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FEA of Chrome–Nickel Composite in Engine Valve Guides

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In this journal paper an attempt has been made to increase the reliability of engine valve guide using chrome-nickel composites as an alternative material for the engine valve guides. chrome-nickel composites are finding increased application in automobiles, FEA of the chrome-nickel engine valve guide was design and analysis is done by using Ansys13 software. The temperature, thermal stress distribution amd structural analysis of the entire surface of the engine valve guide was analysised. The stress distributions were to be found even throughout the existing materials.

Keywords: FEA, principal stress, principal strain.

1. 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. chrome-nickel 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 reinforced matrix composites for different automotive components viz. piston, cylinder liner, engine valves, valve seat inserts etc. [1–6]. Chrome–nickel engine valve guides have been fabricated through casting and powder metallurgy processes

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

- 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 valve 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 chrome-nickel composites are expected to provide a better solution.
The finite element analysis is the most widely accepted computational tool in engineering analysis. The finite element analysis of the engine valve guide has been carried out using Ansys software. Table 1 shows the properties of different materials used for the finite element analysis. To make the analysis simple following assumptions were made:

1. The chrome–nickel composites are homogeneous and isotropic materials.
2. The effect of other neighboring components was neglected.

2. 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 chrome-nickel composite engine valve guide were defined.
4. The temperature, pressure and displacement boundary conditions on the components were applied as follows:
   (a) Temperature boundary conditions:
   Temperature at cylinder end = 620^oC
   Temperature at outer end = 460^oC

(b) 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

(c) Displacement boundary conditions:

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

5. 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.

Table 1 Properties of different material used for the Finite Element Analysis

Material	Elastic modulus GPa	Poisson ratio μ	Coefficient of thermal expansion X10^5/K	Thermal conductivity W/mK	Density kg/m^2
A1-10 wt. % SiC	77.4	0.33	2.0	173	2744.0
A1-20 wt. % SiC	86.0	0.32	1.75	168	2788.0
A1-30 wt. % SiC	92.0	0.31	1.55	164	2835.0
chrome-nickel	220.0	0.26	1.60	17	7750.0

3. Finite Element Model of engine valve guide used for the analysis

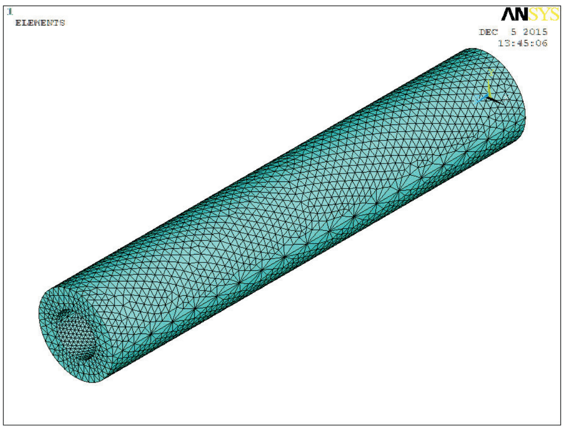

Figure 1 Finite Element model

4. Results and discussion

4.1. *Temperature distribution on the surface of the engine valve guide*

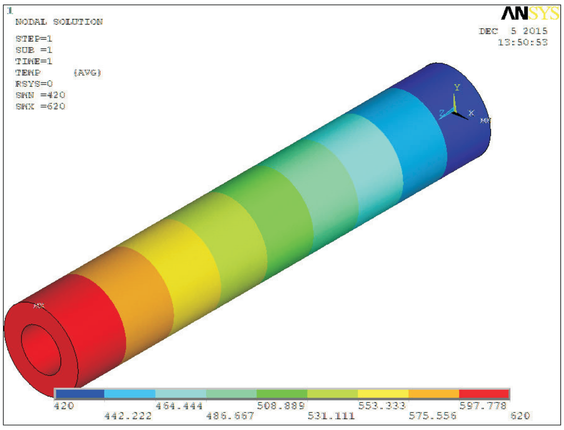

Figure 2 Temperature distribution over the entire surface of chrome–nickel composite engine valve guide

The temperature distribution over the entire surface of the chrome-nickel 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^{o}C and 420^{o}C.

4.2. *Principal stress and principal strain distribution on the surface of the engine valve guide*

Fig. 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 2.067 MPa and -2.173 MPa respectively, which are less then the strength of the chrome–nickel composites.

Fig. 4 shows the principal strain distribution over the entire surface of the chrome–nickel composite engine valve guide. The maximum and minimum principal strain values in the chrome-nickel composite engine valve guide are 2.55 and 2.244 respectively. The maximum deformation in the chrome–nickel 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.

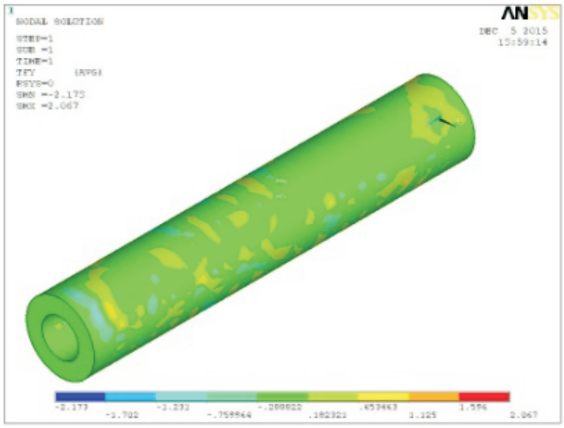

Figure 3 Principal stress distribution on the surface of the engine valve guide

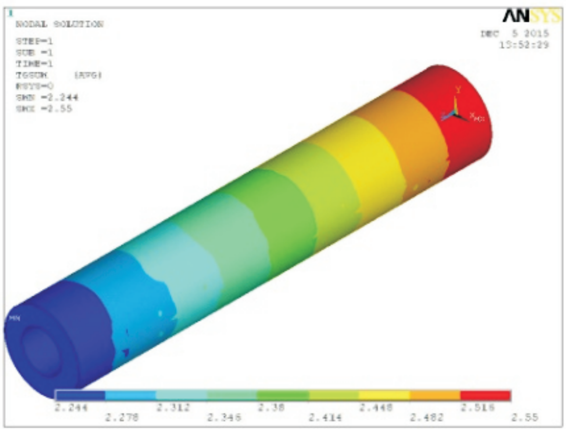

Figure 4 Principal strain distribution on the surface of the engine valve guide

5. Conclusion

The maximum principal stress in the engine valve guide is 2.067 (tensile) and -2.173 MPa (compressive), under the given conditions, which is much less than the strength of the chrome–nickel composites (compressive strength = 302 MPa and tensile strength = 132.4 MPa for chrome–nickel composites [4]). The chrome–nickel 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 chrome–nickel composites have the enough potential as an alternative material for the engine valve guides.

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