PROPOSING A METHOD FOR ASSESSING FUEL CONSUMPTION AND POLLUTANTS EMISSIONS WITH THE USE OF CONTINUOUSLY VARIABLE TRANSMISSION IN TOWN CARS.

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Abstract:

The 21st century brings countless social, economic, environmental and technological challenges to humanity and, to face them, the Sustainable Development Goals (SDGs) were created through the United Nations (UN). The auto industry, which is part of the private sector, aims to reach them. In this context, this dissertation project aims to carry out an evaluation of the consumption and emissions of pollutants by using an automatic transmission of the CVT (Continuous Variable Transmission) type in relation to the automatic transmission of the "Planetary" type. This study will be based on the Consumption/Energy Efficiency tables, published annually by INMETRO (National Institute of Metrology, Quality and Technology) and whose data will be processed and evaluated using the Quik Sense Software. Thus, the work aims to statistically evaluate the advantages of vehicles with automatic transmission of the CVT type in relation to fuel consumption, energy efficiency and emissions, in markets such as Brazil, where these vehicles use ethanol or a mixture of gasoline with up to 27 as fuel % Ethanol. This research can contribute to studies in the areas of emission control and approval, benefiting the automotive industry in general, government agencies, the environment, the economy, and society, and contributing to the achievement of the UN's SDGs.

Keywords: Emissions, Consumption, CVT, Transmission by Planetary, Energy Efficiency, Sustainable Development.

PROPOSIÇÃO DE UM MÉTODO PARA AVALIAÇÃO DO CONSUMO DE COMBUSTÍVEL E EMISSÕES DE POLUENTES COM O USO DE TRANSMISSÃO CONTINUAMENTE VARIÁVEL EM AUTOMÓVEIS DE PASSEIO.

Resumo:

O Século XXI traz inúmeros desafios socias, econômicos, ambientais e tecnológicos para a humanidade e, para enfrentá-los, foram criados os Objetivos de Desenvolvimento Sustentável (ODS), através da Organização das Nações Unidas (ONU). A indústria automobilística, que é parte do setor privado, tem como meta alcançá-los. Neste contexto, este projeto de dissertação tem como objetivo realizar uma avaliação do consumo e emissões de poluentes ao ser utilizado uma transmissão automática do tipo CVT (Continuous Variable Transmission) em relação a transmissão

automática do tipo “Planetária”. Este estudo terá como base as tabelas de Consumo / Eficiência Energética de Veículos Automotores Leves, publicadas anualmente pelo INMETRO (Instituto Nacional de Metrologia, Qualidade e Tecnologia) e cujos dados serão tratados e avaliados utilizando o Software Quik Sense. Assim, o trabalho visa avaliar estatisticamente as vantagens de veículos com transmissão automática do tipo CVT em relação ao consumo de combustível, eficiência energética e emissões, em mercados como o brasileiro, onde estes veículos utilizam como combustível o Etanol ou mistura de gasolina com até 27% de Etanol. Essa pesquisa pode contribuir para os estudos da áreas de controle de emissões e homologação, beneficiando a indústria automotiva em geral, órgãos governamentais, o meio ambiente, a economia e a sociedade e contribuindo para o alcance dos ODS da ONU.

Palavras-chave: Emissões, Consumo, CVT, Transmissão por Planetárias, Eficiência Energética, Desenvolvimento Sustentável.

1. INTRODUCTION

Nowadays, research and development of quality products that meet the demands of consumers are essential, in addition to the broad competition in the market and the relevant legislation (Route 2030: Law No. 13,755). In addition, it is essential that these products are within the Goals for Achieving Sustainable Development (SDG), included in the 2030 Agenda of the United Nations (UN), which Brazil ratified.

The Sustainable Development Goals (SDGs) belong to a global agenda, adopted during the United Nations Summit on Sustainable Development, in September 2015, comprising 17 objectives and 169 goals to be achieved by 2030 (UN, 2015). This agenda includes global actions in the areas of poverty eradication, food security, agriculture, health, education, gender equality, reduction of inequalities, energy, water and sanitation, sustainable patterns of production and consumption, climate change, sustainable cities , protection and sustainable use of oceans and terrestrial ecosystems, inclusive economic growth, infrastructure, industrialization, among others (UN, 2015). Among the 17 SDGs, three are directly impacted by urban mobility and the use of motor vehicles.

