APPLICATION OF SUPER HYDROPHOBIC SURFACES ON AUTOMOTIVE COMPONENTS

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Abstract: The super hydrophobicity observed in the nature has already been transposed to several materials. However, in the automotive industry, super hydrophobicity is a feature that has not yet been fully and satisfactorily explored. This article, therefore, adopts a systematic review methodology, pursuing as general objective the possibility of the application of this superhydrophobic technology in the automotive industry, more specifically in automotive glass components. This research allows to conclude that this application enables to replace disposable wiper systems used nowadays.

Keywords: super hydrophobicity; self-cleaning; automotive components.

APLICAÇÃO DE SUPERFÍCIES SUPER HIDROFÓBICAS EM COMPONENTES AUTOMOTIVOS

Resumo: A super hidrofobicidade observada na natureza foi já transposta para diversos materiais, porém, na indústria automotiva, a super hidrofobicidade é uma característica ainda não explorada de modo pleno e satisfatório. Este artigo, portanto, adota uma metodologia de revisão sistemática, tendo como objetivo geral a possível aplicabilidade da tecnologia super hidrofóbica na indústria automotiva, mais especificamente em componentes automotivos de vidro. A pesquisa permite a conclusão de que essa aplicação possibilita substituir sistemas de limpadores descartáveis utilizados atualmente.

Palavras-chave: super hidrofobicidade; autolimpante; componentes automotivos.

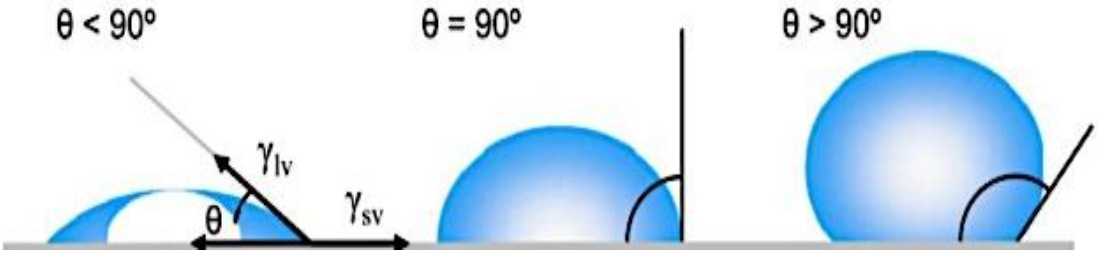
1. INTRODUCTION

In order to understand the characteristics of super hydrophobic surfaces, it is of fundamental importance to start this article by discussing about two aspects that determine wettability, that is, the retention of water on the surfaces of different materials. This water accumulation occurs due to two factors: surface energy and surface topology [1].

In the chemical composition of the surface, each water drop molecule is attracted by the molecules that surround it, seeking to occupy a position of less potential energy and acting so that all directions are in balance. The resultant of the forces inside the water drop is nil, however, on the surface there are only forces directed into the water drop, resulting in stronger attractive forces among its neighbors. Thus, the energy on the surface is substantially greater, as there are fewer connections between neighboring molecules [2].

The topology of solid surfaces, that is, that have solid energy greater than the liquid's tension, will cause the liquid to spread until the contact angle between them - the solid surface and the water drop - is 0 °. When the surface has a high surface energy, but less than the surface tension of the liquid, the surface will be wet and the contact angle resulting from the drop will be between $0° < \theta < 90°$. When the energy of the surface is low, it will be slightly wet and the adhesion of the liquid will be low, resulting in wider drop contact angles (>90°). In a super hydrophobic surface, the contact angle between the surface and the water drop is greater than 150 °: $\theta E > 150$ [3][1], as shown in figure 1:

Figure 1: Contact angle between the water drop and the surface of the solid[2].



