TRANSMISSION BELTS PERFORMANCE IN NORMAL AND HEAVY-DUTY CONDITIONS

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Abstract: The main purpose of this article was to study the behavior of vehicle transmission belts in conditions similar to real ones, which can appear during their use. Transmission belts can be classified into several categories, but depending on their function, can be belts that work in dry conditions or immersed in oil. In this study, were analyzed both types of transmission belts. The samples were subject to different physical-mechanical tests: determination of hardness, density, thickness, abrasion, flex resistance, tensile strength and percentage extension and also to various conditions like, high and low temperature, immersion in liquids (oil, toluene, diesel). All the tests were performed before and after exposure, according to actual standards in ICPI accredited laboratory. Microscopy studies were done before and after the exposure to various factors, in order to appreciate the damage degree. Also, chemical specific analyses were made for determining the transmission belts composition. The findings from this study provide important insights into the behavior of transmission belts under different operating conditions.

Keywords: transmission belts, physical-mechanical tests, chemical analyses

1. INTRODUCTION

A timing belt is a crucial component of an internal combustion engine, controlling the timing and synchronization of the engine's valves and pistons. While it may seem like a small and simple part, a timing belt failure can result in significant and costly engine damage. As such, understanding the function, maintenance, and replacement of a timing belt is essential for any vehicle owner. In this article, different types of timing belts were studied, exploring their purpose, how to know when they need to be replaced, the materials they are made of, and their physical and mechanical properties [1].

A timing belt, also known as a cambelt, is a toothed belt that is responsible for synchronizing the rotation of the engine's camshaft and crankshaft. The camshaft controls the opening and closing of the engine's valves, while the crankshaft rotates to provide power to the pistons. The timing belt ensures that these two components rotate in perfect synchronization, allowing the engine to operate smoothly and efficiently [2].

Timing belts are made of rubber or other materials that are reinforced with fibers such as fiberglass or Kevlar. The teeth on the timing belt mesh with teeth on the camshaft and crankshaft sprockets, providing precise control over their rotation [1].

Timing belts are a critical component of most modern engines, and failure can result in significant damage to the engine. As such, it is important to follow the manufacturer's recommended replacement interval for the timing

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belt. Most manufacturers recommend replacing the timing belt every 60,000 to 100,000 km or every 5-7 years, whichever comes first. Some engines have an interference design, which means that if the timing belt fails, the pistons and valves can collide and cause significant engine damage. Signs that timing belt may need replacement include cracking, fraying, or missing teeth on the belt, as well as engine misfires or a rattling noise coming from the engine. Replacing the timing belt proactively can help prevent engine damage and ensure that vehicle operates reliably [3].

There are several types of timing belts available for different applications. The most common types of timing belts are:
- Rubber Timing Belts: These are the most common type of timing belts used in automotive applications. They are made of a rubber compound with fiberglass or Kevlar reinforcement for added strength and durability.
- High-Temperature Timing Belts: These timing belts are designed to withstand high temperatures and are typically used in applications where the engine operates at high temperatures, such as in racing or high-performance vehicles.
- Silent Timing Belts: These timing belts are designed to run more quietly than traditional rubber timing belts. They are often used in applications where noise is a concern, such as in office equipment or robotics;
- Toothed Timing Belts: These timing belts have teeth on the inner surface that mesh with teeth on the pulleys, providing better synchronization and reducing the risk of slippage.
- Multi-Ribbed Timing Belts: These timing belts have multiple ribs on the inner surface that provide a larger contact area with the pulleys, reducing the risk of slippage and improving power transmission.
- Double-Sided Timing Belts: These timing belts have teeth on both sides, allowing them to be used in reverse rotation applications.

The type of timing belt used will depend on the specific application and the requirements for the engine and from this point of view there are timing belts which work in dry or wet conditions, immersed in oil [4].