The SDG 03 "Good Health and Well-being" aims "To ensure a healthy life and promote well-being for all, at all ages" Within its objectives is the target 3.9: "By2030, substantially reduce the number of deaths and diseases from dangerous chemicals, contamination and pollution of air, water and the soil", which this work will seek to contribute, when offering proof of which transmission will pollute less.

The SDG 01, " Sustainable Cities and Communities", seeks to "Make cities and human settlements inclusive, safe, resilient and sustainable. " Its goal 11.6: "By2030, reduce the negative environmental impact per capita of cities, including paying special attention to air quality, municipal waste management and others; " and, in particular, submit 11.6.2 "Average annual level of inhalable particles (e.g. with particulate diameter less than 2.5 μm and 10 μm) in cities (weighted population)", which are also targets of contribution of this study.

And SDG 13, "Action Against Global Climate Change", seeks to "take urgent action to combat climate change and its impacts". Within this objective, goal 13.2: "Integrate climate change measures into national policies, strategies and planning";

and its goal 13.2.2: "Total greenhouse gas emissions per year"; which are united nations determinations that this research aims to privilege, through the use of a more efficient product by the consumer.

A solution to reduce fuel consumption and pollutant gas emissions in automatic transmission vehicles is the Continuously Variable Transmission (CVT), imagined by Leonardo da Vinci more than 500 years ago, can simulate an infinite amount of gait relationships. It contains a system of two pulleys of different sizes, which are interconnected by a high-strength metal belt, rather than gears with certain sizes (Beltrão, 2015). There is a general consensus that a CVT transmission, when compared to automatic planetary transmissions, presents an advantage in relation to fuel consumption. This is due to the fact that CVT has a “continuous” gear shift, making it possible to keep the engine working in “optimal” regions of torque and power [14].

In a CVT transmission, torque transfer is done by friction between a belt and two pulleys. The torque transmission capacity of the CVT is directly related to the axial forces of the primary and secondary pulleys, these forces are the result of hydraulic pressure from the transmission pumping system. This hydraulic pressure plus the friction of the metal belt with the pulleys are the main points of efficiency losses: oil pump / hydraulic actuation system that works between 50 and 70 bar (a Planetary automatic transmission is less than half of this pressure) and the very high friction torque transmission (in order to prevent slipping). Thus, due to these two points, the efficiency of a CVT is 10% to -20% lower than an automatic transmission by planetary [6].

It is important to note that, in a continuously variable transmission (CVT), the ratio continuously changes between its maximum and minimum values (Span), a characteristic that disassociates the engine's speed (rotation) from the vehicle's speed. This feature allows an additional degree of freedom to accompany the ideal engine operation line (OOL- Optimal Operation Line) and thus operate in a region of greater efficiency. However, for automatic transmission by planetary gears, which have defined gears (“gear sets”), gear changes can only contribute to the operation of the engine in areas “close” to its ideal region.

This difference between them allows an improvement of 5% to 15% in fuel economy for a vehicle with CVT transmission, when compared to a vehicle with automatic transmission for planetary (stepped gears). Especially when the maximum speed of the vehicle is relatively low, it can be seen that the improvement in fuel economy is more significant [14].

In addition, as the number of gears ("gear sets") of an automatic planetary transmission increases and the interval decreases, such as an 8/9 or 10-speed transmission, the influence of the types of "gear changes" (planetary staggered and continuously variable) in the efficiency of the engine operation is reduced. In addition, the improved fuel economy of CVT vehicles became not very clear, as the efficiency of the planetary transmission is greater due to less hydraulic loss. [14].

In this context, the objective of this project will be to compare CVT automatic transmissions with automatic planetary transmissions in vehicles sold in Brazil using E27 and E100 fuels and INMETRO approval data for consumption and emissions, and to analyze the best correlation methodology. Thus, the development of this research can contribute to the goals of SDGs 03, 11 and 13 and the Brazilian “NDC” (“Contribuições Nacionalmente Determinadas”, like Rota 2030), which can bring more savings to the consumer and contribute to the sustainable development of the planet.

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To exemplify, below the graphic of the “sawtooth diagram”, the scaling of a manual transmission (planetary transmissions presents a similar behave) can be compared with a “smoother curve” of a CVT transmission.

