DECHEMA FORSCHUNGSINSTITUT

High Temperature Materials

Oxidation Protection of Recycled TiAl-Alloys

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Motivation for TiAl-Recycling

The conventional production process of TiAl starts with a Vacuum Arc Remelting (VAR) Ingot. Due to the mechanical machining and the casting process a material loss up to 90% occurs (fig. 1).

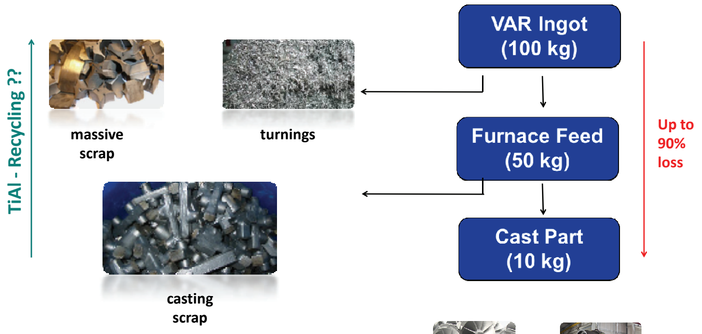


Fig. 1: Scheme of the conventional production process of TiAl-parts. Starting with a 100 kg VAR ingot a material loss up to 90% can occur due to mechanical machining and casting scrap.

Manufactured parts from TiAl

Novel Concept of TiAl Recycling

A new concept of TiAl recycling was proposed by the IME of RWTH Aachen University [1]. The oxygen content must be reduced to < 500 ppm by addition of CaF_2 (fig. 2).

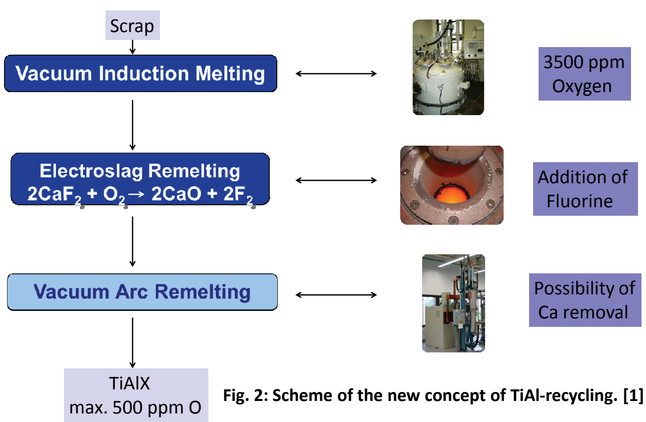


Fig. 2: Scheme of the new concept of TiAl-recycling. [1]

Can TiAl Recycling Improve the Oxidation Protection?

Partial Disintegration of Slag: $2CaF_2 + O_2 \longrightarrow 2CaO + 2F_2$

Formation of Alumina Scale: $2AlF + 1.5O_2 \longrightarrow Al_2O_3 + F_2$

The partial disintegration during the melting process leads to the formation of gaseous fluorine F_2. Thus the bulk alloy may be enriched with fluorine. It is proposed that the F-enriched recycled TiAl can form a protective alumina scale by using the halogen effect (fig. 3) which is well-established for the surface treatment of γ-TiAl.

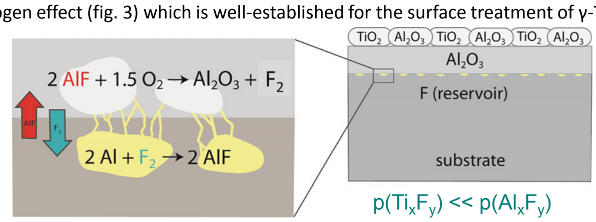
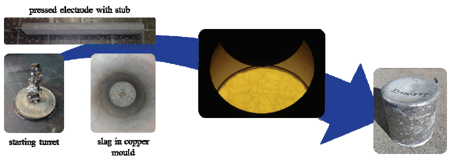


Fig. 3: Mechanism of the halogen (fluorine-) effect at TiAl.

