The Effect of Chrom Element on Oxidation Behaviour of TiAl-based Alloy

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Abstract. Tial-based alloy have long been considered to be suitable candidates for high temperature structural application expecially at below 700°C. Unfortunately, in higher temperature (between 700°C and 900°C), TiAl-based alloy have a poor oxidation resistance. The reason for this is that the alloys generally form rapidly growing titania based surface oxide scales rather than protective alumina layers.Various efforts have been and are being made to overcome these problems. One of alloying elements have been developed is chrom element which hoped could decreased the form of titania and lead to form alumina layers.

Key words : *Oxidation, TiAl-based alloy, high temperature, strength, alumina layer and titania*

1 Introduction

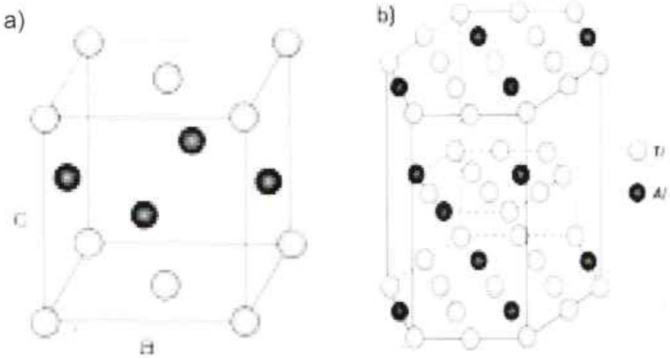
In recent years, intermetallic compound have found considerable interest as potentially suitable construction materials for high temperature aerospace application because of their unique combination of properties such as high temperature strength, low specific weight of about ρ = 3,8 g/cm^3, good oxidation, burn resistance and high elastic stiffness.[1,2,3] Examples of the applications of TiAl-based alloy in combustion engines are valves, connecting rod, piston pins, and exhaust gas turbocharger rotors. Blades, guide vanes, and blade disks for jet engines and stationary low and medium-pressure gas turbine are also under development.[3]

However, a major drawback of TiAl-based alloys is their poor oxidation resistance in the envisaged temperature range application 700°C and 900°C, or limited below 800°C, lower than that permissible by their mechanical properties.[1,4,5] There have been two main approaches, alloy design and surface coating, to enhancing oxidation properties above 800°C.[4] In this paper, alloy design with chrom addition are considerable to enhance oxidation properties.

2 TiAl-based Alloy and Development

Titanium aluminides have been known to be lightweight structural materials since the early 1970's. The intermetallic phase γ-TiAl possesses a face-centered tetragonal (FCT) Li_0 superlattice structure remaining ordered to the melting point at 1440°C. The FCT unit cell is only slightly distored (c/a ≈ 1,02) and consists of alternating planes of Ti and al atoms in the [001] direction (Figure 1a), due to the high Al content, γ-TiAl alloys exhibit a low density of about 3,8 grcm^{-3} and excellent oxidation resistance up to 700°C. However the resricted ability of single-phase γ-TiAl to accommodate plastic deformation causes insufficient ductility and fracture toughness for structural application.

The Ti-rich aluminide α_2-Ti_3Al exhibits a superlattice structure of the $D0_{19}$ type. This complex hexagonal ordered structure is shown in figure 1b. The α_2-Ti_3Al phase does not show any macroscopic tensile deformation at temperature below 800^{0}C. Hence, industrial applications of single-phase γ-TiAl and α_2-Ti_3Al alloys have not been taken into account because of their brittleness and poor workability.[3]



Figurel 1. (a) $L1_0$ ordered structure of the γ-TiAl phase
(b) Do_{19} ordered structure of the α_2-Ti_3Al phase

3 The Addition Cr Element in TiAl-based Alloy

As explanation above, there are two main approaches to enhancing oxidation properties above 800^{0}C. The first is alloy design, which TiAl-based alloy is added by a number of alloying elements and the second is surface coating, which TiAl-based alloy is coated by some Al-Ti-Cr alloy or etc. A number of alloy elements used to enhancing oxidation properties are Cr, Nb, V, Mo, Ta, and B. Some of this alloy elements are still under investigation

The study on the phase diagram in the Al-Ti-Cr ternary system as shown on Figure 2, established that Al-39Ti-5Cr alloy and Al-47TI-3Cr alloy were located in the γ+TiAlCr two phase region, and the amount of Al content and volume fraction of TiAlCr phase in the Al-39Ti-5Cr alloy were longer than in the Al-47Ti-3Cr alloy[4,3].

When TiAlCr alloy (eg. TiAl-5Cr and TiAl-3Cr) exposure at temperature 800^{0}C for 100 hour, as seen in Figure 3, The TiAl-5Cr alloy shows better isothermal oxidation resistance than the TiAl-3Cr alloy[4,5].