Sawtooth diagram (Manual transmission and CVT “smoother curve)

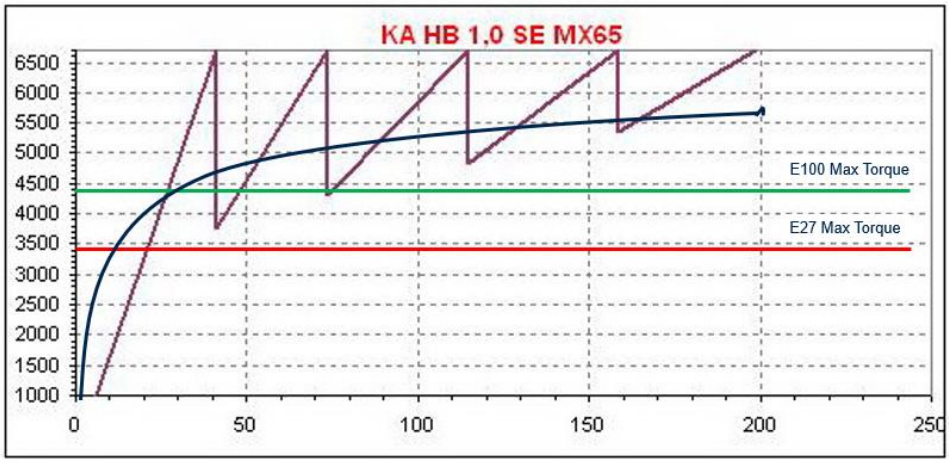


Gráfico dente de serra do novo câmbio manual MX65 do Ford Ka

Image taken from magazine “Autoentusiastas”,f September 30, 2018, and modified by the author of this project. ///

2. METHODOLOGY

Firstly, a bibliographic search was carried out in order to identify results of studies where they were evaluated: fuel consumption as a reason for choosing CVT transmission to equip vehicles; comparisons of types of automatic transmissions regarding fuel consumption and atmospheric emissions and efficiency studies of CVT transmissions.

Got the consumption and emissions data will be extracted from back 2011 the annual publication of vehicle homologation issued by INMETRO (National Institute of Metrology, Quality and Technology – “Instituto Nacional de Metrologia, Qualidade e Tecnologia”) [11]. The choice of the "Fuel consumption / energy efficiency table for automotive vehicles", applied by INMETRO for vehicles sold in Brazil, is due to the standardization of data from various sources (automakers), such as same test procedures. Results are shown in km / l (kilometers per liter) taken under same standard laboratory conditions (NBR7024) and adjusted for the most common simulated conditions of use (applications).

This data was tabulated in a excel spreadsheet, selecting vehicles and engines of most commercialized versions, excluding manual, hybrid, and automated transmissions, will also be excluded diesel engines and vehicles of specific applications (sports and off-road use), focusing on CVT and planetary transmissions and gasoline and flexible engines with maximum displacement capacity of 2.0 liters and with torque and power numbers within a specific range.

