SAND2006-1529C

Friction and Wear Mechanisms in Aluminum Alloy Metal-Matrix Composites

Invited Talk

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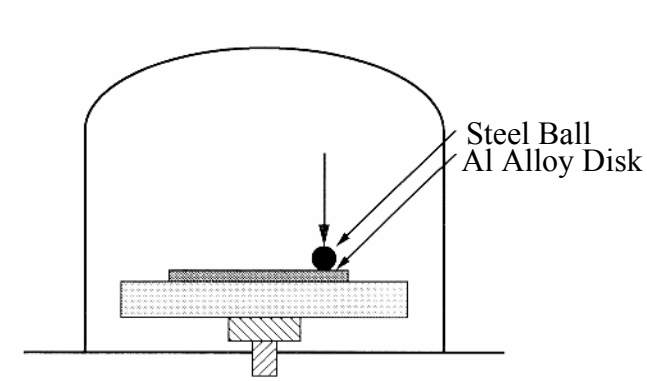
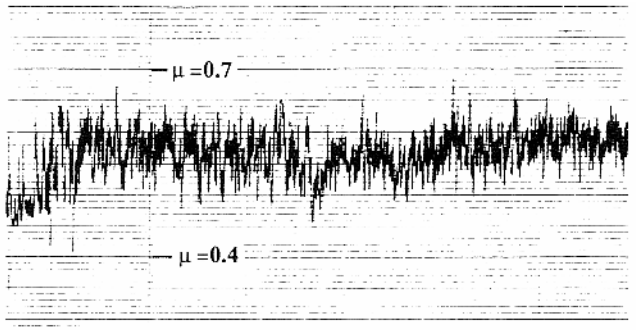
The Rohatgi Honorary Symposium on Solidification Processing of MMCs

TMS Annual Meeting

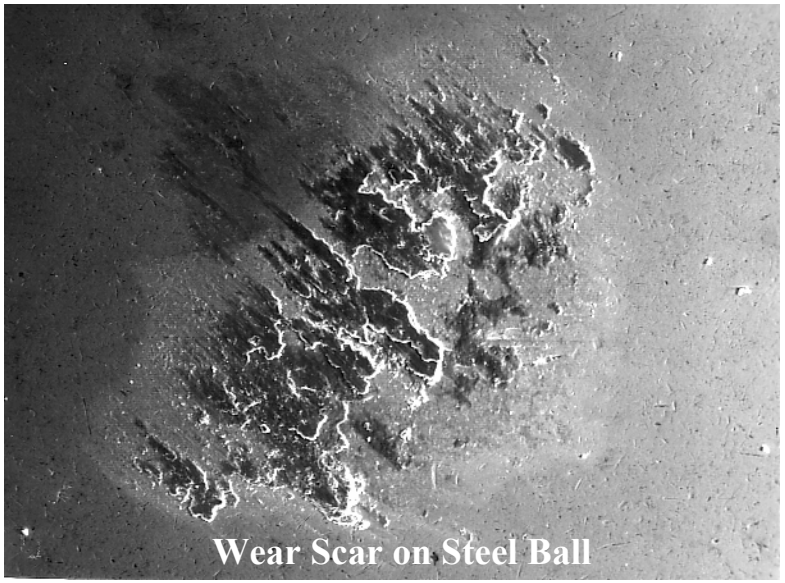
San Antonio, TX March 14, 2006

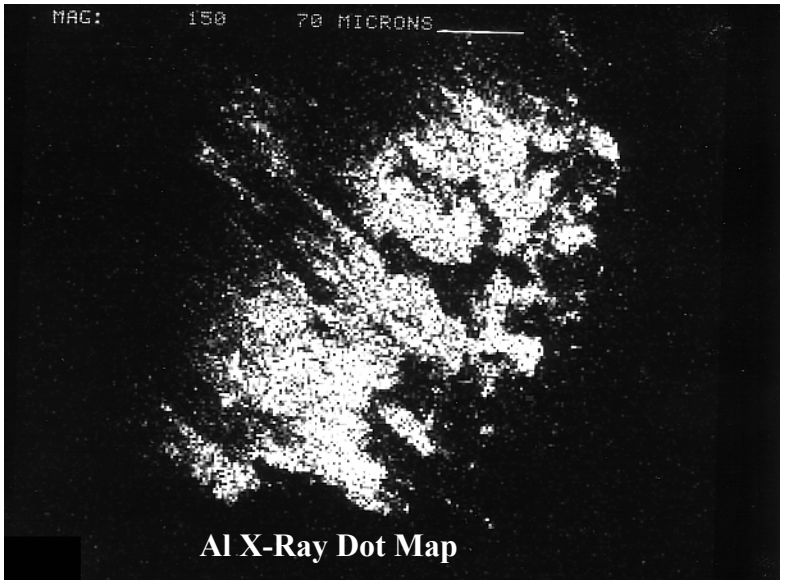
Aluminum has poor resistance to seizure and galling





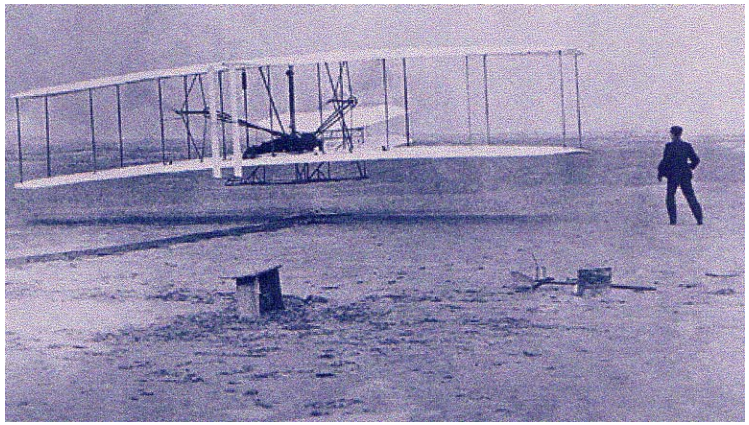
- **In the absence of external fluid lubrication, aluminum has a tendency to adhere to the hard counterface, creating an interface of weak nature. Note the transfer of aluminum to the steel counterface during a ball-on-disk test. Friction is of stick-slip type with a coefficient of 0.5 to 0.6.**