In addition, super hydrophobicity has as a topological characteristic the presence of microstructures dispersed in the surface space, making the drop not penetrate into its cavities and forming an air layer between the surface and the drop (Cassie-Baxter state; IN: [1]). It is important to note that a super hydrophobic surface differs from the others in that it has a low angular hysteresis value, presenting a property of repelling water drops [4].

[1] In addition, if the contact angle between the surface and the drop of water is below 150 ° and above 90 °, it is only called hydrophobic and, below 90 °, hydrophilic ($\theta E < 90$ °).
[2] IN: [3].

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2. METHODOLOGY

This article used the methodology based on the systematic review. This method was developed following these four major steps, as shown in flownchart (figure 2):

1) Determine research question that guide this article such as:
   1.1) 'Why there aren't vehicles with superhydrophobic glass feature?";
   1.2) "Is there any application of superhydrophobic technology in automotive glasses?"
   1.3) "What are the gains of this technology to the automotive industry and to society as whole?";

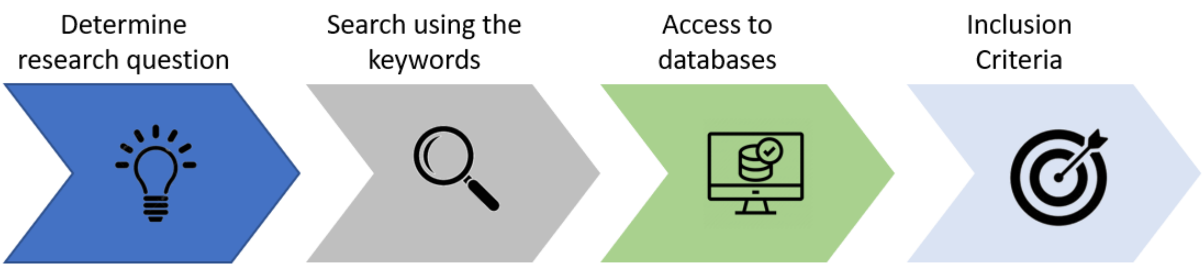
2) Search using the keywords: "superhydophobic surfaces"; "Lotus Effect"; "autocleaning" and "Water-Repellent";

3) Access to databases: ScienceDirect, Scopus, Scielo; Capes and Google Scholar;

4) Inclusion criteria of publications in this article were:
   4.1) the most important in the ressearch theme, indicated by the classification in the Qualis da CAPES system (A1 and A2) and
   4.2) 5 most recent and strongly related to the article's theme.

In this article were considered ressearchs written in Portuguese and English, and works available entirety. This search took place through online access, during the months of May to August 2020.

Figure 2: Methodology flowchart
(Source the author).



2.1. Objectives

Inspired in the nature, solutions can be found for challenges that the industry seeks to solve through its commercialized products. In the early 1970s, the German botanist Wilhelm Barthlott observed that the *Nelumbo nuceliferous* flower (lotus) keeps its surface dry in wet conditions. In addition, it has the additional characteristic of keeping clean, due to the rainwater not penetrating and being repelled taking away the dirt [5].

The study of this natural characteristic has shown great interest due to the many possibilities of application. [6] and [7] for example, evaluated the mechanisms of the flower to repel water. The self-cleaning operation on the Lotus flower is shown in superficiality in Figure 3:

Figure 3: Super hydrophobicity in the Lotus flower[3].

Nowadays, the super hydrophobicity observed in nature has already been transposed to other materials and is widely used, for example, in the textile industry, civil industry and aviation industries. In the textile industry, super hydrophobicity is used as an alternative for waterproofing, providing protection of fabrics against rain and stains in general [8]. In civil construction[4] this technology can be applied to glazing, also seeking less water and dirt retention, the same objectives of being applied in aviation[5].

Thus, the general objective of this article is to reflect scientifically on the natural functioning of the super hydrophobic surface of the *Nelumbo nuciferous* flower (lotus) and discuss the possibility of transposing this functionality to the improvement of other non-natural materials, more specifically in automotive components.

