FEA of Al-Sic Composite in Engine Valve Guides

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***Abstract*— In this paper an attempt has been made to increase the reliability of engine using Al-SiCp composites as an alternative material for the engine valve guides. Aluminum matrix composites are finding increased application in automotive, aircraft and aerospace industries and hold the greatest promise for the future growth. The finite element analysis of the Al-SiCp composite engine valve guide was done using Ansys software. The temperature, principal stress and principal strain distribution over the entire surface of the engine valve guide were obtained. The stresses were found to be well below the allowable stress for the Al-Sic composites.**

Keywords: MMC'S, FEA,

I. INTRODUCTION

In response to increasing global competition and growing concern for environment the automobile manufacturers have been encouraged to meet the conflicting demands of increased power and performance, lower fuel consumption, lower pollution emission and decreased noise and vibration. In order to fulfill these newer and emerging demands the automotive industry has recognized the need for material substitution. Metal matrix composites are offering outstanding properties in a number of automotive components such as piston, cylinder liner, engine valves, brake discs, brake drums, clutch discs, connecting rods etc. Several work has been reported on the substitution of presently used material by the aluminum matrix composites for different automotive components viz. piston, cylinder liner, engine valves, valve seat inserts etc. [1–6]. Al-SiCp composite engine valve guides have been fabricated through casting and powder metallurgy processes. The radial crushing strength, hardness, and wear resistance of the Al-SiCp composite and cast iron engine valve guides were measured and compared [3, 4]. Al-SiCp composites with 5 to 30 wt. % of Sic were found to have higher Rockwell hardness and radial crushing strength than the cast iron engine valve guides as shown in Table 1. Al-SiCp composite engine valve guides with 20 and 30 wt. % of Sic were found to have higher wear resistance than the cast iron engine valve guides as shown in Table 1 [4]. Present work incorporates the finite element technique to envisage the prospects of Al-SiCp composites as a possible alternative material for the engine valve guides. The finite element analysis of the engine valve guides was done using Ansys software. Temperature, pressure and displacement boundary conditions were applied and the temperature, stress and strain distribution over the entire surface of the engine valve guides was obtained.

II. PROBLEMS WITH PRESENT VALVE GUIDE OF CAST IRON

At present the engine valve guides are made of iron-based materials, which cause a number of problems in an automotive

- During cold start condition the viscosity of oil is high and also sufficient lubricant is not available therefore high wear of the valve stem / valve guide takes place. In the adverse conditions the valve may jam in the guide.
- During running condition of the engine the temperature of the valve stem and valve guide increases to about 500°C. Therefore at high temperature the clearance between valves stem and valve guide decreases due to thermal expansion, which results in high wear of the valve stem and the guide.
- The superimposed rocking motion in addition to the sliding of the engine valve causes high wear at the ends of the valve guide called 'bell-mouthing', generally more pronounced in the rocker arm actuation mechanism.

These problems call for a high wear resistant material with low coefficient of thermal expansion and engine valve guides based on the Al-SiCp composites are expected to provide a better solution.

Table 1 shows the properties of different materials used for the finite element analysis. To make the analysis simple following assumptions were made:

- The Al-SiCp composites are homogeneous and isotropic materials.
- The effect of other neighboring components was neglected.

Engine valve guide materials	Rockwell Hardness (HRC)	Radial crushing load (KN)	Wear rate mm3/ min
Al-10 wt. % SiCp composite	46.5	19	0.2497
Al-20 wt. % Sic composite	51.5	23	0.0884
Al-30 wt. % SiCp composite	53	32	0.1378
Cast iron	35	17	0.1945

Table 1 Comparison of the Properties of Cast Iron and Al-SiCp Composite Engine Valve Guides [4]

III. PROCEDURE FOR ANALYSIS

The following procedure was used for the finite element analysis of the engine valve guides:

1. A three-dimensional model of the engine valve guide was created in the Ansys software.
2. The model was divided into a fine mesh of brick type eight nodded solid elements.
3. The material properties data (i.e. elastic modulus, Poisson ratio, thermal conductivity, coefficient of thermal expansion as shown in Table 2 and geometry data (i.e. length, outer and inner diameter) for the Al-SiCp composite engine valve guide were defined.
4. The temperature, pressure and displacement boundary conditions on the components were applied as follows:

(i) Temperature boundary conditions:
Temperature at cylinder end = 620 °C
Temperature at outer end = 460 °C
(ii) Pressure boundary conditions:

Shrinkage pressure on the lateral surface of the engine valve guide due to shrink fitting of the engine valve guide in the cylinder head of the engine = 90 Mpa

Cylinder pressure acting on the cylinder end of the engine valve guide = 10 Mpa

(iii) Displacement boundary conditions:

The outer end of engine valve guide was fixed i.e. on the outer end dx = dy = dz = 0

The analysis was carried out after applying the boundary conditions.

The temperature and stress patterns over the entire surface of the engine valve guide were obtained from the analysis.

Almost similar results were obtained for Al-SiCp composite engine valve guides with 10 to 30 weight % of SiCp, which is due to similarity in properties of the various composites. Figure 1 shows the finite element model of engine valve guide used for the analysis.

Material	Coefficient of thermal expansion X 10^{-5}/°K	Thermal conductivity W /mK
Al-10 wt. % SiC	77.4	0.33
Al-20 wt. % SiC	86.0	0.32
Al-30 wt. % SiC	92.0	0.31

Table 2 Properties of Different Material used for the Finite Element Analysis

Material	Elastic Modulus GPa	Poisson ratio (μ)	Density Kg/m3
Al-10 wt. % SiC	77.4	0.33	2744.0
Al-20 wt. % SiC	86.0	0.32	2788.0
Al-30 wt. % SiC	92.0	0.31	2835.0

Table 2(contd) Properties of Different Material used for the Finite Element Analysis

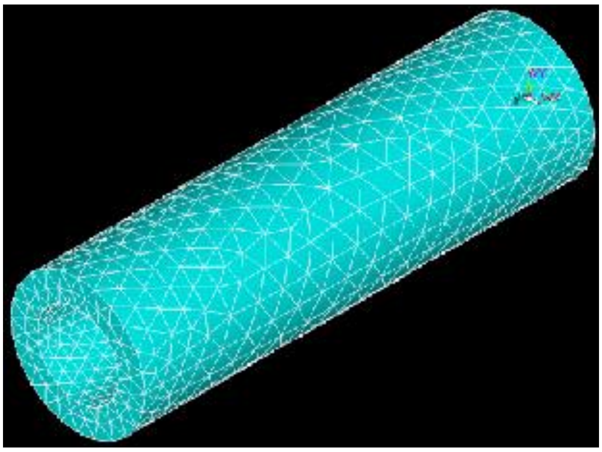

Fig.1 Finite Element Model of Engine Valve Guide used for the Analysis

IV RESULTS AND DISCUSSONS

1 Temperature Distribution on the Surface of the Engine Valve Guide

The temperature distribution over the entire surface of the Al-SiCp composite engine valve guide is shown in Fig.2. The temperature decreases from cylinder side to the outer side. The respective temperature values are 620 °C and 460 °C.

2 Principal Stress and Principal Strain Distribution on the Surface of the Engine Valve Guide

In Figure 3 shows the principal stress distribution over the entire surface of the engine valve guide obtained from the finite element analysis. The maximum and minimum principal stress values found in the engine valve guide were 2.97 MPa and -5.01 MPa respectively, which are less than the strength of the Al-SiCp composites.

