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RELIABILITY QUESTION OF NEW MATERIAL USED IN VEHICLE ENGINEERING

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Abstract

In-vehicle engineering, several types of materials can be used to build vehicles of different sizes and for different uses. Traditionally those materials can be iron, aluminium, steel, rubber, glass, copper, leather, and others. These materials have been in constant development over the years, and this development has accelerated during the last ten years as manufacturers strive to compete on the issue of reliability of these new innovative materials. Reliability requires the production of materials with minimal (or well-known) variations in properties or dimensions. Parts made from these materials must be manufactured using processes that have also been proven to be reliable. This aim of this paper is to explain how reliability criteria can only be obtained if there are means of control suited to the most used materials (metals and polymers).

Keywords: *reliability, automotive manufacture, vehicle engineering, metals.*

1. Introduction

The automotive industry is one of the largest consumers of construction materials in the world [1–5].

The reliability of a vehicle is heavily dependent on the material used. Today, the reliability question is the most important in a vehicle, but the end user does not see this, so they pay little attention to the materials that come with it. And yet the vehicle is a collection of thousands of assembled parts that borrow their functions from the materials they are made of. While metallic materials today represent 64 % to 70 % of a car, the rest is plastic materials and others less numerous such as glasses, textiles, and paints, around which there are sets of techniques involving processing and assembly that must be considered. There are also professional qualifications that are specific to industrial processes which in turn characterize the sector where this economic activity occurs.

Increasing the durability and reliability of the function of car parts is a relevant and important problem materials science.

2. Used material and choice criteria

2.1. Used material

A modern vehicle is made up mostly of heavy metals and plastics which increase its weight. The applied new materials have some advantages (lightweight, high energy absorption, corrosion resistant, etc.) [6–10]. The current situation regarding materials in the automotive industry is still relatively unstable. Metallic materials (Steels, cast irons and Aluminium alloys) are still predominant in mass-produced automobile construction. They represent approximately 64 % to 70 % of the weight of a vehicle and are distributed between 35 % steel sheets, 11 % steel for mechanical parts, 9 % cast iron and 9 % Aluminium. The rest of the materials are shown in Figure 1.

2.1.1. Metals

Steel: The steel industry and component suppliers are investing heavily in innovation. The result of this investment is numerous examples of successful types of steel and iron with the new chemical composition [11–12] for example:

– Low-strength steels;
– Conventional high strength steel (HSS);
– Mild steels high strength low alloy (HSLA);
– Transformation-induced plasticity (TRIP);
– Typical press-hardened steels (PHS).

Aluminium: In recent years aluminium has been of increasing interest for automotive applications due to the general need for weight-saving and for further reduction in fuel consumption it's used for structural parts and body-in-white constructions of the aluminium alloys which meet the main requirements.

These requirements are:
– Sufficient strength (structural and durability, crashworthiness),
– Good formability (stretching, bending and deep drawing operations),
– Joining, (welding, clinching, brazing, soldering) [13],
– High corrosion resistance (against filiform, stress-induced and contact corrosion) [14–16],
– Recyclability,
– Low material fabricating costs.

Magnesium: Magnesium is the lightest metal, with a density of 1.74 g/cm^3. (35 % lighter than aluminium and over four times lighter than steel). It has good ductility, better noise and vibration dampening characteristics and excellent castability. Volkswagen was the first to apply magnesium in the automotive industry on its Beetle model, (which used 22 kg magnesium in each vehicle)

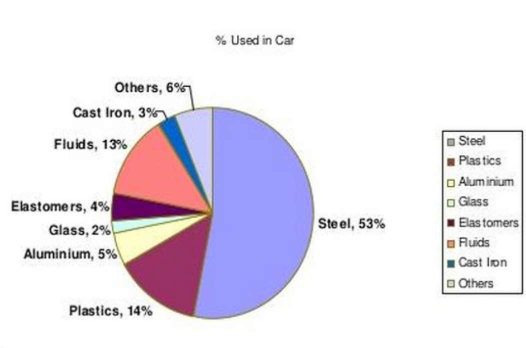
The usage of magnesium per car increased from 3 kg to 50 kg from 2005 to 2015.