3. RESULTS AND DISCUSSION

In the automotive industry, it is observed that super hydrophobicity is a feature not yet fully and satisfactorily explored. The possibility of adapting the super hydrophobicity can be thought in the automotive industry, more specifically in the

[3] Lotus-Effekt (Schmutz auf Lotusblatt) © W. Barthlott, Lotus-Salvinia.de. Available at: <https://www.flickr.com/photos/lotus-salvinia/12476332694/in/album-72157640870446734/>. Access: 8/8/2020.
[4] Available at: <https://www.pilkington.com/en-gb/uk/householders/types-of-glass/self-cleaning-glass>. Access: 8/6/2020.
[5] Available at: <https://www7.fiemg.com.br/noticias/detalhe/cit-senai-fiemg-pesquisa-revestimentos-hidrofobicos->. Access: 8/6/2020.

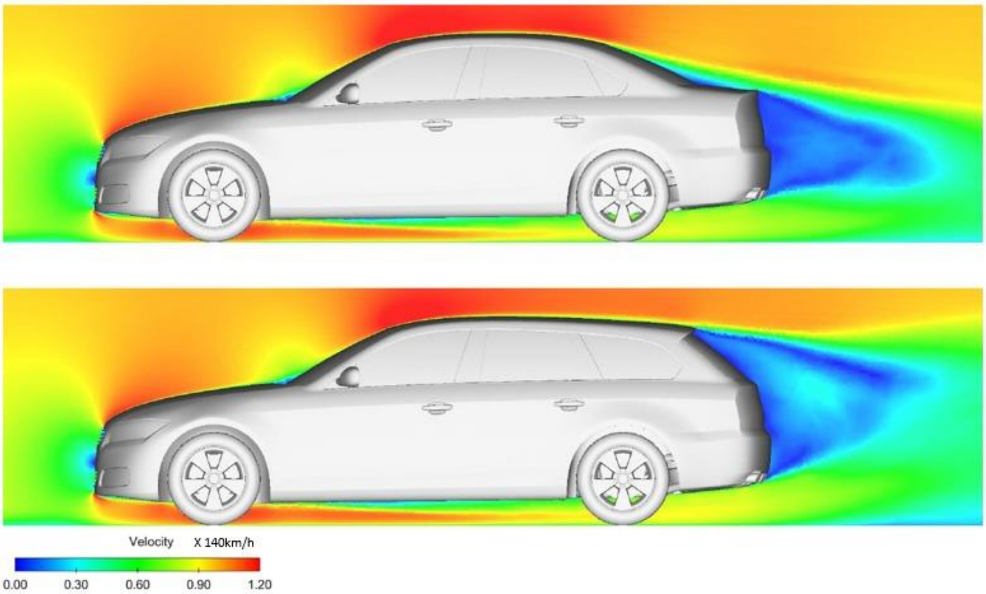
glass components, such as the side, front and rear windows and rear view mirrors.

One of the biggest problems, from the consumers' point of view in the automotive industry, is linked to the visibility that is impaired by the accumulation of water in certain components, such as the exterior mirrors. The glasses and lenses of the auxiliary vision systems, which can retain water in times of rain. In the side windows, this problem has not been fully solved by the automotive industry, becoming a constant complaint on the part of users, therefore, with an opportunity for technological improvement.

In the rear and front windows, for example, to avoid any impairment of visibility for the driver and passengers during periods of rain, the automobile industry offers auxiliary systems, that is, devices designed for cleaning and removing water, but with additional material and assembly costs.

