Stain Repellent fluorine-free Car Interior Textiles

Public report

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Project within FFI / Sustainable production

Innehållsförteckning

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1 Sammanfattning på svenska

Syftet med projektet var att hitta och utvärdera passande kombinationer av miljövänliga kemiska formuleringar och textila strukturer, för att åstadkomma fordonstextil med smutsavvisande (hydrofoba) egenskaper. Detta utgör ett nytt angreppssätt för att ersätta de konventionella fluorerade ämnen som normalt används i många textila applicationer i fordonsindustrin idag. Det övergripande målet med projektet var att ta fram textila material enligt detta koncept i fullskalig produktion, där prestandan hos dessa material kan mäta sig med fluorerade textila material.

En initial studie över tillgängliga kemiska teknologier genomfördes. De mest realistiska alternativen applicerades på olika typer av inredningstextil för fordon, med varierande struktur på fiber, garn och materialnivå. Processbetingelserna optimerades i såväl lab- som fullskala. Plasmabehandling och applicering av kemikalier genom en ny typ av sprayprocess utvärderas som komplement till projektets huvudinriktning. Syftet var att förbättra den vätskeavvisande effekten ytterligare och att minska mängden kemikalier. Dessutom utfördes det omfattande arbete med att försöka ta fram en kompletterande utvärderingsmetod för smutsavvisande egenskaper hos textil.

De viktigaste projektresultaten var utveckling och demonstration av fullskalig tillverkning av icke-fluorerade textila material med goda vattenavvisande egenskaper, för fordonsinredning. Projektarbetet har vidare skapat god kunskap om de parametrar som påverkar smutsavvisning hos textila material. Dessa insikter utgör en god grund för ytterligare utveckling och implementering av lämpliga teknologier i andra typer av produkter, som till exempel funktionella kläder och möbler. På längre sikt kommer projektet därmed att kunna bidra till minskad tillförsel av fluorerade kemikalier till naturen.

2 Executive summary

The aim of the project was to find and evaluate suitable environmentally friendly chemical formulations in combination with different textile structures to achieve vehicle interiors with stain repellent properties, also termed hydrophobic properties. This combination of technologies represents a new approach to replace the conventional fluorinated chemical substances commonly found in vehicle textiles as of today. The overall goal was to demonstrate the new concept in full production scale and to demonstrate good performance in relation to conventional solutions, through quality testing.

An initial study of feasible chemical technologies was conducted. The most realistic alternatives were applied to different types of vehicle textiles, with different structures at fiber, yarn and material level. The process conditions were optimized in both lab and full scale. Plasma technology and chemical application through a new spray method were evaluated to complement the focus of the project, with aim to further enhance the liquid repellent effect and to reduce the amount of chemicals overall. Development work was also performed to obtain a new evaluation method, to assess hydrophobicity of textile materials.

The most important result of the project is the development and industrial production of non-fluorinated textile prototypes with good water repellent properties for vehicle interiors. The development of the project results has provided knowledge about the various parameters that control dirt repellency of textiles. These insights can form the basis for further development and rapid implementation of the technologies in other types of products, including functional clothing and furniture. In the longer term, the effects of the project will thus be reduced supply of fluorinated chemicals in nature.

3 Background

There are demands from consumers, NGOs and authorities to reduce the amounts of per-fluorinated substances (PFAS) used as stain repellent finishing in textiles. Automotive interiors are no exceptions, as a car contains a lot of textile materials, where some of it contains PFAS. The industrial partners of applied project; Borgstena and Volvo Personvagnar AB, have taken decisions to continuously reduce the amounts of PFAS for this reason. So far there is no commercial non-fluorinated chemical technology that delivers properties to meet the requirements of stain repellent textiles for vehicle interiors, but there are research and development activities going on in the field of hydrophobic textiles, both within academia and the chemical industry.

4 Aim, research question and method

The aim of the project was to apply environmentally sound non-fluorinated stain repellent hydrophobic technology, to textile materials of different structures, potentially used as vehicle interiors. This serves to answer the following research question:

Is it possible to combine available chemical technologies with optimal textile structures, to achieve sufficiently stain repellent textile materials for vehicle interiors, using available production equipment?

This idea of combining chemical finishing with innovative textile structures is a new approach to replace PFAS in textiles. The goal of the project is to demonstrate thus developed concept in a full production scale and further as product prototypes for real life evaluation.