Titanium: The application of titanium in the automotive industry began with the Formula One racing cars in the early 1980s, when high output, fast rotation and high response were required of racing cars.

Titanium can be used for the engine (Mitsubishi gallant), suspension springs (VW Lupo), exhaust pipe and mufflers (Kawasaki), shift knobs (Honda S2000), scuff plate (Toyota Crown Majesta).

2.1.2. Polymers and composites

Polymers: AThe application of polymeric materials in automobiles is constantly increasing and this trend is expected to continue. The reason for selecting polymeric materials over other materials is their functionality and more economic manufacturing, as well as reduced fuel consumption, (reduction of mass). The application of polymeric materials allows more freedom in design, and in many cases, only these materials can allow safe



Raw material	Steel	Plastics	Aluminium	Glass	Elastomers	Fluids	Cast Iron	Others
% Used in Car	53%	14%	5%	2%	4%	13%	3%	6%

Figure 1. *Average of material used in typical vehicles*

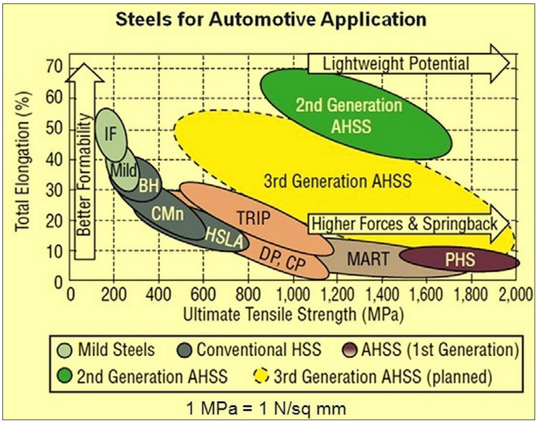


Figure 2. *Classification of steels in automotive applications* [1]

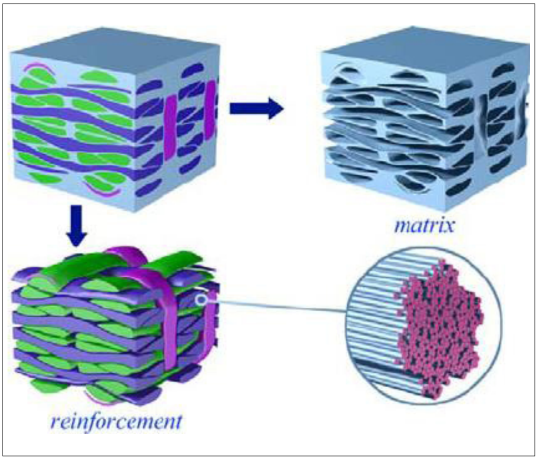


Figure 3. *Material structure of 3D woven composites on meso- and microscale* [8]

geometrical or economic solutions for the construction of parts.

Composites: A composite is composed of a high-performance fibre (such as carbon or glass) in a matrix material (epoxy polymer) that when combined provides enhanced properties compared with the individual materials by themselves. Carbon-fibre composites weigh about one-fifth as much as steel but are as good or better in terms of stiffness and strength. They also do not rust or corrode like steel or aluminium, and, similar to polymers, composites are being considered to make 60 % lighter, safer, and more fuel-efficient vehicles.

2.2. Choice criteria

New materials with better performance characteristics are introduced into the vehicle for various reasons, A large multiplicity of factors is available to the engineers concerning the choice of materials for the design of a part of a set of components performing a given function. In fact, to meet the developing technical criteria, the materials used in the automotive industry need to fulfil several criteria before being approved as a reliable material:

– *Safety:* This is a requirement, with increasingly severe tests at the level of passive safety (at various speeds). In this case, the materials are predominant by their capacity for resistance, and especially by their capacity for progressive absorption of energy. Quality is related to the notions of reliability and durability.
– *Comfort and habitability:* The materials used here contribute to vibratory and acoustic comfort, through adequate use of their mechanical properties relating to the specific modes of vibration of the structure, and through the use of sound-absorbing materials.
– *Low cost:* The cost of the material and that of its implementation is of course essential, thereby often prohibiting the use of high-performance materials. It should always be kept in mind that automobile production is mass production and that one euro saved per vehicle leads to a significant overall saving.
– *Respect for the environment:* Minimum consumption: This sensitive financial factor for the user, meets the need for environmental protection regarding carbon dioxide emissions which are increasingly regulated to limit the greenhouse effect.
– Since 2004, *CO_2 emissions* have decreased by 23 % or 108 g/ml, and fuel economy has increased by 30 % or 5.8 mpg. In 2018, fuel economy increased by 0.2 miles per gallon to 25.1 mpg, achieving a record. Average estimated real-world CO_2 emissions are projected to fall 6 g/mi to 346 g/mi and fuel economy is projected to increase 0.4 mpg to 25.5 mpg.
– *The evolution of the new material* (reliable material for a reliable vehicle): In order to meet the criteria of Functional requirement, monitoring and validating compliance of materials used in vehicle engineering becomes a necessity. The results of testing and quality and safety control services must meet with the required standards by the regulations and protocols of traffic, as well as the needs of the user: qualification tests and performance evaluation, life evaluation, standardized quality control, corrosion tests, characterization of materials, chemical analyses, electronic and electrical properties.

2.3. Study case: ASTM automotive material Standards

ASTM International, founded in 1898, formerly known as the American Society for Testing and Materials, is an international standards organization that develops and publishes voluntary consensus technical standards for a wide range of materials, products, systems, and services. This organization is helping to enhance the quality, safety, and performance of the vehicles we drive. Throughout the industry supply chain, ASTM standards assist in the delivery of high quality, expertly tested parts, and materials to automotive manufacturers. ASTM standards aid consumer confidence by helping to ensure that the vehicles they buy are durable. Out on the road where safety and reliability matter most, those standards facilitate dependable vehicle performance.

Among the most important standards announced by ASTM to assess the reliability of materials for the automotive industry, are the following examples:

Committee G03: Build Durable Autos19

G03 publishes more than 30 standards, many of which provide methods to automotive manufacturers and suppliers for measuring the performance of automotive paint and coatings, and interior dashboard materials, in varying natural outdoor weathering exposures. G03 performance standards include practice for exposing non-metallic materials in accelerated test devices that use laboratory light sources, a practice for operating open flame carbon arc light apparatus for exposure of non-metallic materials and practice for

Figure 4. *Car crash test.*

operating fluorescent light apparatus for UV exposure of non-metallic materials. All these standards help measure the effects of sunlight (either direct or through window glass), moisture such as rain or dew, and heat on automotive components.

Subcommittee F16.02 on Steel Bolts, Nuts, Rivets and Washers.

These components must be strong enough to withstand the impact of accidents, to test the quality, strength, and durability of the fasteners they supply to the automotive market, manufacturers rely on the more than 75 standards, those parts have an extensive array of standards, including many that are widely referenced by fastener manufacturers. Notable among these is a specification for carbon steel bolts and studs, 60,000 psi tensile strength, which covers the chemical and mechanical requirements of three grades of carbon steel bolts and studs in sizes ranging from 1/4 to 4 inches. Also utilized by automotive suppliers is the specification for structural bolts, steel, heat-treated, 120/105 Ksi minimum tensile strength, which covers the requirements for heavy hex structural bolts intended for use in structural connections.

Subcommittee D01.27: Paint and Coatings19

D01.27 provides standards to evaluate film performance of applied paint and finishes subjected to accelerated deterioration in normal and abnormal service environments. Improvements in automotive coating performance and durability can be attributed in part to the group's accelerated test procedures., a popular application is a practice for xenon-arc exposures of paint and related coatings, which simulates the effects of sunlight, moisture, and heat on paints. A popular weathering and corrosion test procedure is the practice for cyclic salt fog/UV exposure of painted metal, which blends cyclic corrosion testing with the evaluation of ultraviolet exposure of metallic paints.

