Introduction

The potential availability of low-cost, high-purity Ti powder via new processes in extractive metallurgy has created increased interest in the area of Ti powder metallurgy. Powder metallurgy is a net-shape production method whereby loose powder is typically compacted and sintered to high density and strength.

A Problem

A persistent problem in Ti powder processing is the difficulty in compacting and ejecting powder parts due to Ti's poor tribological properties. Admixed organic lubricants such as Acrawax C have had a limited effect in reducing the large ejection pressures. Furthermore, organic lubricants must be burnt out before sintering and any residue is potentially volatile during high temperature sintering.

A Solution?

A potential solution which has been devised is to admix solid lubricants which will enhance the sintering as well as aid in the compaction process. In this poster, the effects of common solid lubricants (MoS_2, BN, C-graphite, Sn) on the sintering and ejection of Ti powder compacts are presented.

Experimental

Testing the Sintering Response

- Ti powder with 1 wt% solid lubricant (MoS_2, BN, graphite, Sn) was compacted (400 MPa) and vacuum sintered (1300°C for 2 hours) in a dilatometer
- Changes in density were measured and metallography was conducted

Testing the Lubricating properties

- Ti powder with 1 wt% solid lubricant was compacted to 400 MPa
- Ejection forces were then measured using an Instron operating with a slow (10 mm/min) crosshead speed
- Ejection stresses were calculated using the contact area between the die and the compact

The Sintering of Titanium with Solid Lubricants

Ray Low, Ian Robertson and Graham Schaffer

Results and Discussion

Sintering Response

- Dilatometry and density measurements indicate that MoS_2 additions were beneficial – improving both the sintering rate and the final sintered density compared to pure Ti for the same approximate green density.
  - Fig. A shows MoS_2 additions attain the highest shrinkage and shrinkage rates.
- The enhanced sintering of Ti-1MoS_2 was due to the formation of small amounts of Ti-S eutectic liquid at 1212°C.
  - Fig. B shows Ti-1MoS_2 microstructure – Ti-S eutectic liquid can be seen present at the grain boundaries.
  - The small volume of liquid improves Ti diffusion and generates attractive capillary forces leading to enhanced sintering.
- BN, C-graphite and Sn additions showed detrimental sintering effects.
  - Fig. A shows the above additions have lower shrinkage rates compared to pure Ti.

Lubricating Properties

- None of the candidate lubricants showed an improvement in ejection stresses over Acrawax C.
  - Fig. C plots the shear stress during ejection for all the candidate lubricants
  - Loud vibrations were heard during all ejection tests.

Conclusion

The work thus far has been unsuccessful in finding a solid lubricant which aids in both the compaction and sintering process. MoS_2 has been shown to enhance the sintering of titanium. However, none of solid lubricants tested showed improved lubrication over the commonly used organic waxes.

Fig. A - Dilatometry

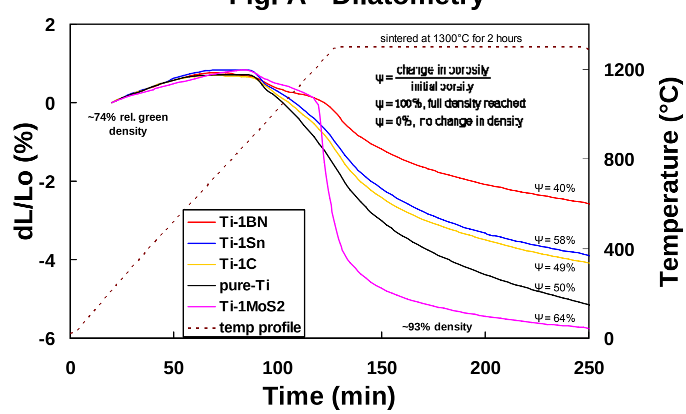

Fig. B – Ti-1MoS_2

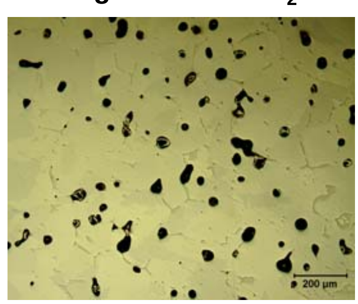

Fig. C – Instron Results