig. 1: SEM micrographs of the specimens after pack aluminization in high-activity bed
a) 700°C b) 900°C

Fig. 2: SEM micrographs of the specimens after pack aluminization
a) low-activity bed, 900°C
b) high-activity bed, 700°C and heat treatment at 900°C.

Fig. 3: XRD CuK α pattern from the specimens after pack aluminization in high-activity bed
 a) 700°C b) 900°C

REFERENCES

1. C.T. Liu and J.O. Stiegler, *Metals Handbook*, 10th ed., vol. 2, 913-925.
2. J.L. Smialek, J. Doychak and D.J. Gaydash, in: *Oxidation of High-Temperature Intermetallics*, T. Grobstein and J. Doychak (eds.), publication of the Min. Met. & Mat. Society, 1988; pp. 97-107.
3. G.H. Meier, in: *Oxidation of High-Temperature Intermetallics*, T. Grobstein and J. Doychak (eds.), publication of the Min. Met. & Mat. Society, 1988; pp. 1-6.
4. R. Streif, "Protection of materials by advanced high-temperature coatings", in: *3rd International Symposium on High-Temperature Corrosion and Protection of Materials*, 1992; p. 95.
5. F.D. Geib and R.A. Rapp, "Diffusion coatings for iron aluminide (Fe_3Al) via halide-activated pack cementation", in: *Proc. Conf. on Processing and Fabrication of Advanced Materials for High-Temperature Applications*, 1991; pp. 347-360.
6. R.A. Rapp, "Codeposition of elements in pack cementation diffusion coatings for various alloys", in: *Proc. Conf. on Processing and Fabrication of Advanced Materials for High-Temperature Applications*, 1992; p. 345.
7. Aruna Bahadur, T.L. Sharma, N. Parida and A.N. Mukherjee, *J. Materials Science*, 28, 5375-5381 (1993).
8. Th. Uihlein, W. Auer and G. Eggeler, *Werkstoffe und Korrosion*, 40, 29-33 (1989).