Timing belts are designed to have specific mechanical and chemical properties to ensure proper engine operation and longevity. Some of the important properties of timing belts include [5-9]:
a. Tensile Strength: The tensile strength of a timing belt refers to its ability to resist stretching or breaking under tension. It is an important property since the timing belt must be able to withstand the tension created by the camshaft and crankshaft.
b. Flexibility: Timing belts must be flexible enough to conform to the shape of the pulleys and to bend around corners. They must also be able to maintain their flexibility over time and under varying operating conditions.
c. Wear Resistance: Timing belts must be able to resist wear from constant rubbing against the pulleys. This is especially important in high-performance applications where the timing belt is subjected to high RPMs.
d. Fatigue Resistance: Timing belts must be able to withstand repeated bending and flexing without developing cracks or breaking. This property is critical for the longevity of the timing belt.
e. Heat Resistance: Timing belts must be able to withstand the high temperatures generated by the engine. The material used in the timing belt must have a high melting point and be able to maintain its strength and flexibility at elevated temperatures.
f. Chemical Resistance: Timing belts must be able to resist degradation from exposure to chemicals, such as engine oil, coolant, and fuel.

The mechanical and chemical properties of timing belts are critical to their performance and durability.

2. EXPERIMENTAL SETUP

2.1. Materials and Methods

In order to achieve the objectives of this study, five types of vehicle transmission belts were analyzed by physical-mechanical methods, according to actual standards, performed in ICPI accredited laboratory, as follows: Determination of thickness ISO 23529:2016, Determination of hardness. Part 4 - Indentation hardness by durometer method (shore hardness) ISO 48-4:2018, Determination of density ISO 2781:2018, Accelerated ageing and heat resistance tests SR ISO 188:2011, Determination of abrasion resistance ISO 4649:2017, Determination of tensile strength and percentage elongation SR ISO 37:2020, Determination of flex resistance SR EN ISO 17707:2005. All these tests were made before and after exposing the samples to heavy-duty conditions like high/low temperature, immersion in toluene/diesel and a high number of flexions.

To determine the material composition of each type of belt, FTIR-ATR measurements were performed using a Thermo Scientific Nicolet iS50 equipment.

Microscopic images were recorded with a S8AP0 Leica stereomicroscope at 10x magnification for the observation of surface aspect and modifications.

The five samples were identified as follows:
A. Oil working transmission belt.
B. Trapezoidal belts with speed variator.
C. Wide tooth belt, 100KW maximum transmission power.
D. Wide tooth belt, 70KW maximum transmission power.
E. Multiband trapezoidal transmission belts.

3. RESULTS AND DISCUSSION

The five samples were measured before being exposed to various conditions and the results are summarized in Table 1.

Table 1. Initial results of physical-mechanical properties of the five transmission belts.

Properties	Sample				
	A	B	C	D	E
Thickness, mm	6.2	5.9	5.4	5	4.4
Width, cm	1.6	2.2	2.5	2	2
Hardness, ShA	97	83	80	86	93
Density, g/cm^3	1.3	1.26	1.35	1.2	1.28
Tensile strength, N/mm^2	>300	>300	>300	>300	>300
Accelerated aging	+1ShA	+1ShA	+1ShA	+1ShA	+1ShA
Flex resistance	>150000	>150000	>150000	<150000	>150000

It can be seen that the five transmission belts, although they are used for different purposes and in different conditions, have quite similar densities, the thinnest being E and the thickest A. In terms of hardness, the hardest is A and the softest is C. Their hardness didn't modify during accelerated aging. The tensile strength could not be measured, because all the five belts resisted to forces higher than 2000N. They all have a very good flex resistance, not undergoing any change even after 150000 flexions. FTIR-ATR measurements were performed in order to determine the chemical composition of each belt.

Sample A (Figure 1) is composed of Perfluoroeicosane – 42.88 %, Myristoyl alcohol – 50.08 % and Polytetrafluorethylene film – 7.05 %.

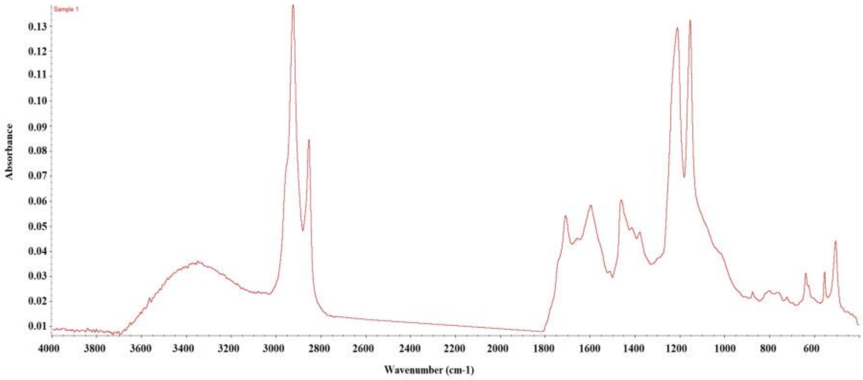


Fig. 1. FT-IR spectra of sample A.