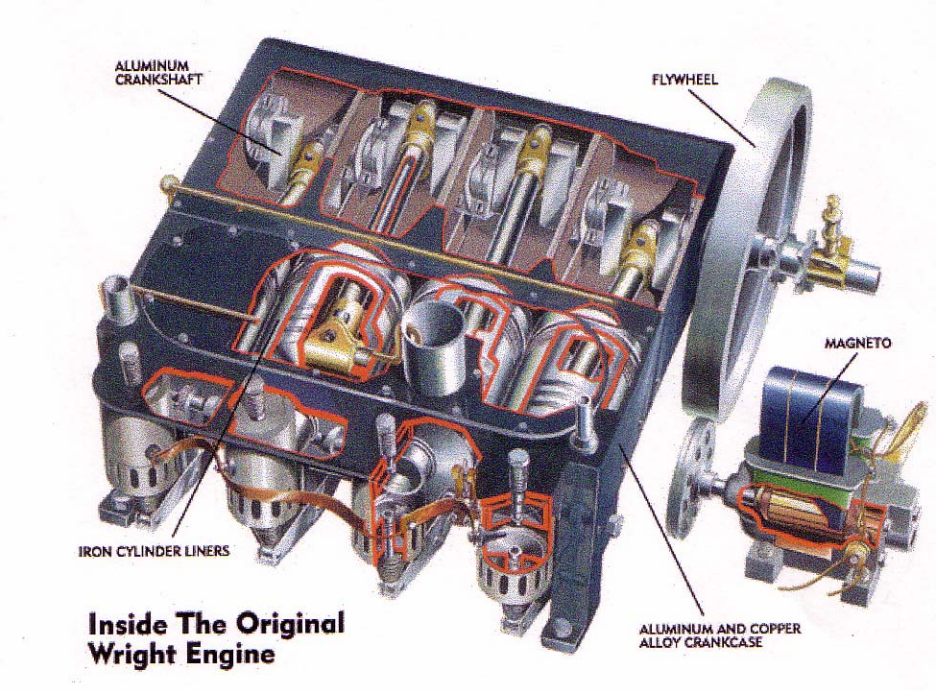
Historical Perspective: The Saga of Wright Brothers' Engine Development

1903



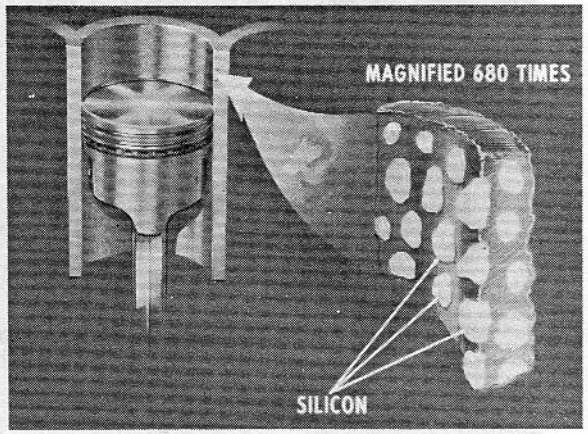
Mr. Charles Taylor

- The Brothers needed an Engine with 8 HP weighing <180 lbs

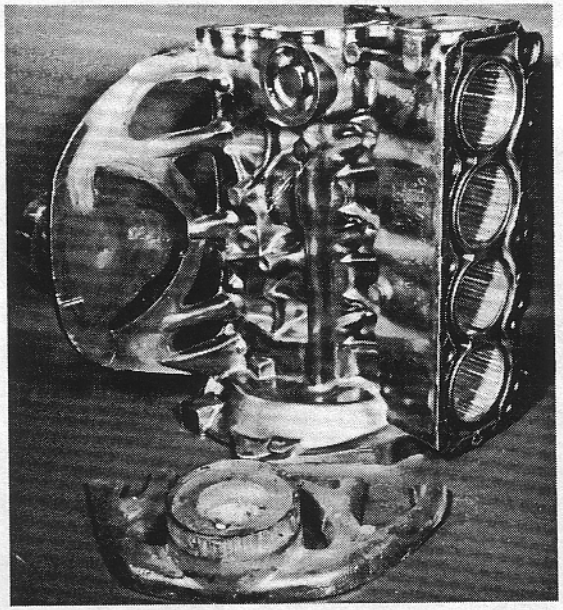


- 16 HP-12HP 178 lbs
- The Brothers used the extra weight allowance to strengthen the wings and frame

