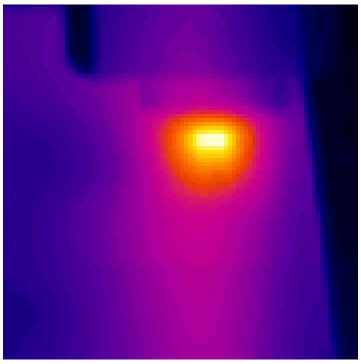
PERU-
"Plasma treatment for efficient windscreen bonding"

Dnr: 2011-03627



Project within **FFI – Sustainable production technologies**

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Content

FFI in short

FFI is a partnership between the Swedish government and automotive industry for joint funding of research, innovation and development concentrating on Climate & Environment and Safety. FFI has R&D activities worth approx. €100 million per year, of which half is governmental funding. The background to the investment is that development within road transportation and Swedish automotive industry has big impact for growth. FFI will contribute to the following main goals: Reducing the environmental impact of transport, reducing the number killed and injured in traffic and Strengthening international competitiveness. Currently there are five collaboration programs: **Vehicle Development, Transport Efficiency, Vehicle and Traffic Safety, Energy & Environment and Sustainable Production Technology.**

For more information: www.vinnova.se/ffi

1. Executive summary

Project summary
The project objectives were to understand if atmospheric plasma could act as cleaning and activation process before bonding and allow for an implementation with a moderate investment cost of a process that is generic for a variety of applications. The project wanted to demonstrate that the introduction of atmospheric plasma as a new process can be done without changes to the existing production line.

The work were divided into work packages and the overall goal were :

- Investigating strength and long term properties of the plasma coatings and adhesive systems.
- Find process windows for plasma treatment of paint and verify these results against the current and future paint- and adhesive systems (including tape).
- Prepare for implementation for atmospheric plasma , including environmental assessment , FMEA and business case .

Objectives of the project work are:

- A reliable and verified process for pretreatment with plasma for paint and adhesives.
- Find limitations for the plasma method.
- Propose a production arrangement to implemented atmospheric plasma in production.

Expected effects
The main effects of the project is to clean and activate surfaces before bonding and painting with a cheaper, faster and qualitatively improved process compared with current process . The positive side effects of the project is the reduction of diffuse CO_2 emissions and less chemical and material consumption and thus reduced destruction. The project also shows the possibility to use a less reactive adhesive and achieve an improved ergonomic situation leading to that backbreaking work procedures can be avoided.

The project consortium were the manufacturing companies , Volvo Cars, Volvo Trucks , Scania, Thule Sweden AB and Agaria .
Research partners have been Swerea IVF and Volvo Technology.

Briefly Results
The project has been divided into 6 work packages

Plasma treatment for bonding and touch-up painting :
A study has shown that soil could be reduced with plasma. The effect on soil reduction is dependent on the process settings. Plasma effect varies with the speed and distance to the surface. Different paint systems that are used in the automotive industry were studied and several common engineering plastics .Process settings that are made are not only linked

to the surface to be treated , but also for the adhesive to be applied on the surface. Process settings prove thus varies depending on material and adhesive. An improved adhesion after plasma treatment for one adhesive doesn´t necessarily show the same good results for a different adhesive.

Plasma treatment long-term effect :
Plasma effects on the paint layer were studied and the results showed that the treated coating is sensitive to humid climate. Surface energy decreases with time and height relative humidity. Surface analysis shows that the plasma treatment increases the level of oxygen in the surface and the concentration of carbon decreases. This indicates that the functional groups are created by the plasma and these functional groups contributing to increased adhesion.The analytical methods that proved to be most useful for detecting dirt and surface modifications, were XPS and contact angle measurement. Results from these methods showed correlation.

Process Window and guidelines:
By using the experimental design could optimal process settings be made based on treated surfaces and materials. Guidelines concerning treatment times of surfaces was developed. This is particularly important to avoid overheating of the plasma-treated surface. The risk to create an under or over treated surface can lead to reduced adhesion and strength of the bonded joint.

Preparing for implementation of atmospheric plasma:
Process FMEA and business case demonstrated the risks and how to make an implementation easer. FMEA has been working with a production unit where the plasma is included with the mounting of the windshield. Among the identified risks during implementation and production is dedication and low knowledge of the plasma method, but with the help of the PERU-project dedication and knowledge can be increased. A risk assessment was made to provide data for the ventilation and protective systems that must be designed. This is because the plasma creates ozone and nitrogen gases.

