

**Effect of fuels on the piston rings of the flexfuel engines****Efeito dos combustíveis nos anéis de pistão dos motores de combustível**

DOI:10.34117/bjdv6n7-288

Recebimento dos originais: 10/06/2020

Aceitação para publicação: 13/07/2020

**Rogério da Silva Nunes**

Mestre em Ciência e Tecnologia de Materiais pela Fundação Centro Universitário Estadual da Zona Oeste de Rio de Janeiro (Uezo)

Instituição: Fundação Centro Universitário Estadual da Zona Oeste de Rio de Janeiro (Uezo)

Endereço: Ave. Manuel Caldeiras de Alvarenga, 1203 - Campo Grande, Rio de Janeiro - RJ, Brasil.

E-mail: rogerio-sn@hotmail.com

**Mauro Carlos Lopes Souza**

Doutor em Engenharia Metalúrgica e de Materiais, pela Universidade Federal de Rio de Janeiro

Instituição: Fundação Centro Universitário Estadual da Zona Oeste de Rio de Janeiro (Uezo)

Endereço: Ave. Manuel Caldeiras de Alvarenga, 1203 - Campo Grande, Rio de Janeiro - RJ, Brasil.

E-mail: mauroclsouza@hotmail.com

**Rodrigo Felix de Araujo Cardoso**

Doutor em Ciências dos Materiais pelo Instituto Militar de Engenharia

Instituição: Centro Brasileiro de Pesquisas Físicas (CBPF).

Endereço: R. Dr. Xavier Sigaud, 150 - Urca, Rio de Janeiro - RJ, Brasil.

E-mail: rfelix@cbpf.br

**Neyda de la Caridad Om Tapanes**

Doutora em Tecnologia de Processos Químicos e Bioquímicos pela Universidade Federal de Rio de Janeiro

Instituição: Fundação Centro Universitário Estadual da Zona Oeste de Rio de Janeiro (Uezo)

Endereço: Ave. Manuel Caldeiras de Alvarenga, 1203 - Campo Grande, Rio de Janeiro - RJ, Brasil.

E-mail: neydaom@yahoo.com

**Carlos Alberto Martins Ferreira**

Doutor em Engenharia Metalúrgica e de Materiais, pela Universidade Federal de Rio de Janeiro

Instituição: Fundação Centro Universitário Estadual da Zona Oeste de Rio de Janeiro (Uezo)

Endereço: Ave. Manuel Caldeiras de Alvarenga, 1203 - Campo Grande, Rio de Janeiro - RJ, Brasil.

E-mail: professorcarlosferreira@gmail.com

**ABSTRACT**

This study describes the wear in piston rings of the internal combustion engines. The objective was to investigate, the rings wear between two engine groups, as gasoline, alcohol or blend fuel. The piston rings were acquired in a motor parts store and engine reconitioner, cataloged, identified, and chosen the samples with high mileage. The first step involved the measurement of height, thickness and ring outer diameter, to compare them with the original measurements of the manufacturers and make comparison between the groups, gasoline and flexfuel engine. In the second step, the rugosimetric parameters of the surface of the samples were checked with a rugosimeter. In the third step, a microscopic analysis was performed by a SEM for analysis of the contact surface coating of

the piston rings. It was found that differences between the two groups of piston ring in respect to the wear. So, it was concluded that the wear of the rings of the two groups of engines are similar quantitatively, however, as for the rugosimetric analysis, a great variation was observed in the rings of the flexfuel motors qualitatively, when compared with the gasoline engines rings.

**Key Words:** Measurement Wear; Piston Rings; Gasoline Engine; Flexfuel Engine.

## RESUMO

Este estudo descreve o desgaste nos anéis de pistão dos motores de combustão interna. O objetivo era investigar, os anéis se desgastam entre dois grupos de motores, como gasolina, álcool ou combustível misturado. Os anéis do pistão foram adquiridos em uma loja de peças e recondicionador de motores, catalogados, identificados e escolhidos as amostras com alta quilometragem. O primeiro passo envolveu a medição da altura, espessura e diâmetro externo do anel, para compará-los com as medidas originais dos fabricantes e fazer a comparação entre os grupos, gasolina e motor flexfuel. Na segunda etapa, os parâmetros rugosimétricos da superfície das amostras foram verificados com um rugosímetro. Na terceira etapa, uma análise microscópica foi realizada por um MEV para análise do revestimento da superfície de contato dos anéis do pistão. Verificou-se que existem diferenças entre os dois grupos do anel do pistão em relação ao desgaste. Assim, concluiu-se que o desgaste dos anéis dos dois grupos de motores é quantitativamente semelhante, porém, quanto à análise rugosimétrica, observou-se uma grande variação nos anéis dos motores flexfuel qualitativamente, quando comparados aos anéis dos motores a gasolina .

**Palavras-Chave:** Desgaste de Medição; Anéis de pistão; Motor a gasolina; Motor Flexfuel.

## 1 INTRODUCTION

In the 70's, during the first oil crisis, the National Alcohol Program (PRO-ALCOHOL), was launched by the Brazilian government, whose objective was to promote the gradual replacement of gasoline powered engines by engines that worked with ethanol.

In 1979, the world went through a second oil crisis, but Brazil wasn't completely dependent on petroleum fuel anymore, since it had already developed its own technology of internal combustion engines powered by hydrated ethyl alcohol or simply ethanol.

Although a very large amount of knowledge was obtained in this technology, concerning to the materials used in the components of the alcohol engines, many of the users, or disbelieving of the continuity of alcohol engines, opted for acquire vehicles with gasoline engines, a fact that would make alcohol engine to disappear in a short time (Cortez, 2016).

