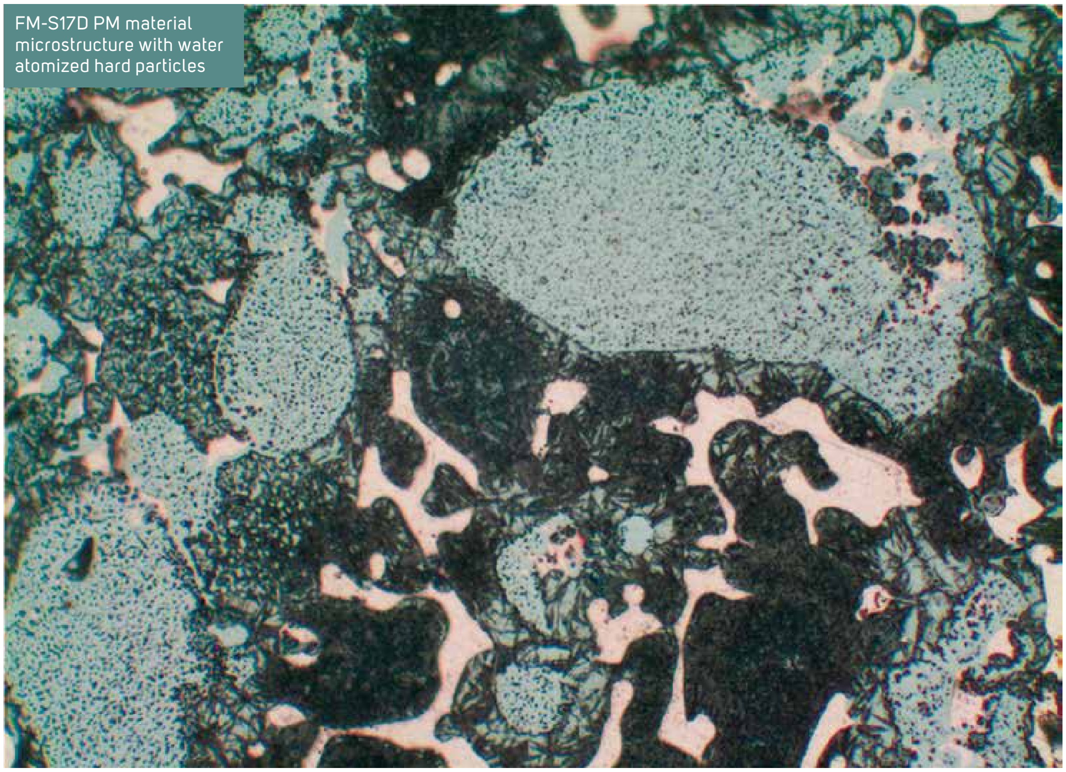
New exhaust materials

Revolutionary powder metal materials for valve seat inserts offer greatly improved machinability and increased wear resistance


FM-S17D PM material microstructure with water atomized hard particles

Downsized, highly loaded engines and those using alternative fuels run at increased temperatures and combustion pressures, placing higher demands on the valvetrain and particularly on the valve seat insert (VSI). For example, exhaust gas temperature at the VSI is driven up by downsizing, high levels of turbocharging and reduced peak-power fuel enrichment. At the same time, the resulting increase in peak combustion pressure causes higher mechanical deflection, while downspeeding and the direct injection of fuels (especially alternative blends such as E25) create challenging tribological boundary conditions.

A further cause of valve seat wear in modern passenger car diesel engines is the requirement for better efficiency and reduced emissions, which drives the use of exhaust gas recirculation and the reduction in exhaust soot concentration, reducing the lubricity of the exhaust gas stream.

The conventional approach to increasing VSI durability in the face of these challenges is to increase the degree of alloying with hard, wear-resistant particles, but this can lead to machining problems that make series production difficult, according to Denis Christopherson, Federal-Mogul Powertrain's valve seats and guides group director of R&D. "Higher alloying and the use of hard particles can potentially result in catastrophic failure of the cutting tool by notching, chipping or fracture, as the particles present an interrupted cut on a microscopic scale," he says.