Method

A comprehensive survey of the state-of-the-art of different chemical technologies to achieve hydrophobic properties of different kinds of substrates was conducted initially. The feasibility of each technology was determined theoretically, both from economic and technological perspectives (e.g. TRL levels). The viable formulations (14 different) were applied to PET fabrics to assess their efficiency in practice. The selected textiles would find uses in seats, headliners, pillars, sun visors and parcel shelves. Following procedure was used:

The chemical formulations of interest were received from the suppliers, along with detailed instructions of use and material safety data sheets. Most of the products were received as milky white dispersions and were diluted with deionized water, according to the instruction. The pH was adjusted in some cases. The freshly prepared dispersions were applied to pieces of fabric by means of a lab scale foulard equipment, according to Figure 1. The chemical formulation was poured between reels of a certain nip pressure and speed. The fabrics were exposed to the chemical formulation and then pressed between the reels, causing a certain amount of the formulation to be absorbed and excess liquid to be removed. The wet samples were weighed and the percental uptake of liquid was calculated by knowing the initial material surface weight. The wet samples were mounted on a lab scale stenter and dried in an oven at moderate temperatures. The chemicals in the dried samples allowed to react with the substrate, at higher setting temperature. The temperatures and residence time were given in the instructions from the supplier.

Figure 1. *Lab scale foulard equipment (RISE IVF).*

The stain- and water repellency of the treated fabrics were assessed using e.g. standard methods. The resistance to surface wetting was assessed via spray test, using standard method EN ISO 4920 in which a specified volume of water is applied to a fabric in a standardised way, assessed visually and grade on a scale 1- 5 (low to high hydrophobicity). This was the most frequently used method in the project. Other standard methods used were oil repellency (ISO 14419:20109) and Bundesmann rain shower test (SS-EN 29865).

The durability of the treatment was assed throughout the project, using the Martindale abrasion method (ISO 12947-1:1998). In this test the samples are mounted in a holder under well-defined load and rubbed against a holder with abrasive wool weave in a standardized pattern for a certain number of cycles.

The described methodology was employed in an iterative manner to find the optimal chemical formulations, including their concentrations and other process conditions. The work also involved the assessment of different textile structures on the fiber, yarn and material level, in combination with selected parameters of the chemical technologies. Three different fibre cross section geometries were studied in more detail: round, trilobal and octalobal. SEM (electron microscopy) was employed on the different textile structures, to find parameters that influence the stain- and water repellent effect. SEM micrographs of a textile material for vehicle interior are shown in Figure 2.

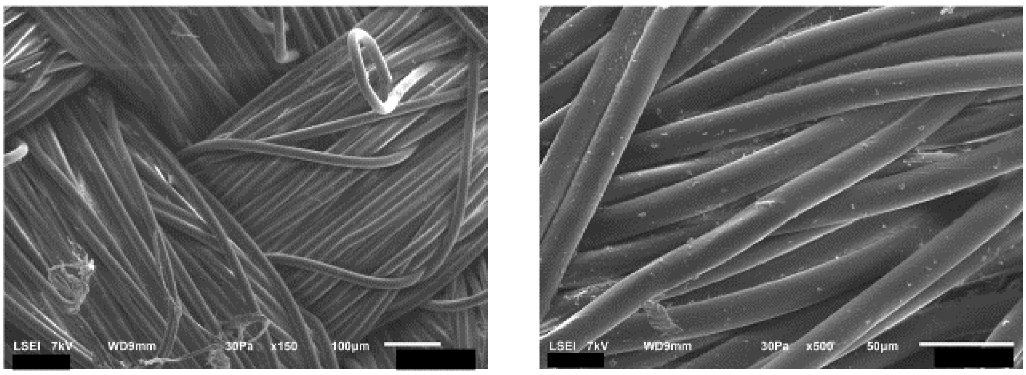

Figure 2. *SEM micrographs of textile materials for vehicle interiors (RISE IVF).*

The insights from the lab work served to select the most promising systems for the full-scale production trials, in which several metres of repellent fabrics were produced and subsequently tested for repellent properties, before and after abrasion. At this stage test methods related to e.g. colour fastness and tactility were employed as well.