In 2003, the Brazilian automobile industry presented a solution in order not to let all the effort of years in research and development of alcohol engines dies, and so, decided to reconcile all the knowledge acquired in alcohol engines with the knowledge of the gasoline engines, launching the motors with flexfuel technology (BOSCH, 2005; SHELL, 2016). Although launched in 2003, after 16 years of continuous development, flexfuel engines have not yet reached their full technological maturity, still needing solutions or improvements to the following problems: cold start; intake

manifold; evaporative emissions system; emission of unburnt alcohol and aldehydes; combustion chamber, catalytic converter; fuel tank; discharge or exhaust pipe; motor oil; speed of alcohol combustion; time available for combustion; mechanical and chemical properties of the materials used in the construction of the engine; alteration of the environment of the tribological system; higher complexity in calibration of the engine; vibrations; creation of gum due to alcohol; lack of miscibility of gasoline with ethanol; cylinder washing and lubricant dilution during cold start; corrosive environment and low lubricity (Merlo, 2019; Santos *et al.* 2015). In addition, there is a specific problem that intrigues the engineers specialized in surface engineering, that is, the wear phenomenon in flexfuel engines, which led to the creation of a research group called TRIBOFLEX.

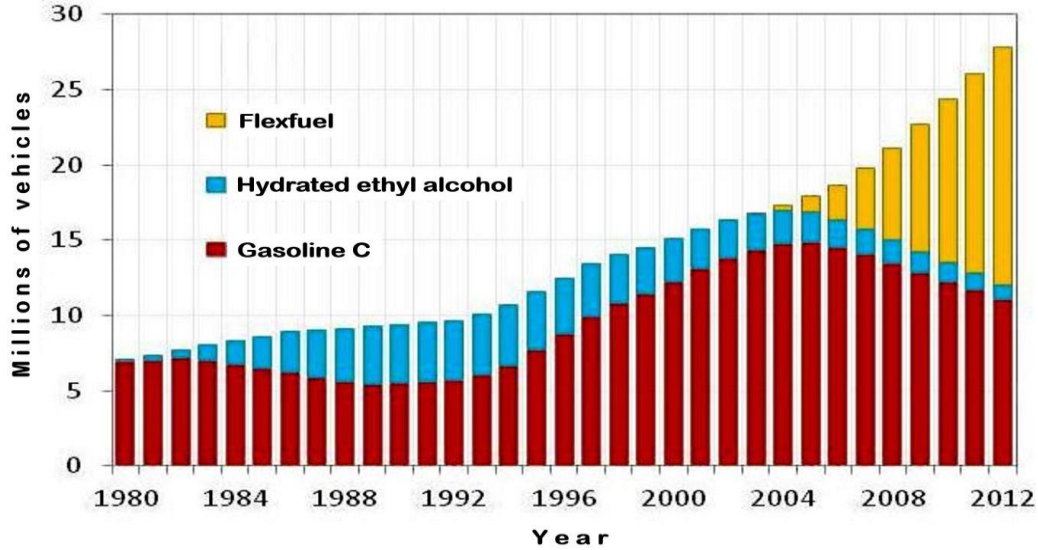
There are also others factors such as compression ratio, since alcohol and gasoline are chemically very different from each other, requiring different compression ratio and temperature conditions to generate as much energy as possible per cycle or combustion and less emission of pollutants (Beserra de Lima, 2019). The thermal degree of the spark plug can also be cited as a problem for heat dissipation of the combustion chamber. Developing an intermediate temperature spark plug that meets the requirement and initiates an efficient combustion with any fuel, or mixture between them, is still a huge challenge.

The tribological challenges are the most complex problems, as it requires in-depth research into materials, lubricants, temperatures, wear, friction and contact surfaces, as well as knowledge of the operation of these engines (Tomanik, 2016); (ASM Metals Handbook, 2002). So, the piston rings, the objects of this research, are one of the most requested components during the operation of the engine, and as it's known, by means of the Stribeck Curve, the working regime of the piston rings are quite critical and needs much attention, due to the fact that their working goes under mixed lubrication regime.

Understanding that the comparative analysis of piston ring, through physical measurements, topographic (rugosimeter) and metallographic (microscope) analysis might bring light to some questions, these procedures, that is, dimensional, rugosimetric and microscopic analysis, are used in this work, for comparative analysis between piston rings of gasoline engine and piston rings of flexfuel engine respectively, which consist the practical part of this research.

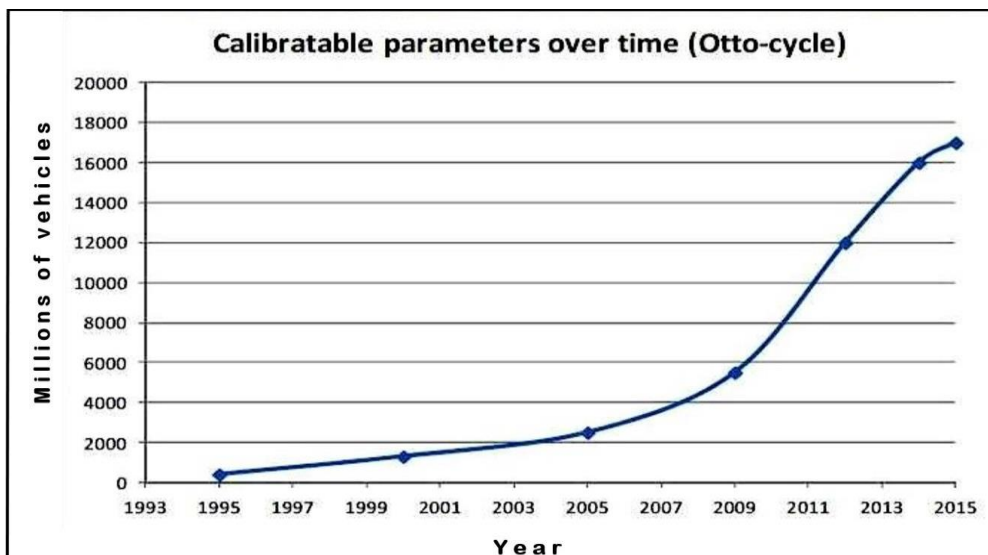
According National Inventory of Atmospheric Emissions by Road Automotive Vehicles, in 2003, the national automotive industry started manufacturing and commercializing flexfuel engines in Brazil and the production increased every year, in parallel, in 2008, the production of alcohol engines began to fall to zero, as shown in figure 1 (ANFAVEA, 2015).