Figure 5. is showing a) 0 days, b) 16 days of UV exposure, c) 0 days of UV light after 80 days of salt fog, d)16 days of UV exposure followed by 80 days of salt fog.

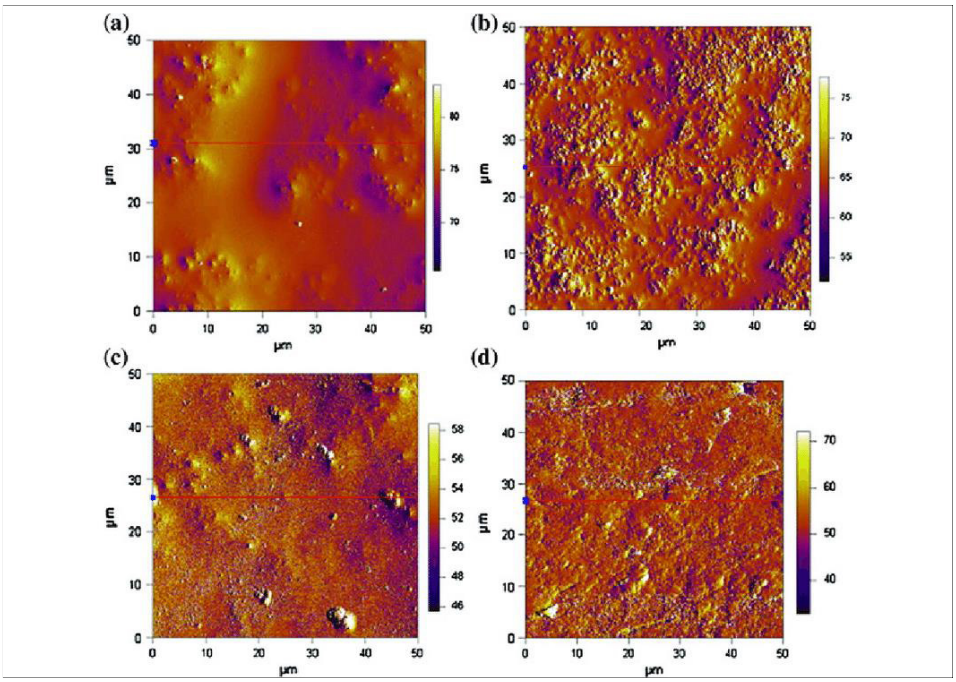


Figure 5. *AFM surface images of samples obtained at various UV exposure and salt fog tests.* [7]

Subcommittee F09.30: Tire Standards and Reliability in Severe Weather Driving19

Subcommittee F09.30 on Laboratory (Non-Vehicular) Testing responded with the practice for accelerated laboratory ageing of radial passenger car and light truck tires through load range E for the laboratory generation of belt separation. Another important role of F09 standards is to measure tire performance in severe weather. The test methods for tire performance testing on snow and ice surfaces and the test method for single wheel driving traction in a straight line on snow- and ice-covered surfaces help assess tire performance on snow and ice. These tests are often done in conjunction with the specification for a P195/75R14 radial standard reference test tire, which is used as a reference for tire traction performance evaluations. Today, many tire manufacturers use a product graphic of a peaked mountain with a snowflake to signify that their product has passed these industries accepted traction performance tests for severe snow, ice, and winter conditions (**Figure 6**).

3. Conclusion

Despite the development of methods for monitoring and ensuring the safety and reliability of the materials used in the vehicle industry, there are still some breaches and technical problems that inevitably require radical solutions, In my opinion, that can be through finding new materials that meet the requirements of our current time's technology (material based on carbon fibre or biological material..), and thus we can talk about the development of lightweight materials that undoubtedly represent the future, especially with the advent of the first generation of flying cars, and according to my future vision, the important question of reliability of new materials will be greater and not limited to professionals only, but also to general users.

Figure 6. *Three Peak Mountain Snowflake logo.*

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