The (Short) Legacy of the Vega Engine



Silicon surface cylinder bores



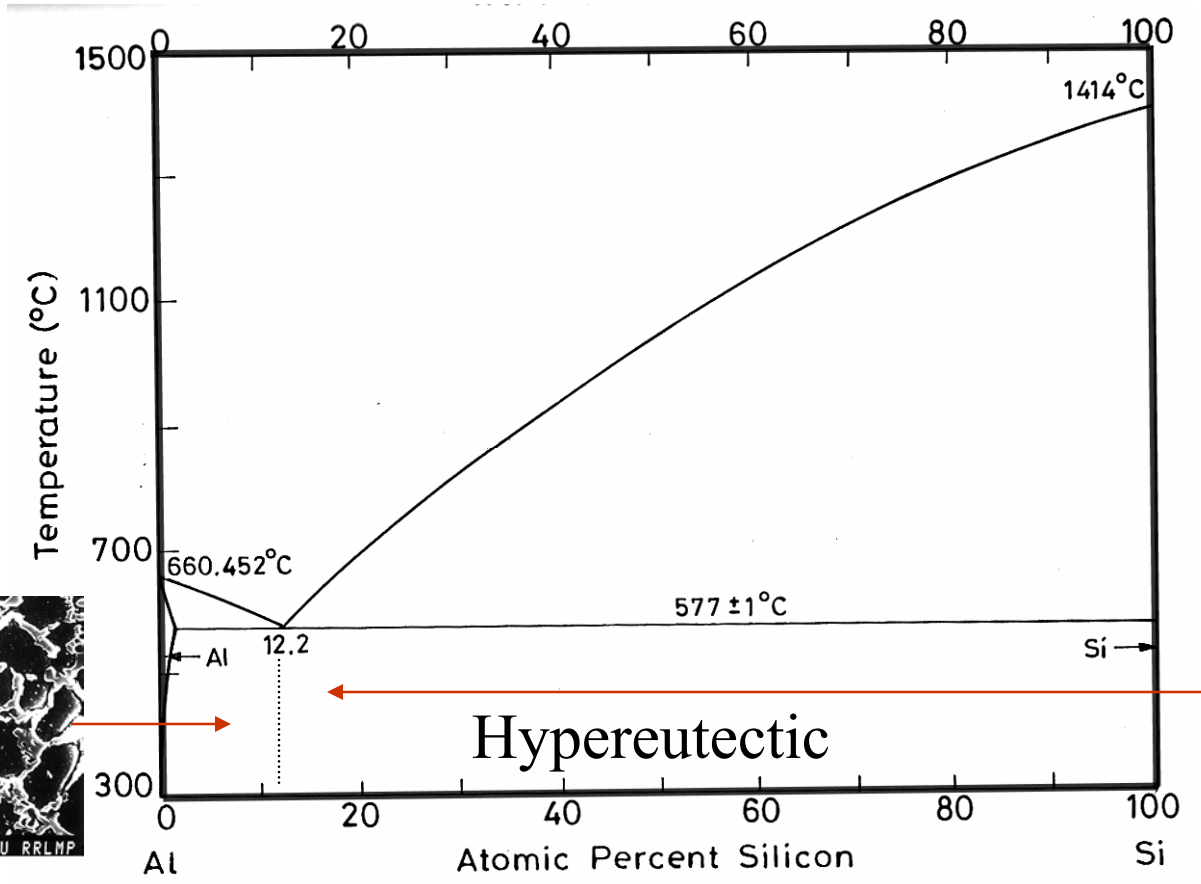
Vega engine block as removed from die

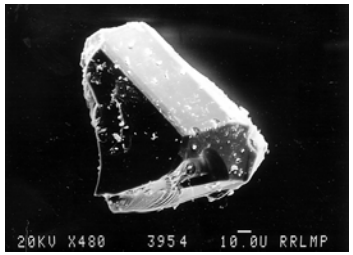
BASIC SPECIFICATIONS
VEGA 2300–140 cu in. Overhead Cam 4-cyl Engine

GENERAL	
Type	In-Line OHC 4-cyl (L-4)
Gross horsepower	
Standard engine	90 at 4600-4800
Optional engine	110 at 4800
Gross torque	
Standard engine	136 at 2400
Optional engine	138 at 3200
Compression ratio	8.00:1
Bore and stroke	3.501 × 3.625
Firing order	1-3-4-2
Engine installation angle	3 deg 50 min
Fuel	Regular leaded and nonleaded 91 Octane
Carburetor	
Standard engine	One-barrel, Monojet
Optional engine	Two-barrel, downdraft
CYLINDER BLOCK	
Material	Die-cast high-silicon aluminum alloy
Bore spacing (C/L to C/L)	4.00
Number of bulkheads	Five

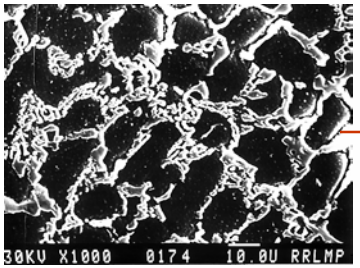
The Vega 2300 Engine, SAE 710147

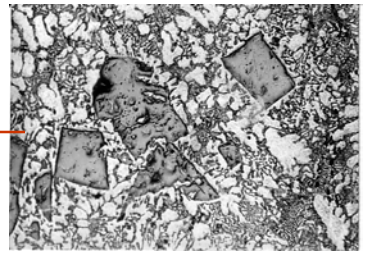
The all Aluminum (Hypereutectic Al-Si) Vega Engine



