

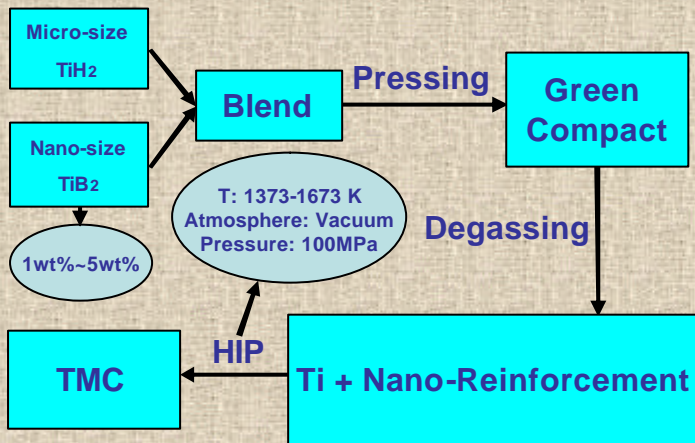


Introduction

In this project, nano-size titanium boride (TiB) particles reinforced titanium matrix composites (TMC) are manufactured through the conventional powder metallurgy process route. Results show that the mechanical properties of the titanium composites are superior to those of the monolithic counterparts.



Designed Experimental Process



Experiment Results

	TMC Exhaust Valves	Near Alpha Alloys	CP Titanium
Hardness (HV)	440	310	250
UTS (MPa)	1210	900~980	240~370
Young's Modulus (GPa)	140	114	105~120
Elongation (%)	3	15	20~30

Randomly Distributed Micron TiB Reinforcement



Fig. 1 - OM image of the cross section of TMC exhaust valve, showing a matrix with Widmanstätten structures

Decoherence Between Matrix and Reinforcement

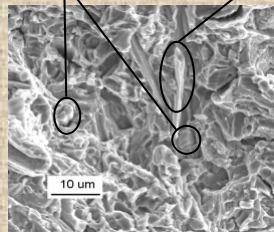


Fig. 2 - SEM image of the fracture surface of TMC exhaust valve

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Background

More than 500,000 powder metallurgy TMC valves have been put into the market from Toyota Motor Corp. since 1998. [1]



About TMC Valves

- Matrix: TiH₂ + Al-25Sn-25Zr-6Nb-6Mo-1.2Si (Master Alloy) → Ti-6Al-4Sn-4Zr-1Nb-1Mo-0.2Si-0.3O
- Reinforcement: Micro-scale TiB Particulates (3 wt%)
- Processing: Powder Metallurgy + Extruding + Forging [1]

Advantages of TMC Valves

- 40% lighter valve weight and 16% lighter valve spring weight compared with the conventional steel-valve engine
- Maximum revolutions increase by 700rpm and noise in the high-revolution range decreases by 30%
- The reduction of friction reduces camshaft driving torque by 20%, and high performance and low fuel consumption are achieved [1]

Why TiH₂ as the Starting Material?

- More cost effective than titanium powder in fabrication process
- Low adherence with the metal die during cold pressing
- Oxygen content is lower than that of the CP titanium

Why TiB and TiB₂ as the Reinforcement?

- TiB:
- Stiffness is over four times higher than titanium alloys
 - Thermodynamic equilibrium with titanium alloys
 - A similar coefficient of thermal expansion ($8.6 \times 10^{-6}/^{\circ}\text{C}$) as that of titanium ($9.7 \times 10^{-6}/^{\circ}\text{C}$)

TiB is formed by in-situ reaction between TiB₂ and Ti

Why Nano Reinforcement?

- Coefficient of thermal expansion is not so important in the nano-scale, so other kinds of reinforcement can also be considered (TiC, TiN etc).
- Aluminium matrix composites (AMC) with addition of 1-4wt% nano-size reinforcements can have competitive mechanical properties as that of 10-20wt% micro-size reinforcements. [2]



Future Works

- Study of dehydrogenation and sintering of TiH₂ powder
- Manufacturing of TMCs with TiB and other nano-reinforcements and improvement on their properties
- Study of dimension control in HIP processes for these TMCs

References:

- T. Saito, *JOM*, pp.33-36, (May 2004).
- Y. C. Kang, S. L. I. Chan, *Materials Chemistry and Physics*, 85, pp.438-443, (2004).