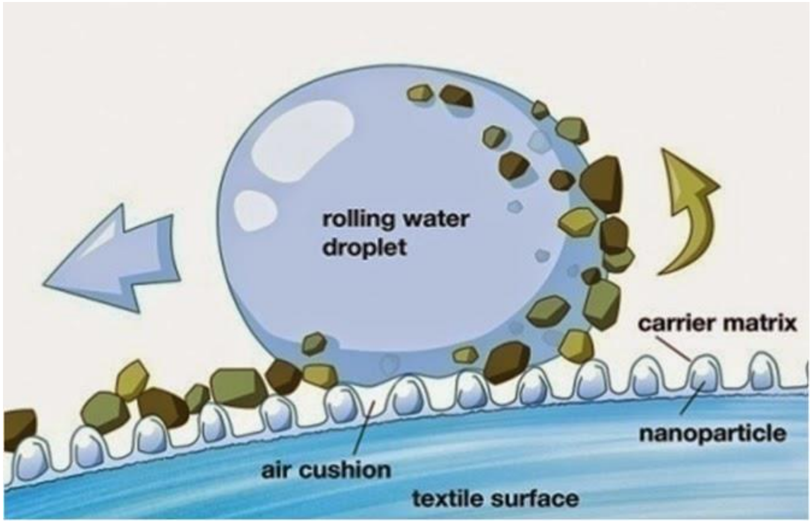
The use of a rear window wiper is mainly determined by the shape of the vehicle and its aerodynamic characteristics. A sedan model tends to have a lower (that is, more efficient) aerodynamic coefficient than a hatch or station wagon model. The hatches or vans, in motion, generate a suction or “vacuum” region at the rear of these vehicles, which sucks up dirt, dust and other contaminants that are deposited on the glass, making rear visibility difficult, as shown in figure 4:

Figure 4: Graphical representation of an aerodynamics test.



The possibility of implementing super hydrophobicity could, in theory, eliminate not only the rear windshield wiper system, but also the window washer system can be removed from the vehicle structure, due to this self-cleaning feature. Hereafter (figure 5), we present a graphical representation of the drop of water carrying specific dirt particles, that is, the self-cleaning characteristic [9].

Figure 5: Representation of the self-cleaning characteristic[6].



In a preliminary research on the implementation of this technological possibility in the glass of the automotive industry, we can mention the research by [10], in which it is possible to observe the transposition of super hydrophobic characteristics for solar energy panels. These solar panels are made of glass and also have a particular need for transparency, a fact that dialogues with the specific object proposed for vehicle windows.

Intelligent surfaces can be implemented from the change of the initial surface by adding a new material graft with super hydrophobic characteristics [8]. From the chemical alteration of a given surface, such as, for example, monolayers of spheres, this technology that belongs to a certain material can be transposed, that is, added to another surface without changing its main characteristics.

Currently coatings already exist on the market, that is, coatings deposited through a specific treatment or application of films that can add the super hydrophobic characteristic to the surfaces on which it is applied (for example, according to [11], in fairings for motorcycles, walls, mini boats, solar panels, shoes, etc.).

Also according to [11] the performance of the super hydrophobicity of coatings shows a strong positive impact when applied to surfaces that have, above all, the main objective of eliminating dust and pollution. It is important to note that all the alternatives briefly presented have a strong impact on the industry, from the reduction of expenses and energy, to the greater satisfaction and safety of consumers.

4. CONCLUSION

Current commercial vehicles have a windshield washer and washer system. The wiper system for the front window is necessary, as it must meet Brazilian regulations that require a minimum coverage of 98% of the driver's vision area to be cleaned. However, the system used for the rear window is offered as an option to

[6] Adapted from [9] p. 4.

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contribute to the cleaning and to solve some difficulty of the rear field of vision, not being a mandatory item for automobiles according to Brazilian regulations.

The possibility of adapting an entire rear windshield wiper system by means of super hydrophobicity can, consequently, reduce costs and use of materials[7]. It is expected to reduce not only specific assembly costs, but also a reduction in the final weight of the vehicle, a fact that contributes to greater efficiency in fuel consumption. In addition, it is possible to observe results in line with the purpose of reducing the use of materials for the preservation of natural resources, aligned with the 17 Sustainable Development Objectives, established by United Nations (UN), representing number 12, which sets the goal of ensuring sustainable production and consumption patterns.

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