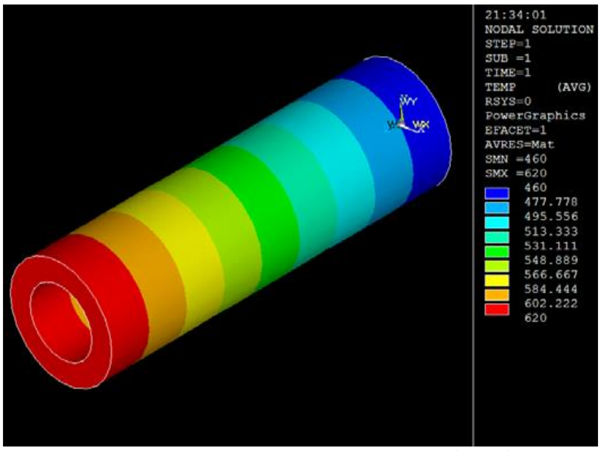

Fig.2 Temperature Distribution over the Entire Surface of Al-SiCp Composite Engine Valve Guide.

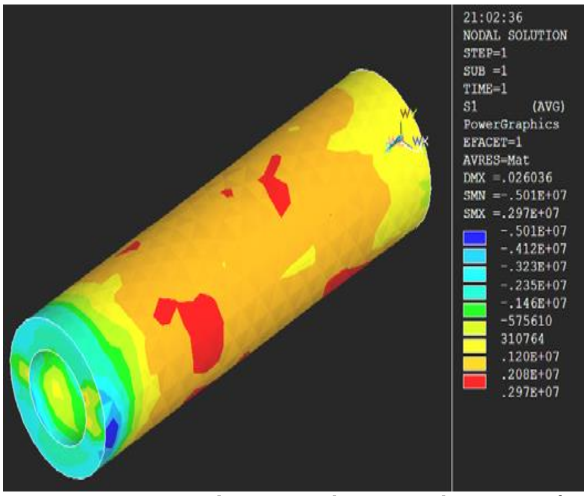

Fig.3 Principal Stress Distribution over the Entire Surface of the Al-SiCp Composite Engine Valve Guide

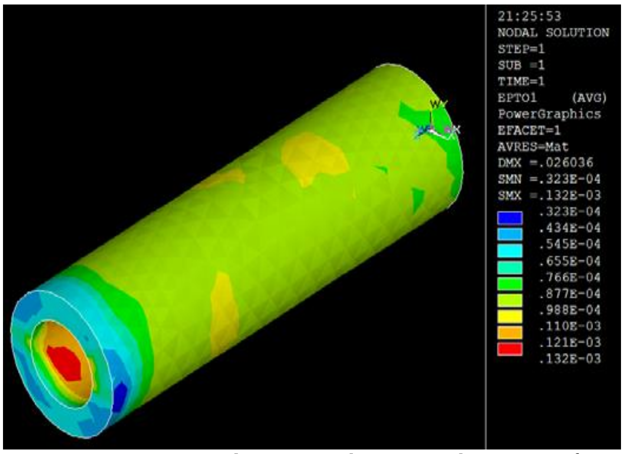

Fig.4 Principal Strain Distribution over the Entire Surface Of the Al-SiCp Composite Engine Valve Guide.

Figure 4 shows the principal strain distribution over the entire surface of the Al-SiCp composite engine valve guide. The maximum and minimum principal strain values in the Al-SiCp composite engine valve guide are 0.132 X 10-3 and .323 X 10-4 respectively. The maximum deformation in diameter of the engine valve guide is 1.89 x 10-3 mm (for 14.34 mm diameter of the engine valve guide), which is much less than the clearance in the engine valve guide and the valve
stem of the order of 0.05 mm. The maximum deformation in the Al-SiCp composite engine valve guides in also much less than the shrink/ heat fitting tolerances for engine valve guides, which is of the order of 0.06 mm. Fig.4 Principal Strain Distribution over the Entire Surface of the Al-SiCp Composite Engine Valve Guide.

V Conclusion

The maximum principal stress in the engine valve guide is 2.97 (tensile) and 5.01 MPa (compressive), under the given conditions, which is much less than the strength of the Al-SiCp composites (compressive strength = 302 MPa and tensile strength = 132.4 MPa for Al-10 wt. % SiCp composites [4]). The Al-SiCp composite engine valve guides also have higher Rockwell hardness, radial crushing strength and wear resistance than the cast iron engine valve guide presently used in engines [4]. This suggests that the Al-SiCp composites have the enough potential as an alternative material for the engine valve guides.

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