Small additions of halogen (e. g. fluorine) into the surface region of γ-TiAl and subsequent heating to 900°C lead to the selective formation of gaseous Al-fluorides in pores and microcracks of the initial oxide scale (fig. 3). During their transport to the surface the Al-fluorides disintegrate into Al and gaseous F_2. Due to the increasing oxygen partial pressure the Al can be oxidized to Al_2O_3. The free F_2 can return into the subsurface zone. As result of this cycle process a dense protective alumina scale is formed on the surface (fig. 3).

Fluorine Uptake of TiAl During Electroslag Remelting



Melting parameters:

- Feedstock:
  - Ti-45Al electrodes
  - Ti-50Al starter turrets
  - CaF_2 slag
- Pressure: 20 bar
- Power: 125 kW
- Temperature: 1800-2000 °C

Fig. 4: Parameters of the electroslag remelting process.

Due to the disintegration of the CaF_2-slag a fluorine uptake during the electroslag process is expected. GDOES-measurements of the bulk alloy Ti45Al show a F-amount of less than 0.3 ppm. Therefore the slag was partly substituted with other additives showing less stability (MgF_2, NaF, Na_3AlF_6) as depicted in fig. 5. In all cases the F-content did not exceed 1 ppm. (fig. 6).

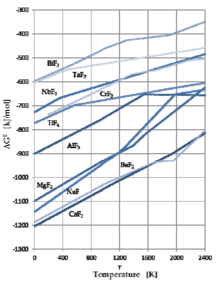


Fig. 5: Chemical stability of several slag constituents.

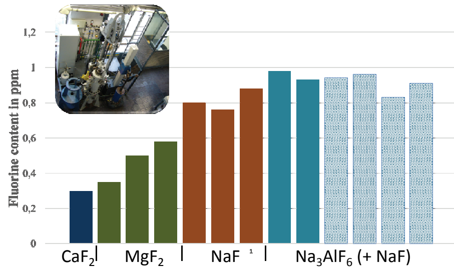
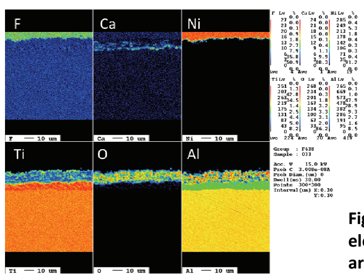


Fig. 6: F uptake in the bulk alloy Ti45A by using several slag constituents.

Results of Oxidation Tests

The results of isothermal oxidation tests for 120h/900°C/air are summarized in figs. 7-8. The existence of an Al-depleted zone reflects the preferred transport of Al to the surface and the partial formation of alumina. However due to the low F content no dense protective alumina scale can be formed. The results indicate that the well-established F effect can be applied via surface modification with fluorine showing excellent oxidation protection for γ-TiAl alloys.



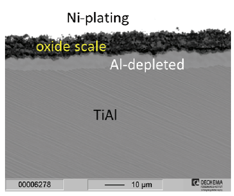


Fig. 7: Metallographic cross-section and EPMA element maps of Ti45Al alloy. The F signal is an artifact due to X-rays from the Ni-plating.

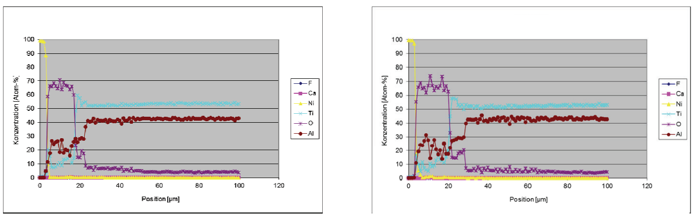


Fig. 8: EPMA linescans reflect the Al depletion leading to an Al-rich oxide at the surface. However Ti-rich oxide was still formed.

References:

[1] Stoephasius, J.-C.; Reitz, J.; Friedrich, B.; Adv. Engin. Mat. 9, No. 4, 2007, 246-252.