

Valve Guide for High Temperature Applications

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Engineered Sintered Components

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ABSTRACT

Sintered valve guides are increasingly used in various engine applications due to their superior durability and cost. Typical valve guide materials are low alloyed materials of the type Fe-Cu-C. More severe applications may require higher alloying content. One such application is EGR where the exhaust temperatures are much higher as compared to the conventional automotive valve guide. A new material was developed to work in this harsh environment. The object of this paper is to report development of this material including material properties and durability test results.

INTRODUCTION

Valve guides are typically tubular structures installed in cylinder head of an internal combustion engine and serve as axial bearings for the valve stem of an engine poppet valve. Sintered or powdered metal (P/M) valve guides have increasingly replaced cast guides due to:

- 1) Superior wear resistance
- 2) Near net shape manufacture
- 3) Unique microstructural design (not possible with cast design)
- 4) Compatibility with valve stem treatments
- 5) Self lubrication properties from impregnated oil
- 6) Lower cost

Sintered or powdered metal (P/M) valve guides are typically made from low alloy steel grades containing mainly iron-copper-carbon and exhibit ferritic/pearlitic microstructures. Compositions containing higher carbon levels (ie more than 1.6%) exhibit carbides and free graphite. Copper levels may vary from 2 to 12%. A solid lubricant is often added to improve wear resistance.

Types of solid lubricants include silicates, free graphite, manganese sulfide, copper sulfide, calcium fluoride, operation of the internal combustion engine replenishes the valve guides with oil. The life expectancy of the valve guides relies on the engine oil to lubricate the interface between the valve stem and the valve guide. Recently, there have been efforts to design what may be termed as "oil starved" valve guides to address the problem of air pollution caused by engine lubricant oil leaking into the combustion chamber through the valve stem and valve guide interface but even these valve guides are intended for use in a cooled cylinder head of an internal combustion engine.

EGR VALVE GUIDE

Other applications for a valve guide can include locations where the valve guide is exposed to high temperatures such as in excess of about 538°C/1000°F. in a system that is not cooled. For example, an exhaust gas recirculation (EGR) valve is disposed between an engine exhaust manifold and the engine intake manifold. The EGR valve uses a poppet valve (which includes a valve guide) to permit the recirculation of exhaust gas from the exhaust side of the engine back to the intake side. The EGR valve controls the flow of exhaust gas that is recirculated back into the intake charge. This recirculation of exhaust gases causes a reduction in NO_x emissions into the atmosphere by lowering the temperature of combustion. (Fig 1)

It has become desirable to operate the EGR valve in a continuously variable mode responsive to control signals from the engine control unit (ECU) for optimum engine performance while simultaneously minimizing emissions. As a result, the poppet valve and valve guide in the EGR valve are exposed continuously to the high temperatures and corrosive properties of the exhaust gas for prolonged periods of time.

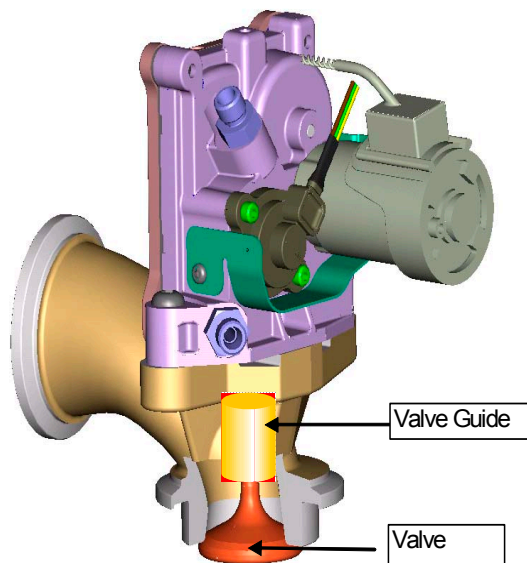


Fig 1 – EGR assembly showing poppet valve and valve guide.

The excessive temperature can negatively affect the performance of the components, and particularly the performance of the reciprocal movement of the valve stem within the valve guide such as, for example, the valve sticking or seizing within the valve guide. The corrosive materials found in the exhaust stream further negatively impact the life of the components.

Analyses of certain engine and field tested EGR valves indicated that poppet valves would stick intermittently at operating temperatures, while at room temperatures the poppet valves would function normally. (Fig 2)

Detailed investigations including wear testing, metallurgical analysis of tested and returned parts, furnace creep testing and analytical analysis (FEA) showed that there was a need to develop a higher temperature valve guide material capable of operating in the regime of 538°C/1000°F. FEA thermal image is depicted in Fig 3

The analyses confirmed two primary failure modes – (a) Reduction of the guide ID caused by press-fit induced creep and (b) Oxidation.

Thus, there still exists a need for a powder metal valve guide capable of withstanding the significantly high temperatures found in EGR valve applications as well as being useful in other high temperature applications where the valve guide is provided with little or no lubrication, or cooling.

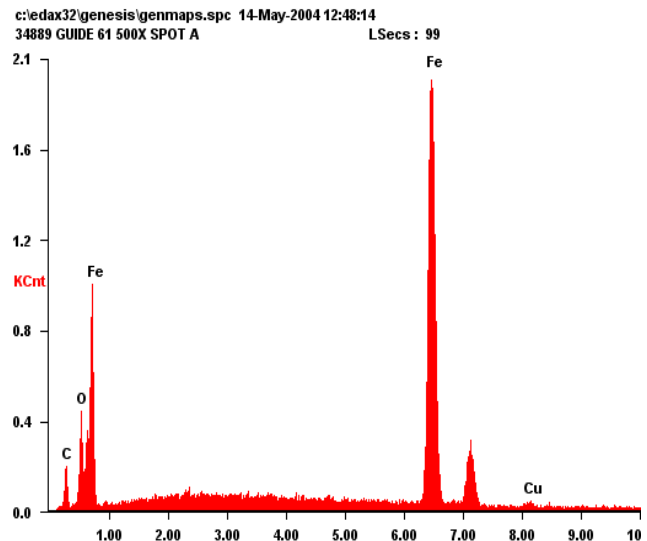
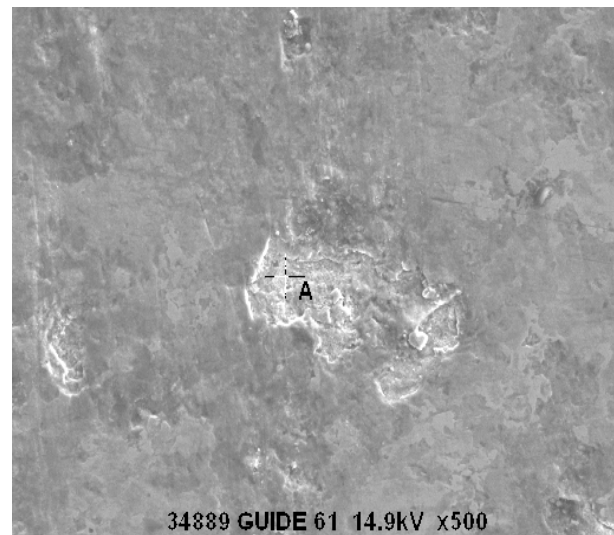


Fig 2 – SEM /EDX characterization of a failed valve guide exhibiting pitting. EDX shows evidence of oxidation. Note: The valve guide tested was a conventional EMS 543 valve guide

Accordingly, the object of the present paper is to review the development of an improved powder metal valve guide capable of withstanding high temperatures and a corrosive environment with little or no cooling.