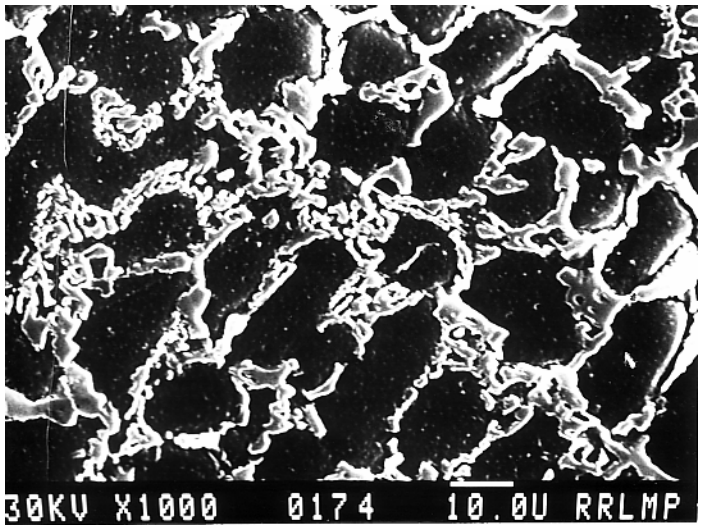


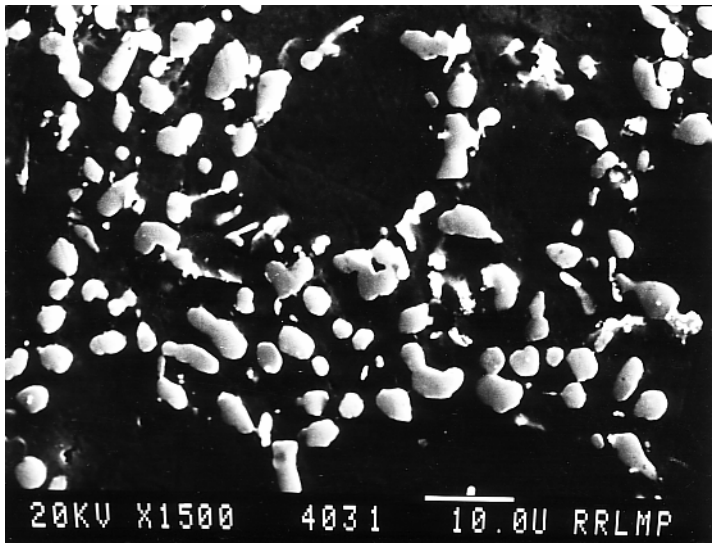
Silicon Debris
From Wear Test

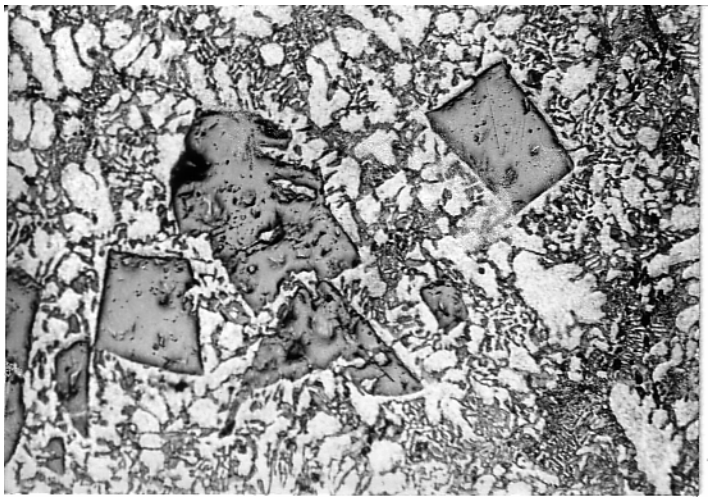


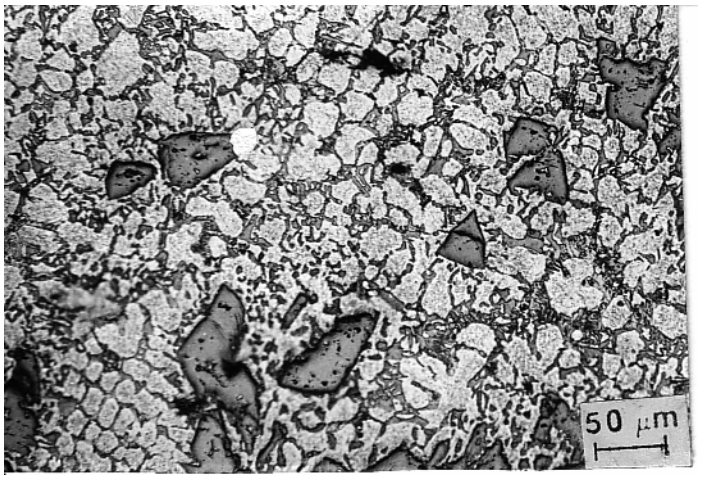


The combination of refinement, modification and heat treatment produces the desirable Si morphology