Figure 1: Evolution of the estimated fleet of automobiles by type of fuel (ANFAVEA,2015).



With the increasing fleet of flexfuel vehicles, numerous problems have appeared, and among them, the calibratable parameters have brought great challenges to the industry and engineers specialized in engine calibration.

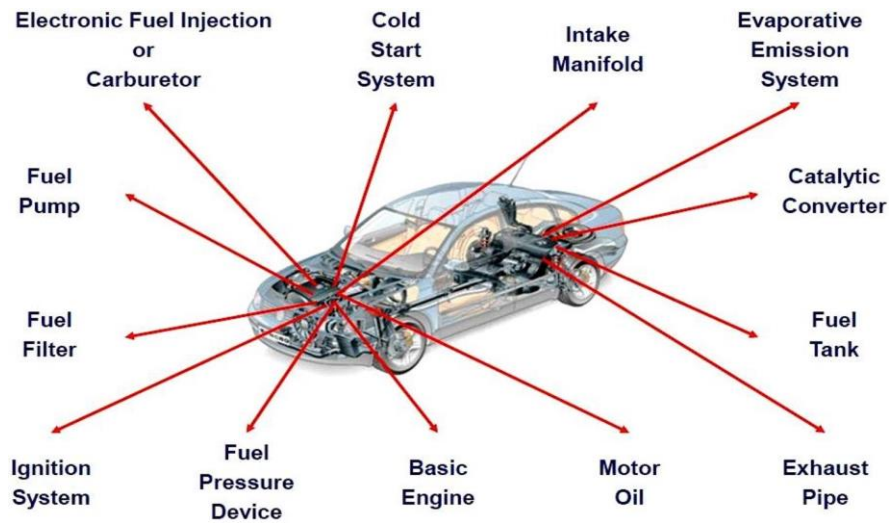
As it stands out in the figure 2, in 2003 there were approximately 1800 calibratable parameters in gasoline engines with electronic fuel injection, but by 2015 it already exceeded the 17000 calibratable parameters in the flexfuel engines (Santos *et al.*, 2015).

Figure 2: Calibratable parameters over time for the Otto cycle (Santos *et al.*, 2015).

The difficulty increases even more when the challenge is to calibrate more components or systems in less time due to evolution and technological development.

As the example of difficulty, figure 3 presents some items liable to modifications for compatibility with the two fuels (FIAT, 1999).

Figure 3: Items liable to modifications for compatibility with the two fuels: Gasoline and/or ethanol (FIAT, 1999).



As for piston rings, the oil film is crucial to its protection, and, as we all know, it has the function of creating a protective interface between the ring and the cylinder and, furthermore, must act between the mixed and hydrodynamic lubrication regime. Due to its critical work and too much load demand, a simple lubrication failure is sufficient to permanently damage the piston rings as well as the engine cylinder. It is worth remembering that the oil film between the piston ring and the cylinder is only 0.5 to 4.0  $\mu\text{m}$  in thickness.

The segment ring is one of the most requested components of the engine, and perhaps one of the most difficult to design, since it is practically impossible to test it during the operation of the engine.

## 2 EXPERIMENTS

The materials used for characterization are piston rings used and worn-out, of the first piston ring groove, also known as upper compression rings. It was collected in an automobile repair shop and in an engine reconditioner, cataloged by mileage, type of engine, gasoline or flexfuel, year of manufacture and manufacturer (Figure 4).

Figure 4: (a) - 1st Compression ring, 2nd compression ring and 3rd ring oil scraper. (b) - Samples acquired in an engine reconditioner.



Initially, there are two groups of engines. The group of gasoline engines and the group of flexfuel engines. It was selected, at random, an amount of 6 samples of gasoline engine piston rings and 6 samples of flexfuel engines piston rings as shown in table 1. Summing up a total of 12 samples. The analysis was performed in pairs, the rings of the first row of the table, second row, third row and so on, due to the kilometer proximity, since the objective is to compare the quality and amount of wear in the two groups.

Table 1: Distribution of engine, model, year and mileage groups.

GASOLINE ENGINE			FLEXFUEL ENGINE		
MODEL	YEAR	km	MODEL	YEAR	km
Fiat Palio 1.0	2003	76540	Fiat Punto 1.4 EVO	2013	52859
Gol 1.0	2005	78643	Renault Clio 1.0	2010	68736
Fiat Palio 1.0	1999	86886	Fiat Idea 1.4	2007	97440
Gol 1.0	2008	87898	Fiat Strada 1.4	2006	98675
Gol 1.0	2007	102000	Spacefox 1.6	2009	111000
Gol 2.0	1999	120000	Fiat Doblo 1.3 16v	2003	112000

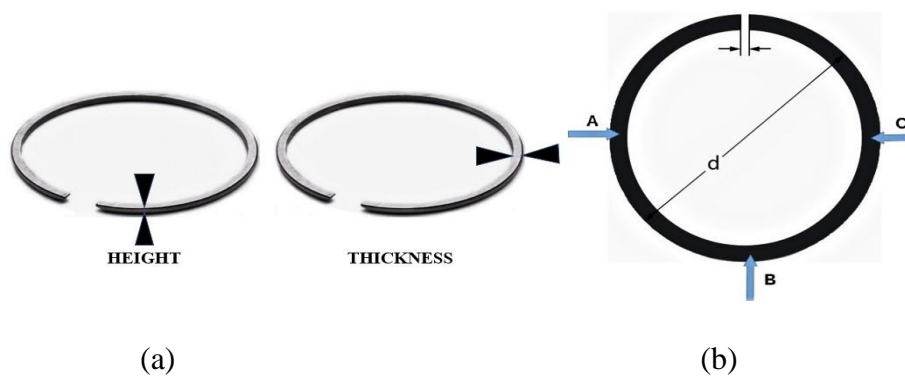
Elaborated by the author, 2017.