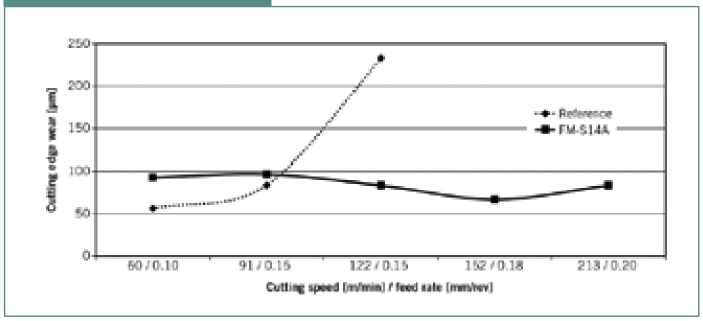
Federal-Mogul Powertrain has eliminated this problem, using advanced powder metallurgy (PM) technology to create two materials that combine a high level of wear resistance with excellent machinability that enables faster throughput and improved productivity on customers' engine cylinder head production lines. PM is recognized as an economically competitive green technology because of its highly automated near-net-shape production processes and use of metallurgically optimized yet readily affordable ingredients.

The new VSI materials, called FM-S14A and FM-S17D, were developed by Federal-Mogul Powertrain to suit inlet and exhaust applications in diesel and gasoline engines. They share a common principle of combining specially developed hard particles that provide wear resistance, with a moderately alloyed matrix to ensure good machinability and cost-effective manufacture. They differ in their use of two distinct chemical approaches to create the desired metallurgy.

The matrix is essentially the major portion of the composite material, which effectively binds the overall composition together in the sintered product. The wear-resistant hard phase is evenly distributed throughout the structure.

FM-S14A is the latest PM material to use Federal-Mogul's patented lean tool steel (LTS) hard particle

Comparison of FM-S14A with reference material showing low tool wear under a wide range of machining conditions




New powder metal materials for valve seat inserts from Federal-Mogul Powertrain offer improved corrosion resistance, higher mechanical strength and reduced costs compared with established cast materials

technology, while FM-S17D uses water atomized hard particle (WAHP) technology, developed for superior wear resistance in corrosive fuel environments.

A unique high-carbon, water-atomized hybrid steel, LTS was developed to meet the need for higher specific wear resistance than conventional tool steel powders, which it achieves by means of a greatly increased carbide content of approximately 50%. Conventional tool steel alloys typically contain only 15%.

This is achieved using a carbon content in excess of 3% during the atomization process, which reduces the solubility of oxygen in the melt, lowering the oxygen content. As a result, the alloying elements are not tied up as oxides and are available to readily – and rapidly – form carbides in much greater quantity during the subsequent component sintering process. By mixing with a moderately alloyed matrix (as in FM-S14A), it is possible to couple the high carbide content, martensitic, hard particles with bainitic and pearlitic matrix structures to obtain 'tool-steel type' durability while achieving high machinability and good manufacturing robustness.

The excess carbon present is also available for diffusing into one or more of the other constituents of the composite, thus acting as a potential carbon reservoir during component sintering. This provides a secondary advantage in limiting the need for further graphite addition, which can lead to harmful segregation or oversized porosity in the material.

FM-S17D uses a completely different hard particle chemistry containing high levels of chrome and tungsten (20-30%), with moderate levels of cobalt and nickel (3-7%) and approximately 2% carbon. The hard phase is evenly distributed throughout a lower alloyed matrix that effectively binds the overall composition together in the sintered product.

It was developed in a two-stage process. The first AHP (atomized hard particle) concept led to several encouraging engine tests and provided an excellent starting point for a second iteration with the aim of optimizing the machining properties. The final alloying and atomization of hard particle powders produced the right characteristics for robust and cost-effective production, while achieving the desired mechanical strength and wear resistance.

Exhaustive testing of both formulations included tribological evaluation, multiple engine tests and machinability trials in cooperation with tool suppliers, using state-of-the-art in-house development labs.

FM-S14A has been tested in both inlet and exhaust valve seat applications in two engine configurations (multipoint injection gasoline and turbo gasoline direct injection) and with three test programs (peak power, alternating load and city mode), using regular and E25 fuel. FM-S17D was tested on the intake and exhaust seats of a Euro 6 diesel engine with a specific output of 70kW/l.

Test results for both materials showed wear rates similar to the best current materials and close to the tool steel baseline, but with much improved machinability. The outstanding tool life compared with conventional PM seat inserts enables reduced machining costs and the use of more environmentally friendly machining concepts, with lower energy consumption.

FM-S14A is already in production with minimally lubricated machining, and series manufacture has confirmed the encouraging development test results. Based on the success of FM-S14A and FM-S17D, Federal-Mogul Powertrain is now investigating additional formulations using LTS and WAHP technologies, such as copper infiltration, as well as new applications that could include turbocharger components, where wear and oxidation resistance are primary considerations.

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