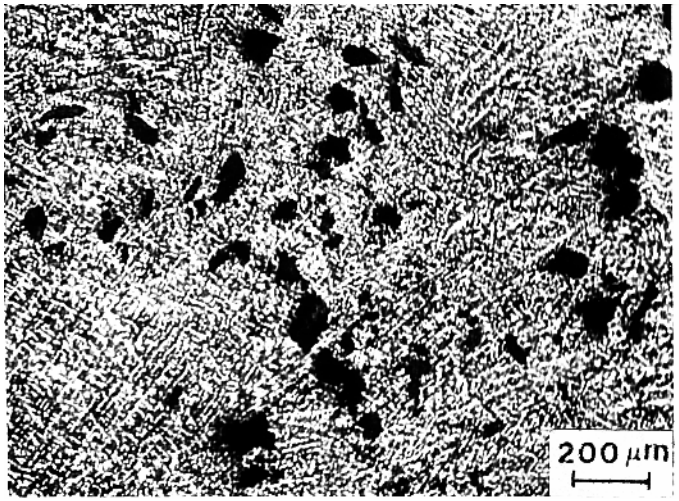


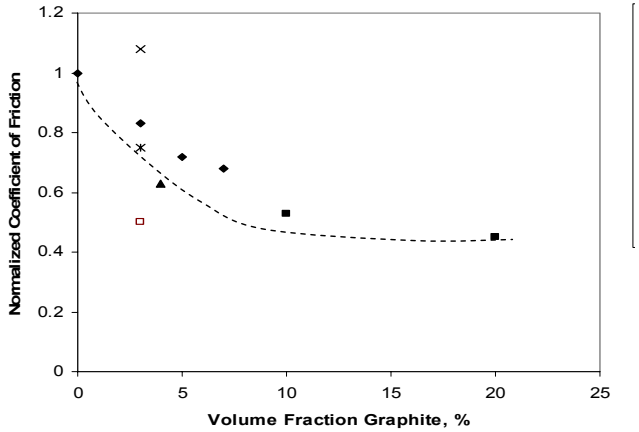


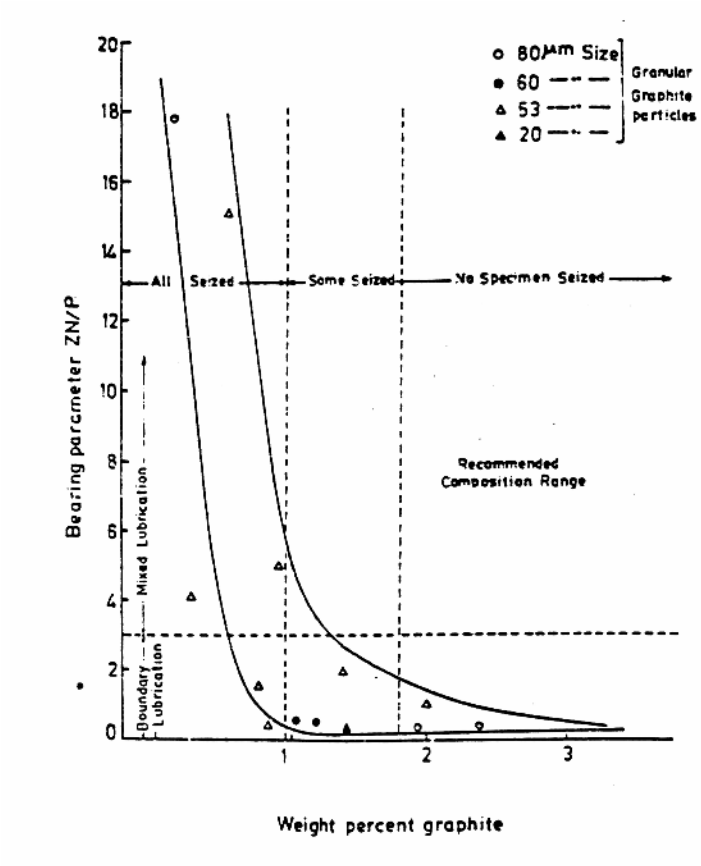




Research Efforts on Al Alloy-Graphite Composites

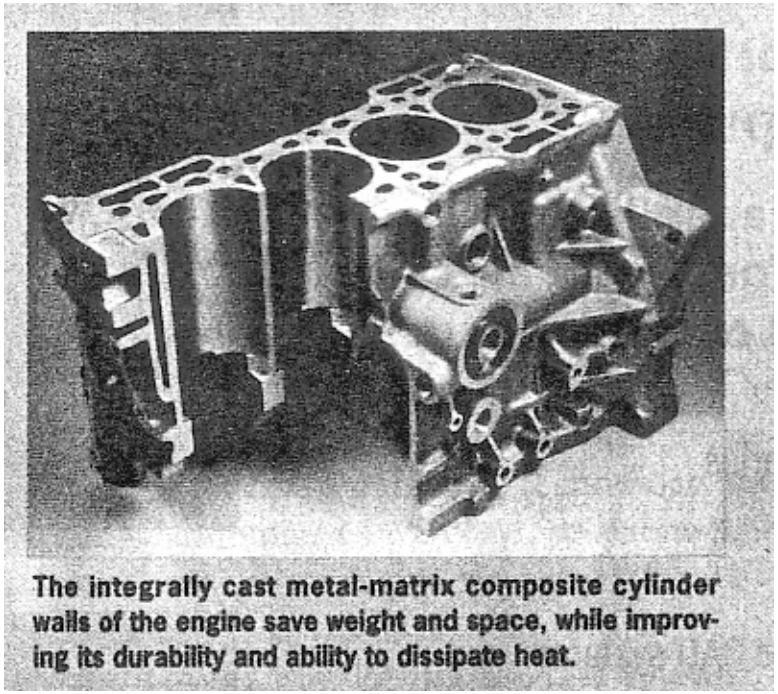




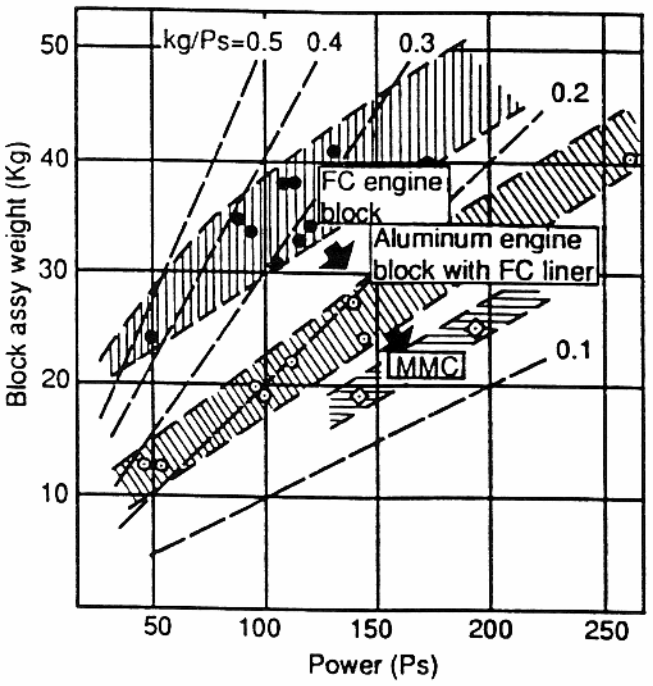


S. V. Prasad, P. K. Rohatgi, J. Metals, 39 (1987) 22.

Integrally Cast MMC Cylinder: Honda Corporation

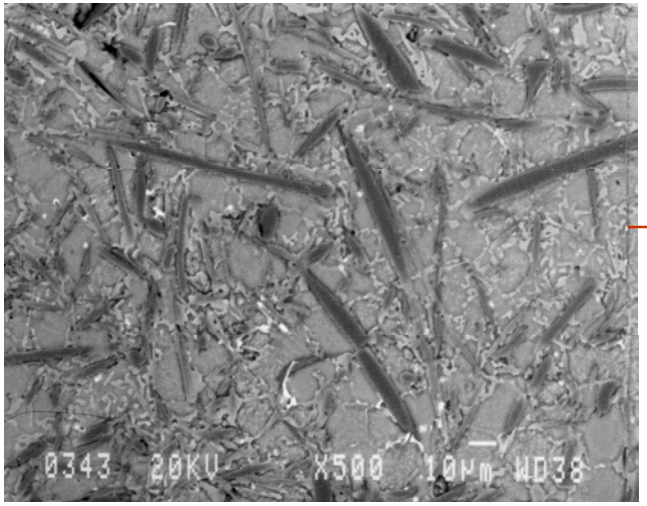


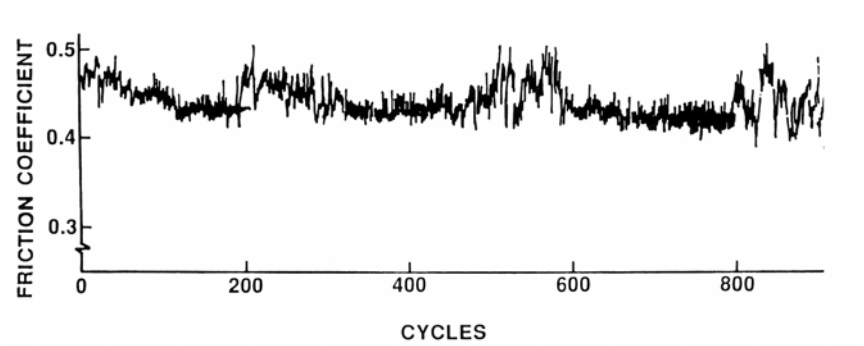
The integrally cast metal-matrix composite cylinder walls of the engine save weight and space, while improving its durability and ability to dissipate heat.