## 2.1. MEASUREMENTS WITH PACHYMETER AND MICROMETER

To compare the wear of the segment rings, the measurements were made using a pachymeter with a scale of 0 to 150 mm and vernier with a resolution of 0,05 mm to measure the outer diameter of the segment rings and compare according to manufacturers' catalog. Then, the measurements were recorded in a table. All measurements were performed at least three times to minimize or avoid parallax errors and achieve the highest possible accuracy. With the use of a micrometer with a scale of 0 to 25 mm and a resolution of the 0.01 mm drum, the measurement of the height of the segment ring and the thickness of the segment ring was performed.

Figure 5: (a) Height and thickness of the segment ring. (b) – Height and thickness measurement points in the segment rings.



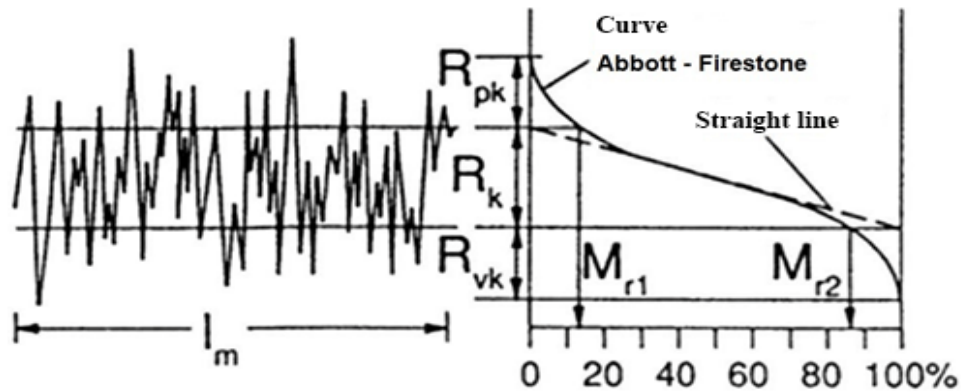
Three measurements were also performed at point "A", three measurements at point "B" and three measurements at the "C" point of the rings, to eliminate possible parallax errors and to obtain higher accuracy of the measurement (figure 5).

## 2.2 MEASUREMENTS USING RUGOSIMETER

The second characterization technique used to compare the piston rings of the gasoline engines and rings of the flexfuel engines was performed using a rugosimeter, to detect the surface roughness parameters, it is, the face of contact with the cylinder, determining the maximum values of the valleys ( $R_{vk}$ ), of the peaks ( $R_{pk}$ ) and the mean values ( $R_k$ ), (ABNT, 2002), as shown in fig 6, to determine Abbott-Firestone curve. The analysis was performed on the contact surface opposite to the ring opening, at an angle of  $180^\circ$ , at point B of the piston ring, (12 samples). The equipment was

calibrated to 1997 ISO Standard with GAUSS filter - Cutoff value  $\lambda_c$  2,5, displacement velocity 0.5 mm / s - Setup range of "AUTO" measurement.

Figure 6: Abbot-Firestone curve or contact fraction curve (ABNT, 2002).



## 2.3 MICROSCOPIC ANALYSIS

Figure 7 shows the third characterization technique, it was used the Scanning Electron Microscopy - SEM, QUANTA FEG-250 SEM model with EDS microanalysis.

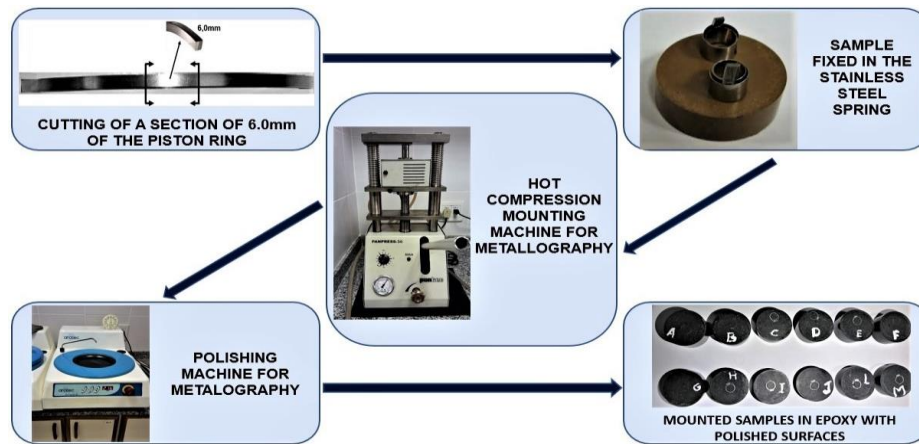
Figure 7: Scanning Electron Microscopy (SEM) – QUANTA FEG-250 With EDS microanalysis.



The microscopic analysis was performed to determine the type of base metal and the surface treatment according to the steps below, shown in figure 8.

Figure 8: Hot mounting of samples in EPOXY.








### 3 RESULTS AND DISCUSSION

#### 3.1 RESULTS OF MEASUREMENTS WITH MICROMETER AND PACHYMETER

Table 2 shows the original diameter, height and width values of the piston rings according to the manufacturer of gasoline rings, as well as year of manufacturing and motorization according to the manufacturer brands (Mahle, 2016).

Table 2: Specifications of the piston rings of gasoline engines.