The full-scale production trials also involved an assessment of innovative spray application technology, along with classical application techniques. Spray application would serve as a more sustainable alternative to foulard application, as less chemicals would be needed for the same repellent effect. With spray application the chemicals are accumulated at the material surface, where it should be most effectively utilised, rather than in equal amounts across the material. Also, spray application means less energy is needed to dry the fabrics after application of chemicals. Plasma technology was evaluated in the project as a way to further decrease the amounts of used chemicals and to make the surface treatment more resistant to abrasion than today, thereby improving the environmental aspect of the newly developed technical solution further.

The best performing system of non-fluorinated chemistry, textile structure and application technology was employed in full-scale production, to develop prototypes for real life evaluation in an office environment.

The development of a novel test methods was part of the project as well, as current methods to assess the hydrophobicity of textiles were shown to have some limitations in the context of this project. Two new approaches were investigated: the concept of contact angle and a method to measure the roll-off angle of liquids applied to a solid surface. Contact angle is a well-known way of determining the hydrophobicity of solid surfaces. The method, however, has been scarcely used for textile materials. As textile materials are rough on the microlevel, the method of contact angle demanded too many repeated measurements to appear as an attractive method for routine-based quality assurance of produced materials. This implies the contact angle method would be of limited industrial interest for the current application.

The work with the development of a roll-off angle method was more thorough. The idea of the new method was to be able to complement the standard method Spray Test (EN ISO 4920), by providing a method with higher resolution, to better distinguish between materials that obtained the same grade by the spray test method. Yet, the new method was initially validated against the spray rate method. The new test method also allows for the use of different liquids in the evaluation of the repellent properties of textile materials. The idea for the method is based on the concept of applying droplets to the surface of a hydrophobic material. The rolling ability of the droplet is observed under defined conditions, at different angles to the horizontal plane. The hydrophobicity of a material is determined by the angle at which the drop starts to roll on the surface, known as the roll-off angle. The roll-off angle can be 5 degrees or less for superhydrophobic surfaces. The Roll-off angle has previously been tested on hydrophobic materials, including textiles, using a sophisticated standard contact angle instrument. Such a set up would not be of interest for routine-based quality assurance in the industry. The current method instead relies on the use of a robust test rig with adjustable tilting angle, developed within the project (illustrated in Figure 3). The new set-up also utilizes a standard syringe of a well-known specification.

Figure 3. *Photo of the test rig developed within the project (RISE IVF)*

5 Objectives of the project

The overall objective of the project was to demonstrate the performance of novel non-fluorinated stain-repellent textiles, achieved by the new concept of combining chemical technology with optimal textile structures. The concept should be finally demonstrated by quality testing of textile materials produced in full production scale, also evaluating atmospheric plasma technology and spray application as complementary process operations to classical foulard treatment. The results should be related to state-of-the-art materials finished with fluorinated substances. This objective with its methodology was specified in the project proposal and followed to a large extent. In the proposal however, a focus on silicone-based chemical formulations were stressed, as this group of chemicals is proven to provide a higher degree of repellency to surfaces compared to other nonfluorinated alternatives. The literature study that was conducted initially in the project, revealed many other promising technologies as well. This stressed a need to widen the scope outside the group of silicones.

One of the intentions of the project, as stated in the proposal, was to obtain prototypes for real life evaluation in test cars. Product prototypes were obtained within the project, but the testing was done in an office environment, as this could be accomplished in a quicker and more smooth way, yet providing similar kind of results, as if test cars were to be used.

A specific objective of the project was the development of a complementary test method to assess the repellency of textiles for vehicles interiors, based on the methods currently used in the industry. The need for such a method was deemed necessary, as present methods do not provide a complete picture of the physical and chemical processes taking place on a textile surface at the time for spillage. Also, the current methods do not cover the wide range of liquids and soils that a textile material could be exposed to in real life situations in a car.

An overall yet intangible objective of the project was to build of knowledge and competence in the field of surface science in general and of stain repellency of textiles for vehicle interiors more specifically. The project also aimed at generating a deeper understanding of product testing and the implication of different test methods to the results. A deeper understanding industrial finishing of textiles is a natural outcome as well.

6 Results and achievements of the objectives

The overall project objectives to demonstrate the performance of non-fluorinated stain-repellent textiles, as described above, were met. The main results are given in the following statements:

- Full scale finishing of textile materials with novel non-fluorinated chemicals was demonstrated and assessed in terms of agreed quality assurance and methods to assess the hydrophobicity.