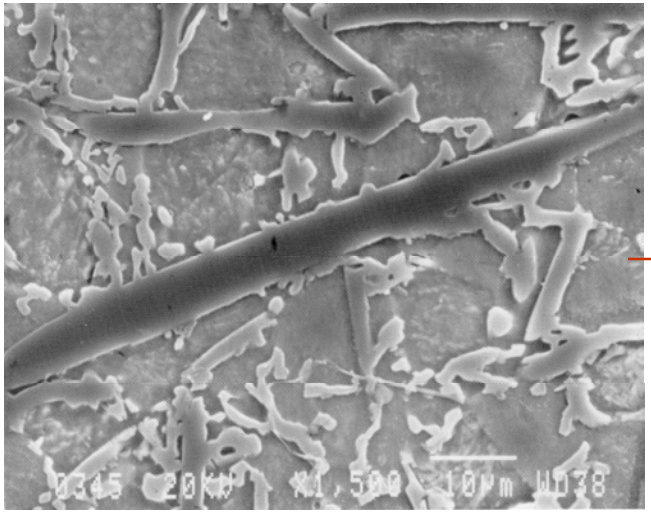


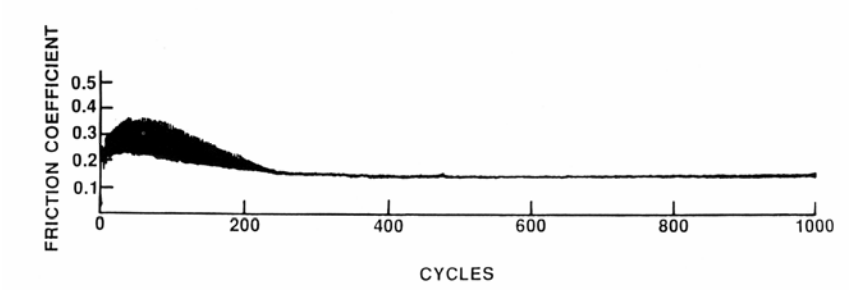
M. Ebisawa et. al, "The Production Process for MMC Engine Block", SAE 910835

Squeeze Cast Al MMCs: Co-operative R&D with GM with Mike Gardos acting as a Catalyst





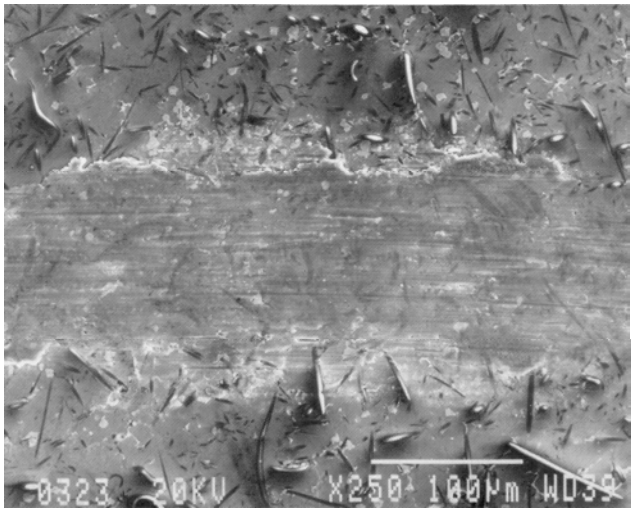


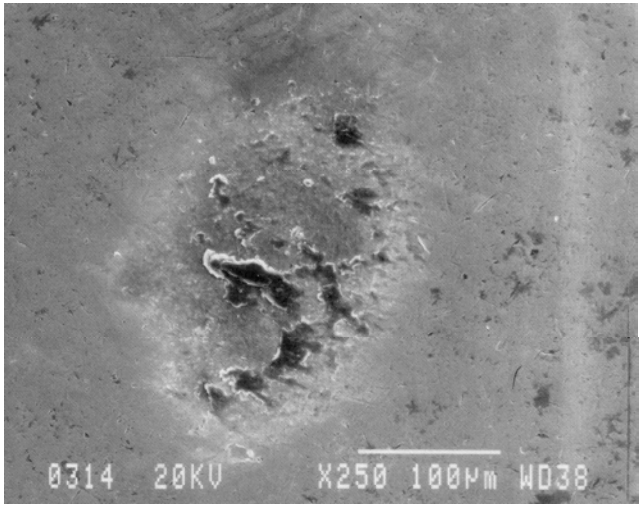


S. V. Prasad and K. R. Mecklenburg, Wear 162 (1993) 47-56.

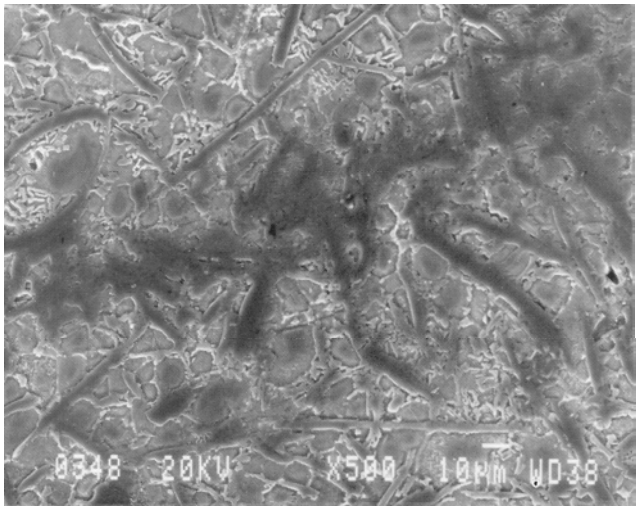
Squeeze Cast Al MMCs: Co-operative R&D with GM with Mike Gardos acting as a Catalyst

