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Design methodology applied in piston testing device

Metodología de diseño aplicada en dispositivo de pruebas en pistones

RAMÍREZ-CRUZ, José Luis†*, JIMÉNEZ-RABIELA, Homero, VÁZQUEZ-GONZÁLEZ, Benjamín and GARCÍA-SEGURA, Pedro

Universidad Autónoma Metropolitana. Unidad Azcapotzalco. División CBI. Departamento de Energía.

ID 1st Author: *José Luis, Ramírez-Cruz* / **ORC ID**: 000-0003-0762-2630, **Researcher ID Thomson**: G-3405-2019, **CVU CONACYT ID**: 921268

ID 1st Coauthor: *Homero, Jiménez-Rabiela* / **Researcher ID Thomson**: S-2299-2018, **CVU CONACYT ID**: 123386

ID 2nd Coauthor: *Benjamín, Vázquez-González* / **ORC ID**: 0000-0002-9030-5662, **Researcher ID Thomson**: S-2417-2018, **CVU CONACYT ID**: 25749

ID 3rd Coauthor: *Pedro, García-Segura* / **ORC ID**: 0000-0003-4947-084X, **Researcher ID Thomson**: S-2360-2018, **CVU CONACYT ID**: 371233

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Abstract

As part of the development and manufacture of engine pistons used by the automotive industry, a series of laboratory tests are carried out that include: Mechanical, metallographic and chemical analysis of the material, dimensional verification, final weight and piston finishes finished, tests on the engine dynamometer of the finished product, etc. The technological development department of an automotive piston manufacturing company, as part of the quality assurance process of its products, has established the need to assess the compressive and fatigue resistance of pistons, both at room temperature and at temperature normal operation of an internal combustion engine. The equipment proposed to carry out these tests is an hydraulic servo machine, which has the capacity to apply dynamic load and static load, with which extreme piston operating loads can be simulated. For this reason, the design goal of this work is to design a device with which the test specimens (pistons) can be held in the machine, in order to perform fatigue and compression tests and in which, the heat can be heated. piston at the required test temperature.

Piston, Mechanical Test, Fatigue, Simulation, Design

Resumen

Como parte del desarrollo y fabricación de pistones para motores utilizados por la industria automotriz, se realizan una serie de ensayos de laboratorio que incluyen: Pruebas mecánicas, metalográficas y análisis químico del material, verificación dimensional, del peso final y de los acabados de los pistones terminados, pruebas en el dinamómetro de motor del producto terminado, etc. El departamento de desarrollo tecnológico de una empresa fabricante de pistones automotrices, como parte del proceso de aseguramiento de calidad de sus productos, ha establecido la necesidad de evaluar la resistencia a la compresión y a la fatiga de pistones, tanto a temperatura ambiente como a la temperatura normal de operación de un motor de combustión interna. El equipo propuesto para realizar estas pruebas es una máquina servo hidráulica, la cual tiene capacidad de aplicar carga dinámica y carga estática, con las cuales se puede simular cargas extremas de operación de los pistones. Por este motivo, la meta de diseño de este trabajo es el diseñar un dispositivo con el cual se pueda sujetar las probetas de prueba (pistones) en la máquina, para poder realizar pruebas de fatiga y compresión y en cual, se pueda calentar el pistón a la temperatura requerida de prueba.

Pistón, Fatiga, Simulación

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* Correspondence to the Author (e-mail: rcjl@azc.uam.mx)
† Researcher contributing as first author.

Introduction

INEGI released the administrative records of the light vehicle automotive industry that develops in the country, from 21 companies affiliated to the Mexican Association of the Automotive Industry, A.C. (AMIA), such as sales to the public in the domestic market, production and exports for the month of September of this year. Approximately 63% of the light vehicles produced in Mexico are exported to the United States market [1] and, therefore, regulations and consumer preferences in this market affect both the vehicles produced in Mexico, as well as the parts and components thereof, including the original and spare piston sector.

(Unidades)

Marca	Septiembre			Enero-Septiembre		
	2018	2019	Var. %	2018	2019	Var. %
Total	**320,288**	**318,906**	**(-) 0.43**	**2,955,719**	**2,931,326**	**(-) 0.83**
Afiliadas	**320,071**	**318,568**	**(-) 0.47**	**2,953,735**	**2,927,733**	**(-) 0.88**
Audi	9,758	15,102	54.8	133,573	127,561	(-) 4.5
BMW Group a/	n.d.	3,197	n.c.	n.d.	11,841	n.c.
FCA México b/	57,643	45,814	(-) 20.5	492,547	440,119	(-) 10.6
Ford Motor	22,413	17,755	(-) 20.8	204,402	225,149	10.2
General Motors	75,010	75,293	0.4	647,463	673,032	3.9
Honda	3,589	16,698	365.3	114,321	163,035	42.6
KIA	28,300	24,200	(-) 14.5	211,900	216,400	2.1
Mazda	9,686	3,644	(-) 62.4	119,464	59,676	(-) 50.0
Nissan	66,043	60,142	(-) 8.9	569,734	517,043	(-) 9.2
Toyota	18,410	17,644	(-) 4.2	143,449	146,143	1.9
Volkswagen	29,219	39,079	33.7	316,882	347,734	9.7

Figure 1 Total production of light vehicles *(Taken from www.inegi.org.mx)*

It should be noted that the statistics on the production of pistons in the aftermarket does not include the production of pistons used in the production of engines, therefore the total production of pistons in Mexico for 2018 reached around 19 million pieces.