- Textile materials finished with novel non-fluorinated chemicals obtained Spray rate 5 (EN ISO 4920), shown for lab- and full-scale samples. This is the highest spray rate and hence, would correspond to high repellency to stains of more hydrophilic character, whereas more oily stains would still require the use of fluorinated substances. This implies that the physical structure of the textiles cannot fully cover the gap in the hydrophobic properties between that of nonfluorinated and fluorinated chemicals.

- Martindale abrasion reduced the obtained Spray rate to level 3 (EN ISO 4920), shown for lab- and full-scale samples. This was shown for textile materials finished with fluorinated and non-fluorinated chemical technology.

- Atmospheric plasma technology improved the spray rate (EN ISO 4920) with approximately one unit, shown for abraided lab scale samples.

- Full-scale spray application of chemicals was promising but further work is needed to fully understand the underlying physical and chemical mechanisms of the process and their implications to the hydrophobicity of textile materials.

- Test in an office environment, of hydrophobically finished textiles did not show any visible stains. No soiling appeared after extensive use for several weeks, both for non-fluorinated samples and fluorinated counterparts.

- The work with the novel roll-off angle test method revealed that the test conditions had a large impact on the result. Some parameters of relevance were the choice of materials, the placing and the diameter of the syringe and the properties of the fluid (viscosity and surface tension). The numerous parameters made it challenging to determine the reliability and validity of the new method, but the work resulted in several suggestions for further method development.

The contribution of the project results to the FFI and the sub programs

The project have had a clear environmental approach of limiting the use of hazardous PFAS and thereby addresses the first overall objective of the FFI program*: reducing the environmental impact of road traffic*. The project tackles this challenge by substituting current fluorinated chemical technology with less harmful alternatives.

The project has contributed to the generation of knowledge within the field of environmentally sound stain repellent textile surfaces, at two Swedish companies in the automotive sector. Up to now knowledge within this field has been more the property of chemical suppliers: the know-how among textile producers and product owners has not been as extensive. Most chemical suppliers are based overseas but a considerable volume of the automotive industry and the subcontractors are based in Sweden. Improving the competitive advantage of the Swedish automotive industry, by increasing the knowledge within the field of environmentally sound technologies is in line with the overall vision of the FFI program, as stated in the FFI roadmap. Furthermore, the knowledge gained within the project will be relevant not only for textile surfaces, but also for stain repellency of any kind of polymeric surface materials on a global arena, i.e. all kinds of plastics used in vehicles.

The project is part of the sub program Sustainable production, which addresses the overall challenge: "*the ability to produce new products and components, using new materials, keeping the environmental impact as low as possible*". The overall objective of the project was replace harmful fluorinated substances (PFAS) in textiles, as PFAS is inevitably emitted to the environment during the manufacturing, use and disposal phases of the textiles. Hence, the main tasks of the project were concerned with the development of new textile components based on less harmful non-fluorinated technologies. This clearly addresses the stated challenge of the sub-program Sustainable production.

7 Dissemination and publication

7.1 Dissemination of knowledge and results

How has the project results been used and dissiminated (and what is planned)	Mark with an X	Comment
Increase the knowledge in the field	X	Increased knowledge of surface science, stain repellency and test methodology of textiles, within the project consortia
Transfer to other advanced technical development projects	X	Project results might be applicable for vehicle interior areas exposed to less abrasion
Transfer to product development projects	X	Project results might be applicable for vehicle interior areas exposed to less abrasion
Market introduction		No information
Use for investigations/policies/regulations/political decisions		No information

7.2 Publications

- The project was presented at the annual conference within FFI (2019-10-16). The PowerPoint presentation was distributed to the participants of the conference.

- The findings from the project were continuously disseminated within the organisations of the project partners, through meeting notes and PowerPoint presentations.

8 Conclusions and further research

The overall conclusion of the project is that it is possible to develop and on a large scale produce non-fluorinated textile materials with good water- and stain repellent properties for vehicle interiors, as long as the stains are of a hydrophilic character.

Ideas for further research

- Optimisation of the spray application process, involving increased understand of the underlying physical and chemical mechanisms and their implications to the hydrophobicity of textile materials

- Atmospheric plasma optimised for full scale production, to outline the possibilities with the technique.

- Further development of a new evaluation method, to obtain complementary information to the standard methods used today.

- Evaluation of biobased textile materials, as replacement to conventional PET fabrics.

9 Participating partners and contact persons

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