Marca - Motor - Modelo Application - Engine - Model Marca - Motor - Modelo	Ano Year Año	$\varnothing$				PREMIUM	
						METAL LEVE MAHLE	Tipos Types Tipos
Fire 1.0L 8V/16V Palio	2003	70,00	4	1,20 1,20 2,50	3,05 3,05 2,98	TD.7508 STD/ 0,20/ 0,40/ 0,60	E4 T3 86T
Motor AT 1.0L 16V Mi - Gol, Parati Aspirado / Turbo	2005	67,10	4	1,20 1,50 2,00	2,65 2,80 3,19	TA.7251 STD/ 0,25/ 0,50/ 0,75	SL T6 C81
1000 / 1500 - Palio (Gasolina/ Álcool)	1999	76,00	4	1,50 1,50 3,00	3,30 3,30 3,63	DD.7391 STD/ 0,40/ 0,60	CE4 T6 87
Motor AT 1.0L 16V Mi - Gol, Parati Aspirado / Turbo	2008	67,10	4	1,20 1,50 2,00	2,65 2,80 3,19	TA.7251 STD/ 0,25/ 0,50/ 0,75	SL T6 C81
Motor AT 1.0L 16V Mi - Gol, Parati Aspirado / Turbo	2007	67,10	4	1,20 1,50 2,00	2,65 2,80 3,19	TA.7251 STD/ 0,25/ 0,50/ 0,75	SL T6 C81
VW AP 2000 Álcool / Gasolina Gol 2.0	1999	82,50	4	1,50 1,50 2,00	3,35 3,55 3,28	DT.7072 STD/ 0,25/ 0,50	CE T6 86

Elaborated by the author, 2017.

The table 3, below, shows the results obtained in the height, width and diameter measurements of gasoline engine piston rings. The measurements of the diameters were taken by pachymeter and the measurements of the heights and thicknesses of the worn-out rings, taken by micrometer, respecting the laboratory standards for metrology.





Table 3: Results of measurements of piston rings of gasoline engines with best data arrangement.

GASOLINE ENGINE			NEW RING HEIGHT (mm)	RING HEIGHT USED (mm)	$\Delta$ (D - E) (mm)	$\Delta\%$ (D - E)	NEW RING THICKNESS (mm)	RING THICKNESS USED (mm)	$\Delta$ (H - I) (mm)	$\Delta\%$ (H - I)	DIAMETER OF THE NEW RING (mm)	DIAMETER OF THE USED RING (mm)
MODEL	YEAR	km										
Fiat Palio 1.0	2003	76540	1,20	1,16	0,04	-3,33	3,05	2,92	0,13	-4,26	70,00	69,75
Gol 1.0	2005	78643	1,20	1,17	0,03	-2,50	2,65	2,45	0,20	-7,55	67,10	66,70
Fiat Palio 1.0	1999	86886	1,50	1,46	0,04	-2,67	3,30	3,12	0,18	-5,45	76,00	75,65
Gol 1.0	2008	87898	1,20	1,18	0,02	-1,67	2,65	2,46	0,19	-7,17	67,10	66,90
Gol 1.0	2007	102000	1,20	0,97	0,23	-19,17	2,65	2,35	0,30	-11,32	67,10	66,50
Gol 2.0	1999	120000	1,50	1,45	0,05	-3,33	3,35	3,32	0,03	-0,90	82,50	82,45

Elaborated by the author, 2017.

Table 4, below, shows the original diameter, height and width values of the original piston rings of the flexfuel engines (Mahle, 2016).

Table 4: Specifications of the piston rings of flexfuel engines.

Marca - Motor - Modelo Application - Engine - Model Marca - Motor - Modelo	Ano Year Año					PREMIUM	
						METAL LEVE MAHLE	Tipos Types Tipos
Motor Evo 1.4L 8v Flex Fiat Punto	2013	72,00	4	1,00 1,00	2,85 3,15	TA.8760 STD	E4 IT7
Clio, Twingo Motor D7F	2010	69,00	4	1,50 1,50 2,50	3,05 3,05 3,33	DD.7270 STD A18800	CE4 T3 88
Fire 1.4L Flex - Idea, Palio, Wee- kend, Siena, Strada	2007	72,00	4	1,20 1,20 2,00	3,05 3,15 2,83	TT.8330 STD/ 0,40/ 0,60	E4 T6 86T
Fire 1.4L Flex - Idea, Palio, Wee- kend, Siena, Strada	2006	72,00	4	1,20 1,20 2,00	3,05 3,15 2,83	TT.8330 STD/ 0,40/ 0,60	E4 T6 86T
Motor EA 111 1.6L 8V Flex Fuel - Gol, Parati, Saveiro, Fox Spacefox	2009	76,50	4	1,20 1,50	2,85 3,30	TA.8126 STD/ 0,50	SL T6
Fire 1.3L - 8V/16V Doblo	2003	70,80	4	1,20 1,20 2,50	3,05 3,05 2,98	TD.7500 STD/ 0,20/ 0,40/ 0,60	SL4 T3 86T

Elaborated by the author, 2017.

In the table 5, it's shown the results obtained in the measurements of height, width and diameter of the piston rings of the flexfuel motors.

Table 5: Results of measurements of the piston rings of flexfuel engines with best data arrangement.

FLEXFUEL ENGINE			NEW RING HEIGHT (mm)	RING HEIGHT USED (mm)	$\Delta$ (D - E) (mm)	$\Delta\%$ (D - E)	NEW RING THICKNESS (mm)	RING THICKNESS USED (mm)	$\Delta$ (H - I) (mm)	$\Delta\%$ (H - I)	DIAMETER OF THE NEW RING (mm)	DIAMETER OF THE USED RING (mm)
MODEL	YEAR	km										
Fiat Punto 1.4 EVO	2013	52859	1,00	0,98	0,02	-2,00	2,85	2,74	0,11	-3,86	72,00	71,80
Renault CLIO 1.0	2010	68736	1,50	1,48	0,02	-1,33	3,05	2,75	0,30	-9,84	69,00	68,40
Fiat Ideia 1.4	2007	97440	1,20	1,18	0,02	-1,67	3,05	2,91	0,14	-4,59	72,00	71,80
Fiat Strada 1,4	2006	98675	1,20	1,18	0,02	-1,67	3,05	3,04	0,01	-0,33	72,00	71,90
Spacefox 1.6	2009	111000	1,20	1,17	0,03	-2,50	2,88	2,70	0,18	-6,25	76,50	76,20
Fiat Doblo 1.3 16v	2003	112000	1,20	1,16	0,04	-3,33	3,05	2,92	0,13	-4,26	70,80	70,55

Elaborated by the author, 2017.