The trends in the manufacture of gasoline engines for the automotive industry can be included in the following requirements:

– Reduce polluting emissions
– Increase fuel efficiency
– Put up with:
– Elevated temperatures (> 350 ° C).
– High pressures in the combustion chamber (Figure 5)
– High revolutions per minute (> 5000).
– Attrition processes.
– Corrosion processes.

Figure 2 Piston damage due to fatigue and wear
Source: Self Made

The pistons are one of the most complex components among all the components of the automotive industry or others, being these the most important part of an engine. Due to the number of cycles and high temperatures, fatigue studies have been carried out in different cases, simulating these conditions. In Figure 3 it is possible to see the state of efforts of a piston under a working pressure.

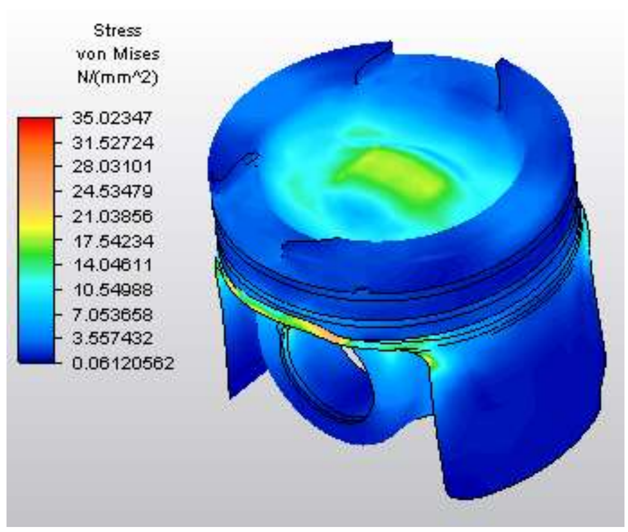

Figure 3 Simulation of forces in a piston
Source: Self Made

The technological development department of an automotive piston manufacturer, as part of the quality assurance process of its products, has established the need to evaluate the resistance to compression and fatigue of the pistons that it develops and manufactures, both at room temperature. as at the normal operating temperature of an internal combustion engine. The equipment proposed to carry out these tests is the servo hydraulic machine, which has the ability to apply dynamic load and static load, with which extreme piston operating loads can be simulated.

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The present work aims to show the design of a device with which the test specimens (pistons) can be held in a mechanical testing machine that will be used to carry out fatigue and compression tests and that can be heated in this the piston at the required test temperature.

Design requirements

Design activity begins with the recognition and determination of a need or desire for a product, service, or system, and the ability to satisfy that need. The requirements of the characteristics of the test device were generated by personal interviews and by telephone, which have been grouped and are described below:

Mandatory requirements

- That allows to evaluate the resistance to fatigue of a finished piston.
- That allows to evaluate the compressive strength of a finished piston.
- Let the device perform the test reliably.
- Have the device coupled to the Instron machine.
- That the assembly and disassembly maneuvers are safe.
- That unsafe conditions are not generated during the test.
- That it takes place within a maximum period of 8 months.
- That the cost of the device does not exceed $ 7,500.00 dollars.

Desirable requirements

- That reproduces wear phenomena on the test piston.
- That different pistons can be tested.
- That simulates the normal operating temperature of the piston.
- That the assembly of the device is easy.
- Make it easy to assemble and disassemble the testing device on the testing machine.
- Easy assembly and disassembly of the pistons in the test fixture.

Information concerning the identified problem becomes the basis for a problem statement, which may consist of information, presented for formal consideration.

			Design goals	
#	**Variable**	**Unit**	**P-1**	**P-2**
1	Maximum load.	KN	400	180
2	Minimum load.	KN	0	80
3	Load application frequency.	Hz	1	10
4	Test temperature.	°C	25-350	25-350
5	Percentage of area in contact with the piston head.	%	100	100
6	Device length.	mm	300	300
7	Device width.	mm	300	300
8	Device height.	mm	700	700
9	Piston diameter.	mm	55-100	55-100
10	Piston height.	mm	40-60	40-60
11	Piston race.	mm	60-100	60-100
12	Maximum weight of device parts.	kg	< 15	< 15
13	Maximum total weight of the device.	kg	< 50	< 50
14	Staff needed.	Cantidad	3	3
15	Tools needed.	Cantidad	4	4

Table 1 Design goals. P-1 Compression test. P-2 Fatigue test
Source: Self Made

Definition of the functional model

A function represents the role played by an item or a complete assembly. A product function is a statement of a clear and reproducible relationship between the available input and the desired output of a product, independent of any particular form.