"Fuel consumption / energy efficiency table for automotive vehicles" snapshot

Marca	Modelo	Versão	Motor	Transmissão Velocidades (nº) Manual (M) Automática (A) Automática Dupla Embreagem (DCT) Automatizada (MTA) Contínua (CVT)	Ar Cond. Sim (S) Não (N)	Direção Assistida Hidráulica (H) Mecânica (M) Elétrica (E) Eletro-hidráulica (E-H)	Combustível Etanol (E) Gasolina (G) Flex (F) Diesel (D)	Emissões no Escapamento – Poluentes NMHC (g/km)	CO (g/km)	NOx (g/km)	Redução Relativa ao Limite	Gás Efeito Estufa – Etanol CO_2 fóssil (g/km)	Gasolina ou Diesel CO_2 fóssil (g/km)	Quilometragem por Litro – Etanol Cidade (km/l)	Etanol Estrada (km/l)	Gasolina ou Diesel Cidade (km/l)	Gasolina ou Diesel Estrada (km/l)	Consumo Energético (MJ/km)
CAOA CHERY	NEW QQ	1.0 LOOK / 1.0 LOOK PLUS / 1.0 SMILE / 1.0 SMILE PLUS / 1.0 ACT / 1.0 ACT PLUS	1.0 - 12V	M-5	S	H	F	0,014	0,244	0,032	B	0	98	8,9	9,9	12,9	14,4	1,59
KIA	PICANTO	EX5/ LX5 1.0 FF MT	1.0 - 12V	M-5	S	E	F	0,013	0,364	0,055	C	0	104	7,9	10,3	11,6	15,0	1,69
KIA	PICANTO	EX5/ LX5 1.0 FF AT	1.0 - 12V	A-4	S	E	F	0,012	0,353	0,041	B	0	105	8,1	9,9	11,4	14,7	1,70
VW	up!	move	1.0-12V	M-5	S	E	F	0,023	0,218	0,032	B	0	89	9,6	10,6	14,2	15,3	1,46
VW	up!	move (I-Motion)	1.0-12V	MTA-5	S	E	F	0,037	0,599	0,018	C	0	89	9,4	10,6	14,0	15,8	1,47
VW	up! TSI	move (Rodas aro 14")	1.0-12V	M-5	S	E	F	0,027	0,296	0,031	B	0	86	10,0	11,5	14,3	16,3	1,40
VW	up! TSI	move (Rodas aro 15") / pepper	1.0-12V	M-5	S	E	F	0,032	0,357	0,026	B	0	88	9,6	11,1	14,1	16,0	1,44
VW	up! TSI	cross	1.0-12V	M-5	S	E	F	0,022	0,189	0,032	B	0	93	9,5	10,4	13,7	14,7	1,50
FIAT	500	CULT	1.4-8V	M-5	S	E	F	0,007	0,316	0,024	A	0	111	8,0	9,0	11,4	13,0	1,79
FIAT	MOBI	DRIVE	1.0-6V	M-5	S	E	F	0,010	0,320	0,017	B	0	90	9,6	11,3	13,7	16,1	1,45

Example extract from "Fuel consumption / energy efficiency table for automotive vehicles", applied by INMETRO

3. RESULTS AND DISCUSSION

Using the "Qlick Sense" software for the consumption, efficiency and emissions data, from the sample resulting from the tabulation, we can understand the collective behavior of each type of transmissions studied (planetary and Continuously Variable). The analysis, also, have been validated by statistical reviews and comparisons.

Finally, a dashboard was created (examples presented on Figures 1 and 2) per a cluster system we can understand the collective behavior of each type of transmission, associated with type of fuels and engines applications.