### 3.2 RESULTS OF THE RUGOSIMETRIC ANALYSIS

The Table 6 presents the distribution of the results of the laboratory evaluations obtained with a rugosimeter, which analyzed the surface roughness of the surface of gasoline engine piston rings. The values Rvk, Rk and Rpk are observed respectively.

In the left vertical legend are the values in  $\mu\text{m}$  and in the lower horizontal legend, the numbers 1, 2, 3, 4, 5 and 6 that represent the engines of the vehicles in the order arranged in the table 6.

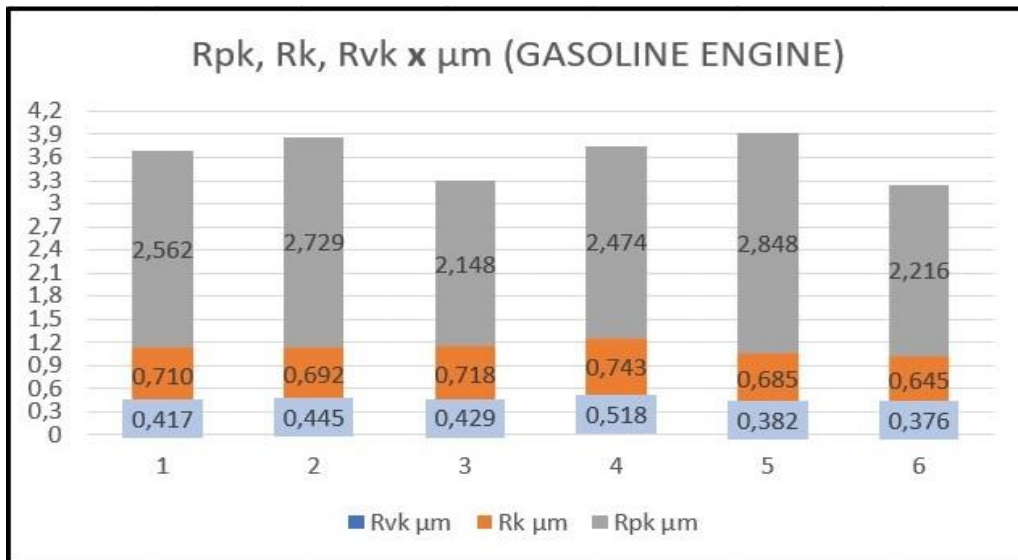
Table 6: Results of the values of Rvk, Rk and Rpk found in the rugosimetric analysis of the gasoline engines.

GASOLINE ENGINE			Rvk	Rk	Rpk
MODEL	YEAR	km	$\mu\text{m}$	$\mu\text{m}$	$\mu\text{m}$
Fiat Palio 1.0	2003	76540	0,417	0,710	2,562
Gol 1.0	2005	78643	0,445	0,692	2,729
Fiat Palio 1.0	1999	86886	0,429	0,718	2,148
Gol 1,0	2008	87898	0,518	0,743	2,474
Gol 1.0	2007	102000	0,382	0,685	2,848
Gol 2.0	1999	120000	0,376	0,645	2,216

Elaborated by the author, 2017.

The graph of Figure 9 shows the results of Rpk, Rk and Rvk X for the rings of the gasoline engines.

Figure 9: Graph of results of Rpk, Rk and Rvk X  $\mu\text{m}$  for the rings of gasoline engines.



The table 7 shows the distribution of the results of laboratory evaluations using a rugosimeter to analyze the surface roughness of the face of the piston rings of flexfuel engine. The values of Rvk, Rk and Rpk and the graph of columns are also observed respectively, where the rugosimetric values are shown. In the left vertical legend are the values in  $\mu\text{m}$  and in the lower horizontal legend, the numbers 1, 2, 3, 4, 5 and 6 represent the engines of the vehicles in the order arranged in the table.

Table 7: Results of the values of Rvk, Rk and Rpk found in the rugosimetric analysis of the flexfuel engines.

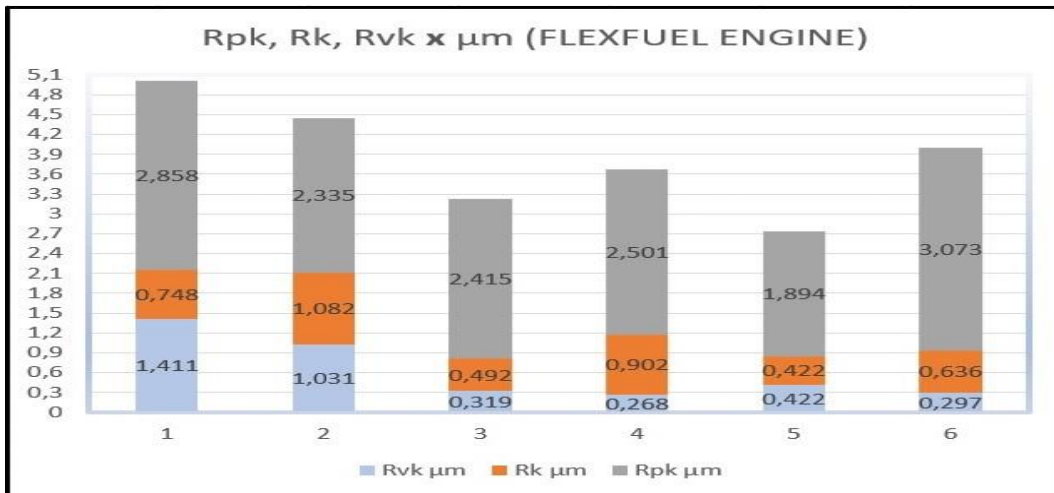
FLEXFUEL ENGINE			Rvk	Rk	Rpk
MODEL	YEAR	km	$\mu\text{m}$	$\mu\text{m}$	$\mu\text{m}$
Fiat Punto 1.4 EVO	2014	52859	1,411	0,748	2,858
Renault CLIO 1.0	2010	68736	1,031	1,082	2,335
Fiat Idea 1.4	2007	97440	0,319	0,492	2,415
Fiat Strada 1,4	2006	98675	0,268	0,902	2,501
Spacefox 1.6	2010	111000	0,422	0,422	1,894
Fiat Doblo 1.3 16v	2003	112000	0,297	0,636	3,073