Sample B (Figure 2) is composed of Myristroyl alcohol – 48.04 %, Poliamide 6 – 26.81 % and Poly(phthalamine) – 25.15 %.

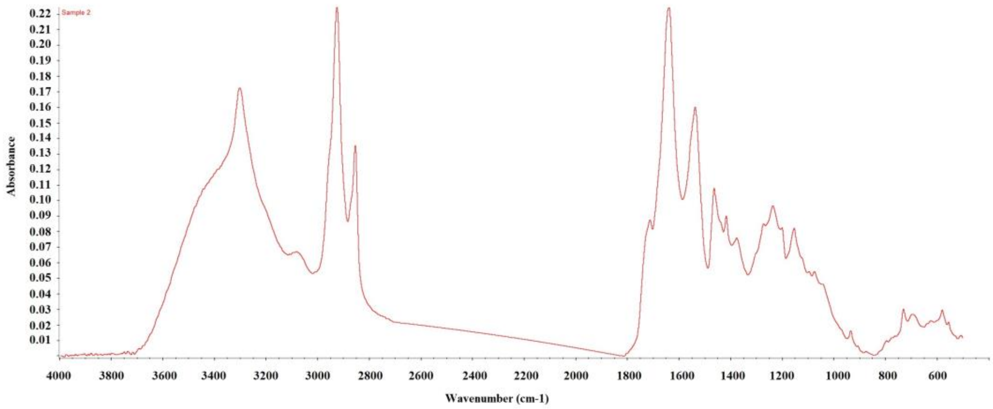


Fig. 2. FT-IR spectra of sample B.

Sample C (Figure 3) is composed of 11-Mercapto-1-undecanol – 42.76 %, Poliamide nylon 6/6 – 34.61 % and Perfluoroeicosane – 22.63 %.

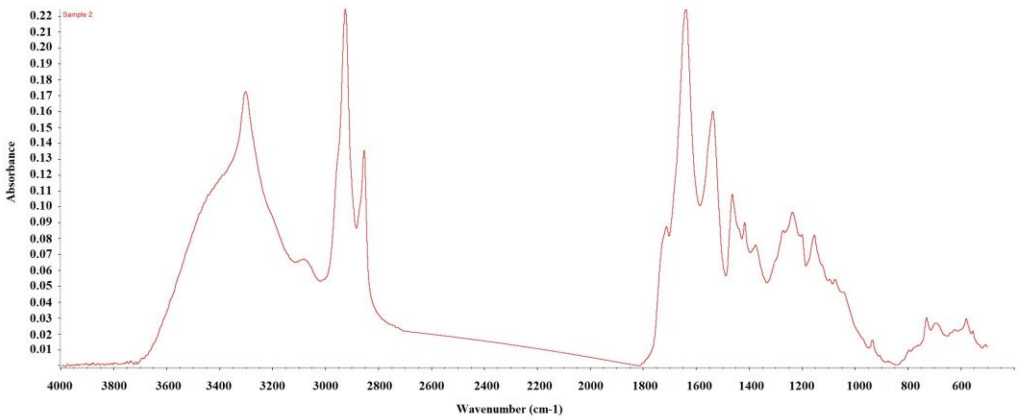


Fig. 3. FT-IR spectra of sample C.

Sample D (Figure 4) is composed of Galactan– 64.04 %, Polymer of phtalamine – 25.82 %, Ester containing polyether – 10.13 %.