Figure 1. Ethanol Fuel Consumption Average Scatter Plot

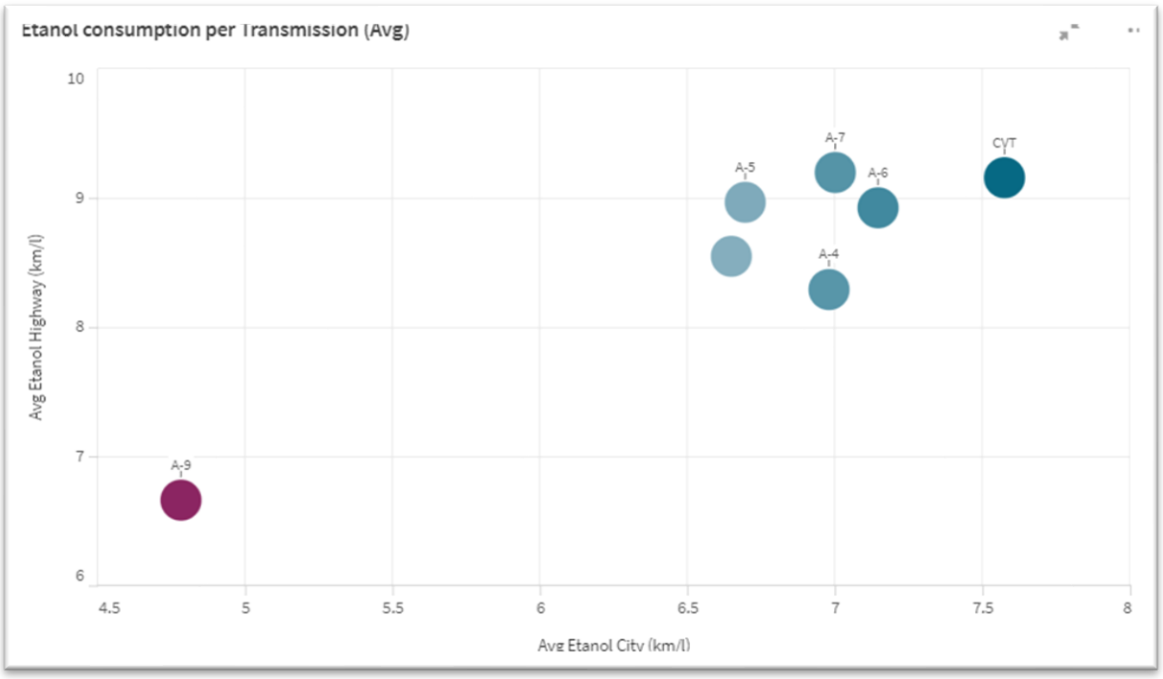
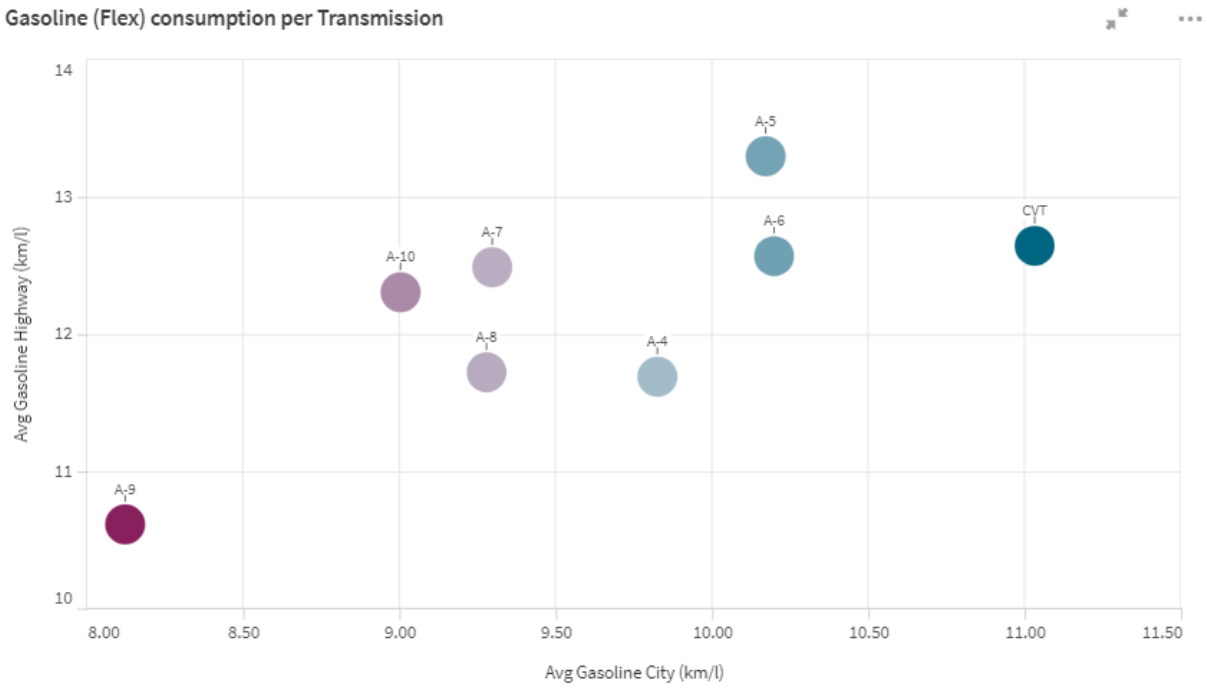


Figure 2. Gasoline Fuel Consumption Average Scatter Plot



In both "scatter plot" graphs we can see that CVT transmission presents the lowest consumption result for the city cycle in both Ethanol and Gasoline, when compared to planetary transmissions. In the road cycle, the CVT achieves consumption values similar to the best Planetary transmission (A7 - 7 gears) when using Ethanol and is among the lowest consumptions for the road cycle when using Gasoline.

4. CONCLUSION

Through the development of the research we were able to conclude:

1) Based on a summary of IMETRO Homologation data for fuel consumption, energy efficiency and exhaust emissions for PL6 (Brazilian market in the last 10 years), CVT has been showing an advantage in relation to fuel consumption, but planetary transmissions launched in the last years it has been showing good consumption figures in "Highways", and like the "Dashboard", we will be able to expand it to other vehicles and markets that use homologation tables similar to those used in Brazil.

2) Further work may provide to the reader a view of the Brazilian market, its competitors and what are the trends in the short and medium term.

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