The following describes the functional model of the Device for fatigue and compression tests, for pistons of gasoline engines. The service functions and their classification of the device for fatigue and compression tests, for pistons of gasoline engines, are indicated in Table 2 and, in Figure 4 the global service function is shown that relate to each of the service functions.

Key	Service function
A1	Mount the piston in the device
A2	Place interface between piston and device
A3	Heat piston and interface to test temperature
A4	Transfer fatigue and compression loads to the piston
A5	Fracturing the piston by fatigue or compression
A6	Remove the fracture piston

Table 2 Service functions and their classification
Source: Self Made

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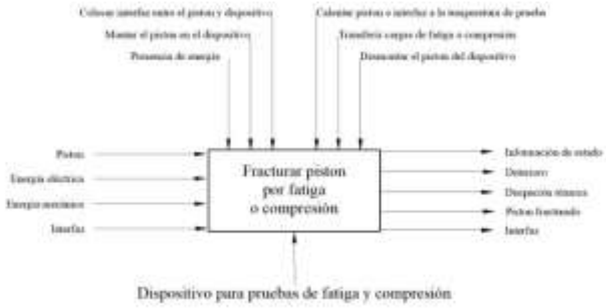

Figure 4 Description of the global function
Source: Self Made

Detail design

Design activity begins with the recognition and determination of a need or desire for a product, service, or system, and the ability to satisfy that need. Once the characteristics that must be met and how they will be covered have been defined, then we move on to the design stage to see the proposed characteristics obtained in a visual way.

At this time all parts are carefully designed based on their strength and function. Once the product is well defined and always taking costs into account, it must be built in a minimum period of time. At present, through a specialized computer program it is possible to obtain a virtual model very close to reality.

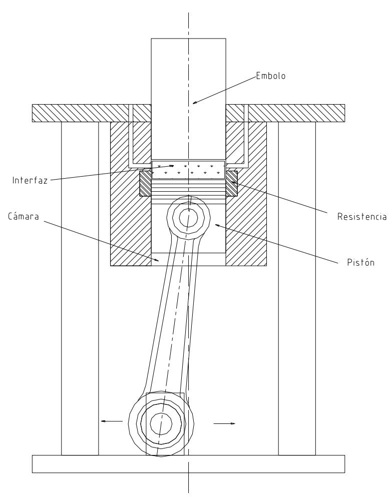

Figure 5 Outline of the device design concept for fatigue and compression tests
Source: Self Made

Figure 6 Exploded view of the virtual assembly of the device for fatigue and compression tests for gasoline engine pistons
Source: Self Made

To do this, software for 3D mechanical drawing and part and assembly modeling was used. In Figure 6, you can find the proposal that resulted from the analysis with the design methodology. The result of the design of the device characteristics is shown in Figure 7. This device contains the characteristics described above and would be the most suitable for machine manufacturing and placement.

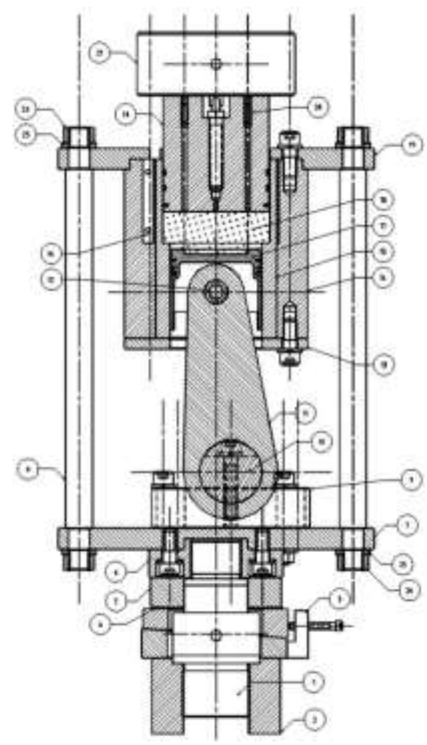

Figure 7 Virtual assembly drawing of the device for fatigue and compression tests for gasoline engine pistons
Source: Self Made

Conclusions

The proposed article refers to the development of a design methodology that applies to any type of machine, equipment or device to be developed.

The project satisfactorily meets the specifications established in the design, such as the capacity of the machine and its performance. It is concluded that the methodology is a tool that allows efforts to be focused in order to understand the client's needs and translate them into engineering design terms, thereby ensuring the success of the project.

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