Elaborated by the author, 2017.

Figure 10 shows the results of Rpk, Rk and Rvk X  $\mu\text{m}$  for the rings of the flexfuel engines.

Figure 10: Graph of results of Rpk, Rk and Rvk X  $\mu\text{m}$  for the rings of flexfuel engines.





Thus, by analyzing the graphs of figures 4 and 5, so, we come to an understanding that the wear of the piston rings of the gasoline engines has more regular wear, therefore, inferences and forecasts of wear averages can be made with accuracy and reasonableness with regard to wear quality.

As for the piston rings of the flexfuel motors, wear occurs in a random and non-uniform way, with some unpredictability regarding the quality of the wear.

### 3.3 RESULT OF MICROSCOPIC ANALYSIS

The results of the micrography are arranged in columns, following the same sequence adopted in this work, which are, the gasoline engines (A, B, C, D, E, F) and in the sequence, flexfuel engines (G, H, I, J, L, M). The left column shows the micrographs of the rings of the gasoline engines, and the right column shows the micrographs of the flexfuel engines rings.

The analyzes were performed at the top of the ring in an attempt to observe the base metal, the deposition interface and the deposition metal which is the surface treatment layer according to figure 6.

Analyzing the table 8, it can be seen that, although the samples had had randomly collected in some engine rectifiers, having doubtful origin, including real mileage, the results of the micrographs are in accordance with the segment ring manufacturer's specification regarding respect to the base material.

Figure 11: Gasoline and flexfuel piston rings micrography.

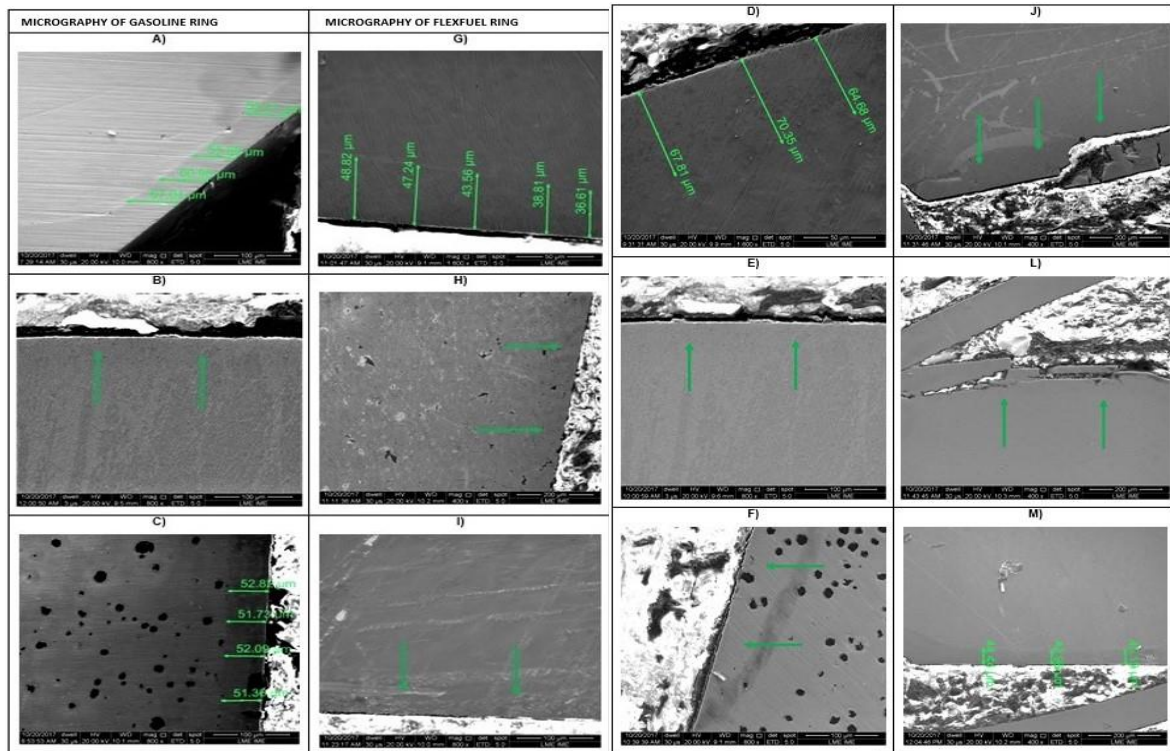


Table 8: Code of materials used in piston rings.