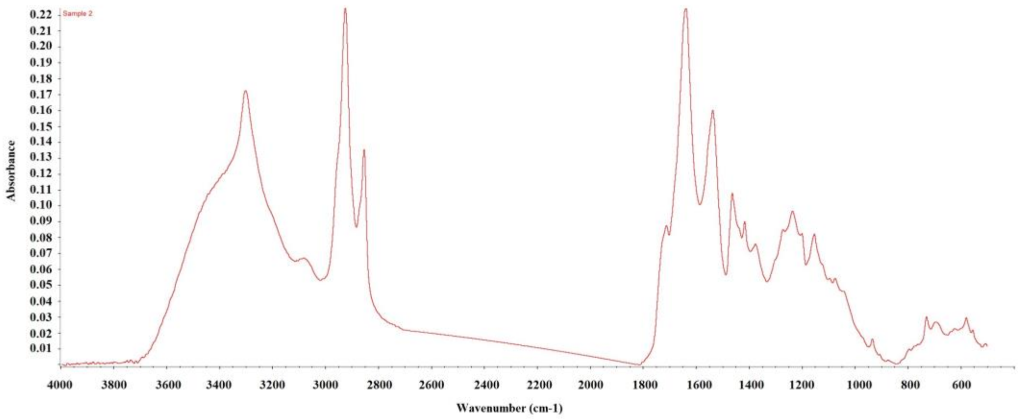


Fig. 4. FT-IR spectra of sample D.

Sample E (Figure 5) is composed of Apiezon M – 62.20 %, Polyamide 6 – 25.97 % and D-pantothenyl alcohol – 11.82 %.

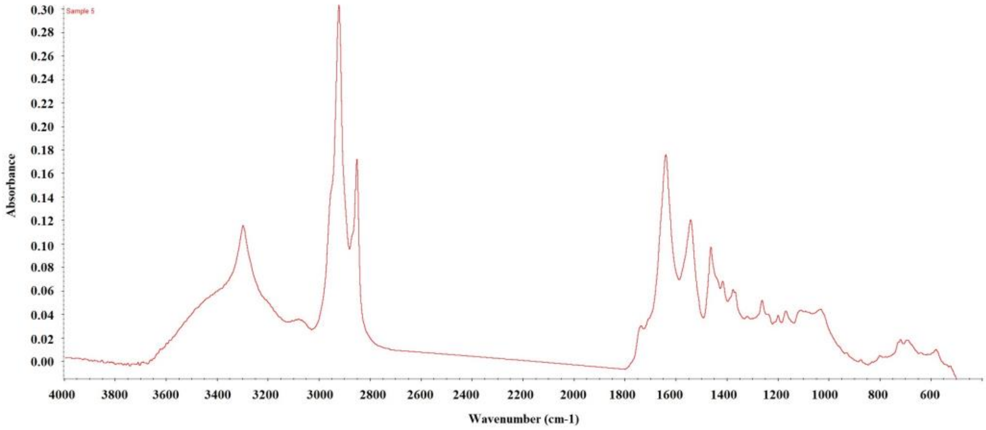
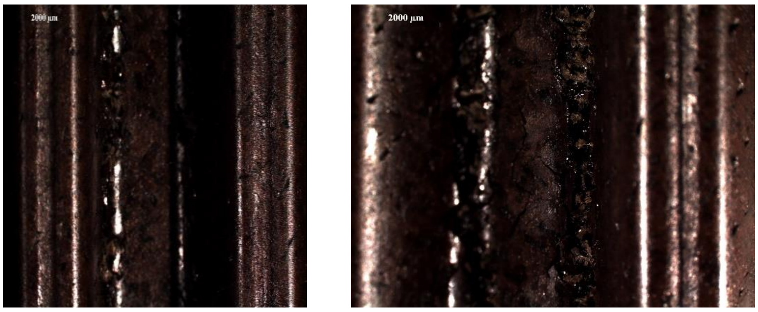


Fig. 5. FT-IR spectra of sample E.

Although the samples were subjected to very harsh conditions for at least 24 hours, the results of physical-mechanical tests showed no modification of their properties.

For a better appreciation of the belts surface modification optical microscopy was used, which is a non-invasive technique that can provide information regarding the morphology of samples by displaying a specific image. Below are the microscopic images of the belts before and after 150000 flexions.

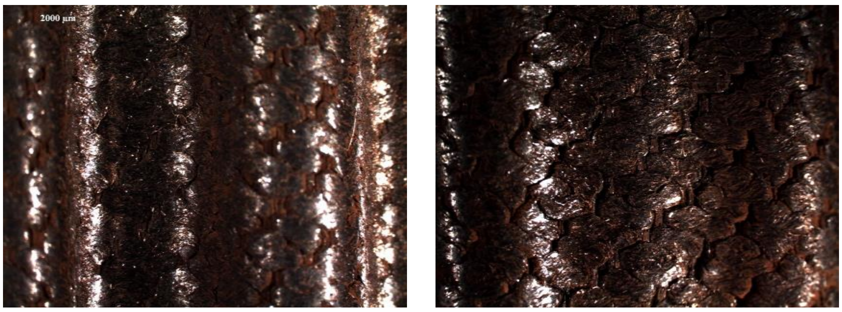
Microscopic image of sample A (Figure 6), before flexions, indicates a smooth surface, with no cracks. After 150000 flexions, small cracks can be observed.



