Wear 342-343 (2015) 129–137

Contents lists available at ScienceDirect

Wear

journal homepage: www.elsevier.com/locate/wear

Design and operation of a high temperature wear test apparatus for automotive valve materials

Luis Alberto Breda Mascarenhas [a,*], Jefferson de Oliveira Gomes [b], Valter Estevão Beal [a], Andrey Teixeira Portela [a], Cristiano Vasconcellos Ferreira [c], Celso Antonio Barbosa [d]

[a] SENAI CIMATEC, Av. Orlando Gomes, 1845, Piatã, CEP 41650-010 Salvador, BA, Brazil
[b] ITA/CCM, Praça Marechal Eduardo Gomes, no. 50-Vila das Acácias, CEP 12228-970 São José dos Campos, SP, Brazil
[c] UFSC, Universidade Federal de Santa Catarina, Campus Joinville, R. Pres. Prudente de Moraes, Santo Antônio, Joinville, CEP 89218-000 SC, Brazil
[d] ABINOX, Av. Brigadeiro Faria Lima, 1234 Cjto.131, CEP 1451-001 São Paulo, SP, Brazil

ARTICLE INFO

Article history:
Received 22 March 2015
Received in revised form
20 August 2015
Accepted 21 August 2015
Available online 31 August 2015

Keywords:
Wear testing
Wear test apparatus
Automotive valves
Automotive valve seats
High temperature wear tests

ABSTRACT

A current trend in the automotive industry is to reduce the engine size while increasing power. The valve and valve seat perform the functions of ensuring the entry of air and combustible material, the output of combustion gases and sealing during the compression and combustion processes. As a result, the pair valve and seat are the most critical components in high-efficiency engines. To ensure the robustness of their operation while providing clean combustion and low emissions, the use of the correct materials is required. The high temperatures of the exhaust gases, the velocities of the valves and the high operating pressures are several of the parameters that cause wear on the valve seats and valves. The materials used to create the valve must be characterized by good workability, high wear resistance, good mechanical strength and good fatigue and corrosion resistance at high temperatures. However, the tests applied to develop new materials are limited to lower temperatures than those expected in the next generation of combustion engines. In this study, the development of a new valve seat and valve test machine for high temperatures is presented. A comparison of the currently available designs of apparatuses for this purpose is also presented with the new proposed design. The results of testing the valve seats and valves using this new design are presented and evaluated along with the results of the standard test machines.

1. Introduction

Currently, vehicle combustion engines are designed to be smaller but with greater output power, producing lighter powertrains and higher overall automobile efficiency. Smaller engines also save space under the hood, where other devices such as electrical motors and accessories are housed, allowing cars to utilize hybrid technology and potentially other energy sources. One of the challenges posed by the worldwide automotive industry is for 1.2-liter cylinder engines to achieve power approaching 200 hp [1]. Today, 1.4-liter engines deliver a power output near 100 hp. One of the strategies for obtaining greater power is to employ a turbo-compressor that increases the mixture volume in the combustion chamber at a higher pressure, improving the combustion power. Other alternatives include improving the fuel combustion, the use of lighter and more resistant materials, decreasing friction and improving heat exchange, etc. These changes typically lead to higher temperatures and pressures in the combustion chamber and thus require exhaust valves and valve seats that will operate at higher temperatures; these new operating conditions are not currently supported by available materials [1].

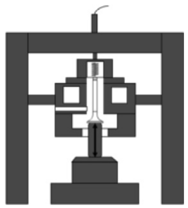
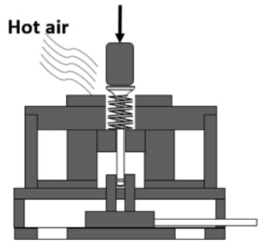
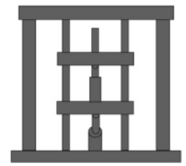
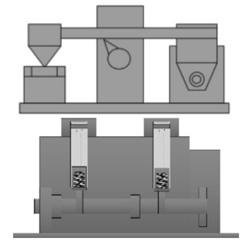
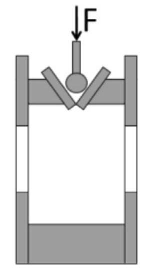
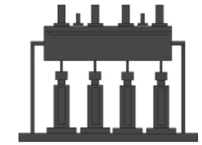
Many changes in the valve and valve seat materials, processes and designs have contributed significantly to increased engine durability and efficiency; however, there is still a significant amount of research to be done [2]. The engine valve and the seat insert that are used in engines must operate normally in severe environments at high temperatures and pressures and must perform as designed for a long period of time [3]. The development of new materials for automotive engine valves is based on the need for increased service durability, low material cost and good manufacturing characteristics, both for the valves and the valve seats [4]. The following characteristics must be considered: high-temperature resistance, wear resistance, corrosion resistance, toughness, high-temperature fatigue resistance and high thermal conductivity [5]. Different researchers have developed test apparatuses for wear analysis of these two components. The equipments developed by Lewis [6], Wang et al. [7], Chun [8], Slatter et al. [9], and Ramalho et al. [10] were used as references for the new design proposed.

* Corresponding author. Tel.: +55 71 3462 9500.
E-mail address: breda@fieb.org.br (L.A.B. Mascarenhas).

http://dx.doi.org/10.1016/j.wear.2015.08.017
0043-1648/

Table 1
Primary characteristics of the currently available valve and seat test machines.

Benchmarking analysis

	Wang (1996)	**Lewis (2002)**	**Chun (2007)**	**Slatter (2009)**	**Ramalho (2009)**	**Mascarenhas (2014)**
Concept						
Construction features	Structure based on a universal testing machine	Valve mounted upside down. The spring opens the valve	Structure based on a universal testing machine	Two separated experiments. Reciprocating movement from a cam. Twin valve test rig	Does not test the component, test material	Four independent combustion chambers and four actuators
Operating characteristic	Temp: 180, 570 °C Load: 2 kN to 22 kN Spin: 4 rpm Off Set 0.76 mm	Temp: 130 °C Load: 6 kN to 18.6 kN Freq: 10 Hz Spin: 1 rpm Off set: 0.25 mm	Temp: 760 °C Load: up to 39 kN Freq.: 50 Hz Spin: 4 rpm	The operating speed of a 2.2 KW motor is maintained and controlled by a speed controller.	Temp: 20, 200 and 400 °C Freq.: 10 Hz	Temp: 900 °C Load: 1 kN to 25 kN Spin: 4 rpm Off Set: 0.1 to 10 mm Freq.: 50 Hz
Time/number of cycles	1.5×10^3 Up to 3.4×10^6	2.4×10^4 Up to 5.5×10^4	2×10^6	100 h to 3.6×10^6	Not mentioned	Flexible
Analysis method	Scanning profilometry, SEM, EDS	Optical microscopy	Optical laser scanning, SEM, EDS, scanning profilometry	Optical microscopy, profilometry	SEM, EDS, scanning profilometry	Chemical Analysis, Stereoscopy, Metallography, MEV, EDS, Surface, Macro- and Micro-Hardness
Analysis quantitative	Wear depth	Wear depth	Rmax	Wear volume	Wear volume	Rt and Rmax