GASOLINE ENGINE	FLEXFUEL ENGINE
<b>Palio 1.0 – 2003</b> CÓD.: TD.7508 (Nitrided steel)	<b>Punto 1.4 – 2013/14 EVO</b> CÓD.: TA.8760 (Nitrided steel)
<b>Gol 1.0 – 2005</b> CÓD.: TA.7251 (Nitrided steel)	<b>Clio 1.0 – 2010</b> CÓD.: DD.7270 (Chromed nodular iron)
<b>Palio 1.0 – 1999</b> CÓD.: DD.7391 (Chromed nodular iron)	<b>Idea 1.4 – 2007</b> CÓD.: TT.8330 (Nitrided steel)
<b>Gol 1.0 – 2008</b> CÓD.: TA.7251 (Nitrided steel)	<b>Strada 1.4 – 2006</b> CÓD.: TT.8330 (Nitrided steel)
<b>Gol 1.0 – 2007</b> CÓD.: TA.7251 (Nitrided steel)	<b>Spacefox 1.6 – 2009/10</b> CÓD.: TA.8126 (Nitrided steel)
<b>Gol 2.0 – 1999</b> CÓD.: DT.7072 (Chromed nodular iron)	<b>Doblo 1.3 – 2003</b> CÓD.: TD.7500 (Nitrided steel)

Elaborated by the author, 2017.

In figures A, D, G and M, it is possible to identify the surface treatment layer of nitriding and, in figure C, it was possible to observe the chromium layer in the nodular cast iron ring.



In the samples B, E, F, H, I, J, L, it was not possible to identify the surface treatment or coating layer applied to the rings. The samples L and M suffered fractures and detachment of material during the inlay work. The rings of segments B, E, J, L, are made, apparently, from the same base material. Thus, a microscopic analysis with EDS in only one of the rings, just the ring of segment B, was made to identify the existence of structural metallographic changes near the edge and more towards the interior or center of the material.

#### **4 CONCLUSION**

Regarding to the measurements, it was concluded that piston rings of gasoline engine, compared to each other (among them), this is, within the group itself, do not show significant variation of worn out.

Piston rings of flexfuel engines, compared to each other (among them), that is, within the group itself, do not show significant variation of worn out.

By the analysis of the roughness profile, it was concluded that the values of  $R_{vk}$  for the rings of the gasoline engines are lower than the values of  $R_{vk}$  for rings of the flexfuel motors. The  $R_k$  values for the gasoline engine rings are lower than the  $R_k$  values for the flex-fuel rings. The  $R_{pk}$  values for the gasoline engine rings are lower than the  $R_{pk}$  values for the flex-fuel motor rings.

For the analysis of microscopy, it is possible conclude that despite some inaccuracies and uncertainties, the samples of the rings of both, gasoline engines and flexfuel engines, proved to be consistent and reliable since they show consistent characteristics with the base metal indicated in the component manufacturer's manual.

Although some samples of nitrided steel rings show surface treatment, four samples of nitrided steel rings appear to have no surface treatment, but for certification of this, it would be necessary to perform an EDS analysis on all components. It should be noted that the values found are based on direct results of measurements, taking into account the tests conditions and that they are experimental.

Non-controllable factors that affect the analyzes and samples should also be take into account, such as: Uncertainties of the real mileage of the engines; Uncertainties regarding to the fuel used in flexfuel engines, whose ring samples served as testing, as some owners opt for the exclusive use of gasoline over the life of the engine.

Engine of Gol 2.0 1999 - 120000km gasoline and Fiat Strada 1.4 2006 - 98675km flexfuel engine, with piston rings presenting little or almost no wear, raises suspicions, this engine may have had undergone recent disassembled / grinding, and, due to some maintenance or assembly failure, returned to new disassembly and had the relatively new rings discarded.

There is uncertainty regarding to the fuel used in both models, both gasoline and flexfuel, it could have been used Vehicular Natural Gas, adaptation too common these days.

## NOMENCLATURE

SEM - Scanning Electron Microscopy

ASM - American Society of Materials

ANFAVEA - Associação Nacional de Fabricantes de Veículos Automotores

RPK - Reduced Peak Height Along (X, Y)

RVK - Reduced Valley Depths Along (X, Y)

RK - Core Roughness Along (X, Y), is a measure of the core (peak to valley)

ABNT - Associação Brasileira de Norma Técnica

EDS - Energy Dispersive X-Ray Spectroscopy

## ACKNOWLEDGEMENTS

The authors would like to thank the financial support given by the Research Support Foundation of the State of Rio de Janeiro (FAPERJ) to the study.

## REFERENCES

ABNT, NBR ISO 4287, Rugosidade: Método do perfil – Termos, definições e parâmetros de rugosidade. 2002.

ANFAVEA - National Inventory of Atmospheric Emissions by Automotive Vehicles. 2015.

ASM METAL HANDBOOK, Friction, lubrication and wear technology. Vol. 18. 2002.

BESERRA DE LIMA, A.J.T. AND GALLO, W.L.R. Chemical kinetics analysis of NO and CO formation based on thermodynamic data from an ethanol-fueled engine computational model. **Brazilian Journal of Development**, v. 5, n.8, p. 12607-12622, 2019.

BOSCH, Manual de Tecnologia Automotiva. Ed. Edgard Blücher. 25ª edição. 2005.

Cortez, L. A. Barbosa. PROÁLCOOL 40 ANOS – Universidades e Empresas: 40 anos de ciência e tecnologia para o etanol brasileiro. Ed. BLÜCHER. 2016.

FIAT - Motor Show, Nova enciclopédia do automóvel. Ed. Três. 1999.

MAHLE – Metal Leve, Catálogo de aplicações. 2016.

Merlo, N.P., Rocha, M.A.P., Júnior, M.R.F., Aud, B.N., Silva, T.A.L., Rocha, N. R.A. Comparison and Analysis of the Effects of Several Improvements in the Traditional Model on Engine Working with Otto Cycle. **Brazilian Journal of Development**, v. 5, n.10, p. 19003-19011, 2019.

Santos, L. R., Ferreira, R. P., Engenharia de motores flexfuel automotivos: Concepção, simulação e calibração. Apostila de curso SAE Brasil. 2015.

# *Brazilian Journal of Development*

SHELL Research & Technology Centre - Thornton. 2016.

Tomanik, E., Tribologia em motores de combustão interna. Apostila curso SAE Brasil 2016.