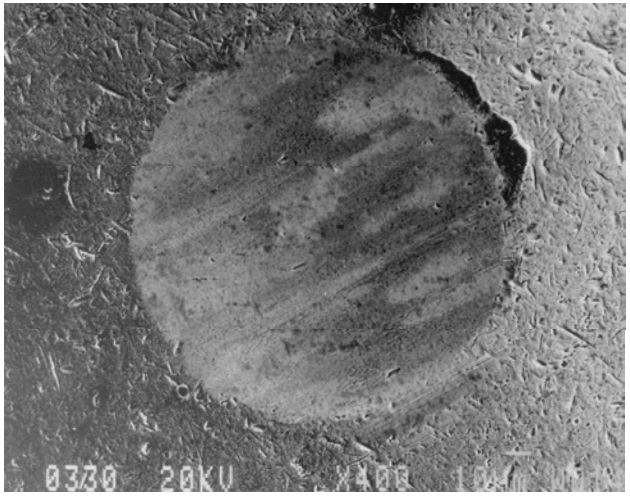
Polished MMC Surface





Etched MMC Surface





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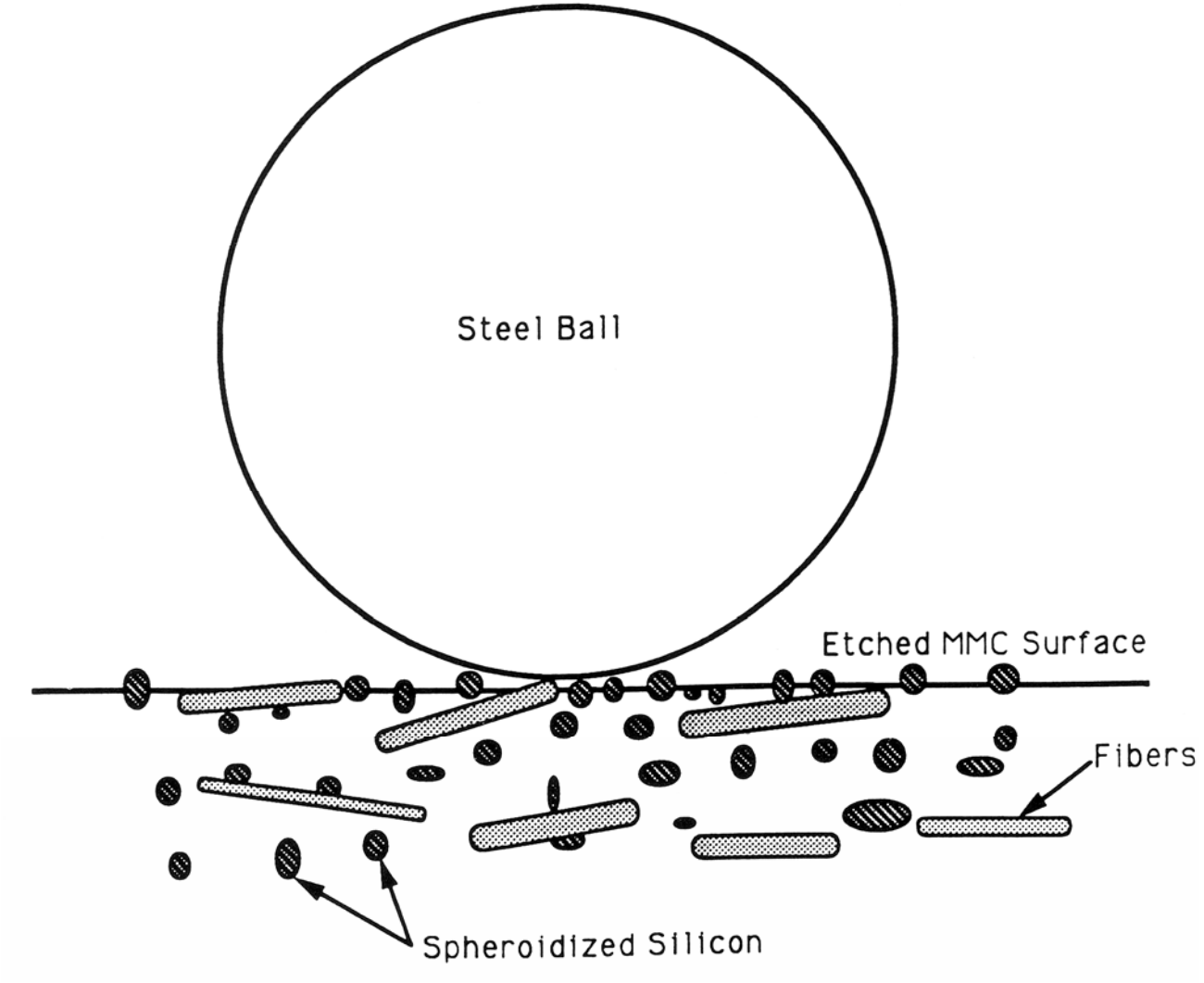
Engineered Surfaces for Precise Balance of Tribological and Physical Properties