Before After

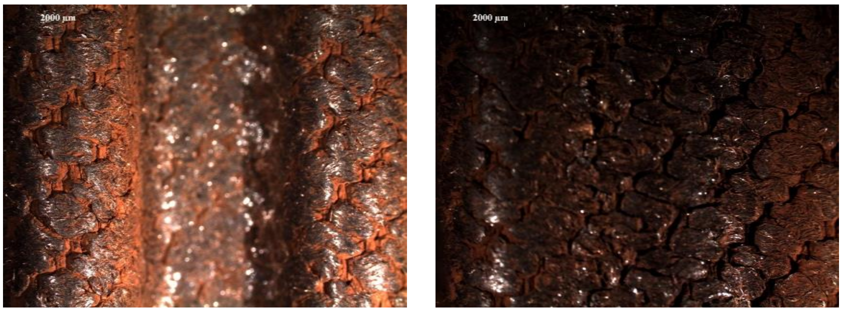
Fig. 6. Microscopic images of sample A.

Microscopic image of samples B, C, D, E indicates an interlaced structure of the belt materials and showed no cracks after flexions (Figures 7-10).



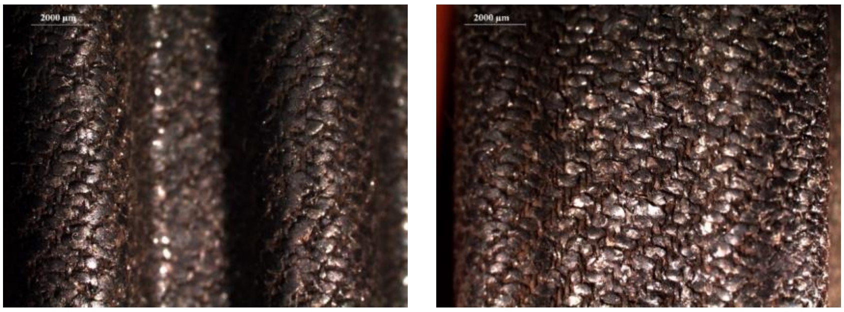
Before After

Fig. 7. Microscopic images of sample B.



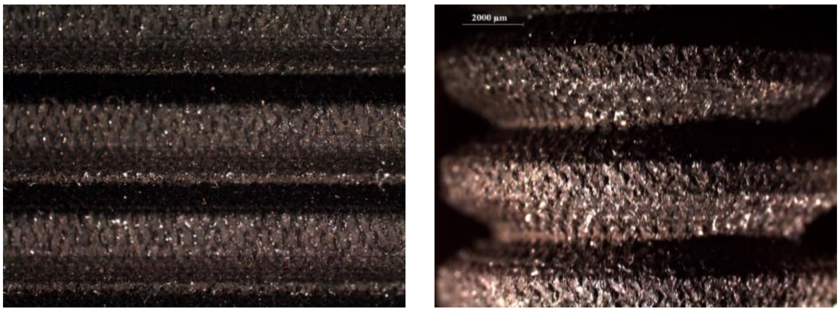
Before After

Fig. 8. Microscopic images of sample C.



Before After

Fig. 9. Microscopic images of sample D.



Before After

Fig. 10. Microscopic images of sample E.

4. CONCLUSIONS

The objective of this article was to analyze the physical-mechanical and chemical properties of vehicle transmission belts in various conditions similar to real ones, which can appear during their use. Five different types of transmission belts were tested according to actual standards in ICPI accredited laboratory. Although the samples were subjected to very harsh conditions for 24 hours, the results of physical-mechanical tests showed no modification of their properties compared with the initial ones. All the five belts resisted to forces higher than 2000 N and they all have a very good flex resistance, not undergoing any change even after 150000 flexions. FTIR-ATR measurements showed different composition for each belt and microscopic images revealed only very small cracks in the case of sample A.

Overall, the five belts have very good physical-mechanical properties and good resistance in heavy-duty conditions.

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