The XRD analysis confirmed the oxidation layer for TiAl-5Cr alloy and TiAl-3Cr alloy consisted of Al_2O_3 and TiO_2 and rather pure TiO_2 respectively as shown in Figure 4[3,4,5]

Perkins et. al.[6] proposed that TiAl-5Cr alloy was located in the boundary of the stable Al_2O_3 forming region and the mixed Al_2O_3 and TiO_2 forming region, while TiAl-3Cr alloy

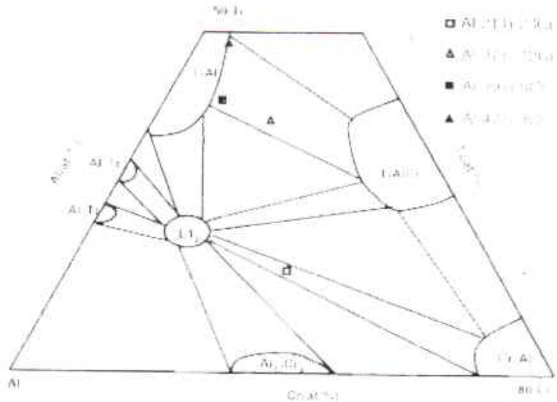


Figure 2 Schematic partial phase diagram in the Al-Ti-Cr alloy system at 1000°C

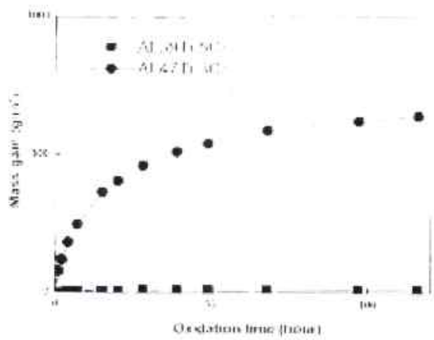
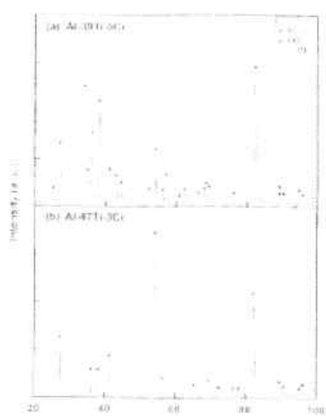


Figure 3 Isothermal oxidation curves of Ti-Al-5Cr and TiAl-3 Cr at 1000°C



Figurel 4 XRD results for surface of (a) Al-39Ti-5Cr and (b) Al-47Ti-3 Cr oxidazed at 1000°C for 100 h in the air

was located in the region where Al_2O_3/TiO_2 mixture informed in the oxide map for Ti-Al-Cr alloy system.

Brady et al. studied oxidation properties and reaction properties with Al_2O_3 scale for γ single phase alloy in the Ti-Al binary system and γ+TiAlCr two-phase alloy in the Al-Ti-Cr ternary system and noted that the γ+TiAlCr two phase alloy exhibited better oxidation properties and low reactivity with Al_2O_3 scale asa compare to γ single phase alloy[7]. γ single phase which belong to TiAl based alloy not capable to produce or forming a protective Al_2O_3 scale when expose to the air above 800^0C. For good oxidation resistance and low reactivity with Al_2O_3 scale, despite the same γ+TiAlCr two phase region, a suitable amount of TiAlCr phase and a larger amount of Al than Ti are required.

Therefore, as reported by Brady et al.[7], TiAl-3Cr alloy was more reactive with Al_2O_3 scale than the TiAl-5Cr alloy and this could prove that TiAl-5Cr alloy is more effective in prohibiting the oxygen diffusion into the substrate.

4 Conclusions

1. TiAl-based alloy have poor oxidation properties when exposed to the air above 800^0C because of this alloy not capable of forming a protective Al_2O_3 scale.
2. The addition of Cr element could improve the oxidation resistance of TiAl-based alloy.
3. TiAl-5Cr is more effective in prohibiting the oxygen diffusion into the substrate than TiAl-3Cr.

References

1. A. Gil and H.Hoven,*The Effect of Microstructure on the Oxidation behaviour of TiAl-based Intermetallics,* Corrosion science, 1993, Vol. 34, pp 615-630
2. G. babu and Vijay K., *Microstucture effect on the tensile properties and deformation behaviour of Ti-48Al Gamma Titanium Aluminide,* Metallurgical & Material Transactions, 2003, Vol 34A, No. 10
3. S. Knipp, Cheen, and G. Trammeyor,*Intermetallic TiAl (Cr, Mo, Si) Alloy for Light Weight Engine Parts,* Advanced Materials 199, No. 34 pp.1438-1656
4. J.K. Lee & M.H. Oh, *Long-term Oxidation properties of Ti-Al-Cr Two-phase Alloy as coating materials for TiAl Alloys,* Intermetallics 2002, pp. 347-352
5. Kim S., Paik P, *Matter Sci Tech,* 1998, 14 ,822
6. Perkins Ra, Merer GH., Smith F et al. *Proceedings of Industry-University Advanced Materials Confrence II,* 1989, p 82
7. Brady MP., Smith, *Acta Matter,* 1997, 45, 2357