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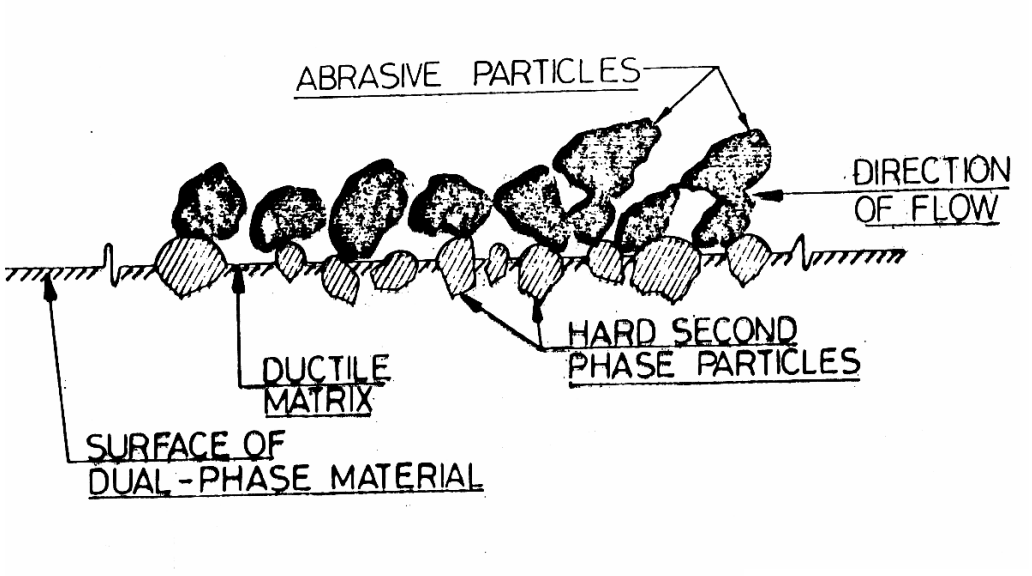
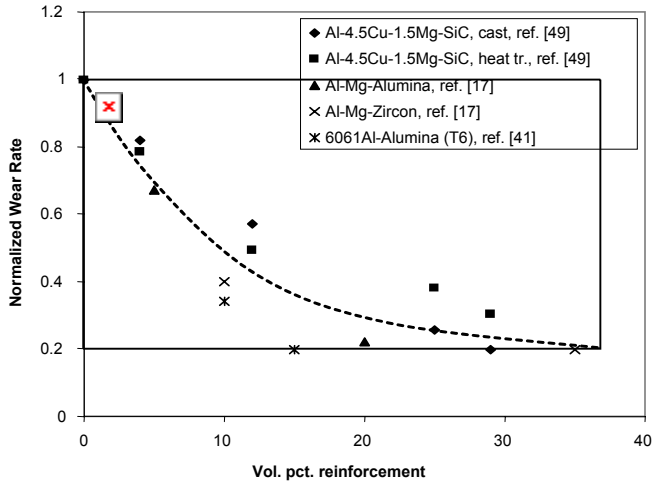
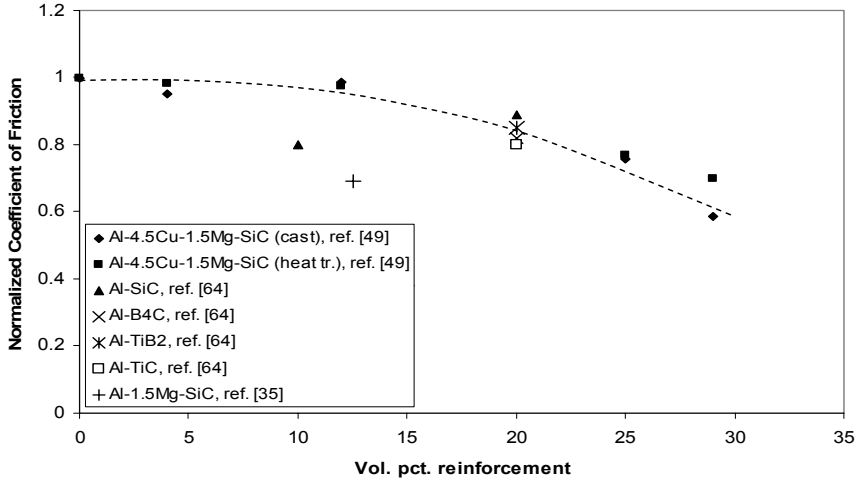
Al MMCs can be tailored to provide abrasion-resistant surfaces



- **SPP Size, VF**
- **Interparticle Spacing**
- **Abrasive Size**
- **Particle-Matrix Interface**





Commercial Applications

Manufacturer	Component & Composite
Duralcan, Martin Marietta, Lanxide	Pistons, Al/SiC_p
Duralcan, Lanxide	Brake rotors, calipers, liners, Al/SiC_p
GKN, Duralcan	Propeller shaft, Al/SiC_p
Nissan	**Connecting rod, Al/SiC_w**
Dow Chemical	Sprockets, pulleys, covers, Mg/SiC_p
Toyota	Piston rings, Al/Al_2O_3 (saffil) & Al/$Boria_w$
Dupont, Chrysler	Connecting rods, Al/Al_2O_3
Hitachi	Current collectors, Cu/graphite
Associated Engineering, Inc.	Cylinders, pistons, Al/graphite
Martin Marietta	Pistons, connecting rods, Al/TiC_p
Zollner	Pistons, Al/fiberfrax
Honda	**Engine blocks, Al/Al_2O_3 – C_f**
Lotus Elise, Volkswagon	Brake rotors, Al/SiC_p
Chrysler	Brake rotors, Al/SiC_p
GM	Rear brake drum for EV-1, driveshaft, engine cradle, Al/SiC_p
MC-21, Dia-Compe, Manitou	Bicycle fork brace and disk brake rotors, Al/SiC_p
3M	Missile fins, aircraft electrical access door, Al/$Nextel_f$
Knorr-Bremse; Kobenhavn	Brake disc on ICE bogies, SiC/Al
Alcoa Innometalx	Multichip electronic module, Al/SiC_p
Lanxide	PCB Heat sinks, Al/SiC_p
Cercast	Electronic packages, Al/graphite foam
Textron Specialty Materials	PCB heat sinks, Al/B

Concluding Thoughts