Dissemination of results
The project has participated in national conferences / seminars to spread knowledge about plasma pre-treatment method. Articles in the journal "Verkstäderna" , as well as in "Teknik och Tillväxt" have been published. As a part of the dissemination the project has had work-shops with the project consortium regarding the implementation, testing and analysis .

Project management
The project has had an industrial project manager Peter Porsgaard from VCC . Continuous reconciliations with monitoring of performance and economy has been held. The project succeeded with existing project consortium and with additional skills to go ahead with new complimentary research questions that were not housed in this FFI project. This resulted in a approved FFI project "Joining of Float glass . VINNOVA Dnr: 2013 - 04691

2. Background

Atmosphere Plasma equipment is not in contact with the surface. The method requires no chemical consumption . The equipment is connected to the compressed air and electricity and can be easily automated. The method is used in the automotive industry in Germany and England for cleaning. Before the Peru project atmospheric plasmas was a new and unknown method in the Swedish automotive industry.

The process gives great flexibility as it can be used both handheld and connected to an automation equipment but given the results of the project on the major impact of process parameters has recommended an automation equipment for the best possible reproducibility. The treatment takes place in the "open air". To implement atmospheric plasma in the automotive industry and their suppliers in Sweden means a radical leap in technology awareness. The knowledge about Plasma process is generic and can be transferred to a variety of other applications for cleaning and surface activation of organic surfaces . The method can enable to introduce an improved working environment with reduced emissions, dust, higher quality and better ergonomic operation.

The great advantage of atmospheric plasma is that it can both clean and activate in the same process .

In Sweden, the atmospheric plasma is an unknown method in engineering and automotive industries. There for it is a lack of experience for the plasma process possibilities and limitations. Atmosphere Plasma is used by a small number of Swedish company for activation mainly of electrical products.

Plasma is a known method and frequently evaluated, but it is the vacuum plasma that occurs in a plasma chamber where it treats the whole details. The cycle time for vacuum plasma makes it not possible to treat large parts in large series. The traditional vacuum plasma process that occurs in chambers are used for surface activation while atmospheric plasma has both a cleaning effect and a surface- activating effect.

A large number of vehicle components is today applied with tape (emblems, labels, etc.) preceded often with an uncertain cleaning process with isopropanol (IPA) solutions . This type of assembly processes is frequently exposed to quality disturbances, usually due to uncertainty in manual cleaning with solvents.

There are higher demands on crash safety of vehicle components. When the vehicle is equipped with airbags, it is required that the windshield must withstand the loads from the expanding air bags in a crash. To ensure that the windshield will remain intact in a crash , it is extremely important that the adhesive that is used in the joint between the Windshield/ Body in White retains its adhesion. Today's direct glazing is carefully selected and adapted to have good adhesion to the paint which it will be bonded on, for example, E-Coating , or Powder Coating. Therefore, is a PVC- or tape masking used.

When refinishing of paint is used, it is important to get good adhesion between refinishing layer and the original paint layer. This is usually ensured by mechanical grinding and cleaning. If it is possible to remove the grinding step, several benefits are achieved as less generated dust, the quality becomes more repeatable.

Grinding and masking is a job that has a big negative ergonomic environmental impact. Grinding and masking can´t be automated, but that could be avoided if the effect of plasma makes the masking unnecessary.

It is generally known in the automotive industry that different colours on the basecoat have different levels of adhesion, and cohesive strength. It is a desirable to apply the adhesive directly on the top coat. Then would it result in a time-and cost reduction in the form of avoiding the work to mask and remove the mask. Often there is a special solvent-based paint primer to secure adhesion between adhesive and paint surface. Paint primer is a solvent-based chemically reactive liquid that has a negative influence on the work environment and provides diffuse CO_2 emissions.

Scania, Volvo Trucks and Volvo Cars has independently before the Peru project started done internal projects to avoid masking before adhesive bonding of windshields. The three companies had so far not succeeded in realizing the reduce of masking. Atmosphere Plasma was seen, by the companies, as a method that can solve this.

In addition to a simpler and cheaper process with atmospheric plasma it can also be achieved an environmental benefit since it can remove the material consumption of masking material , equivalent to about 0.5 kg per car. Grinding may be reduced and a non-environmentally friendly paint primer with diffuse CO_2 emissions reduced. IPA cleaning solvents can also be reduced .

Atmospheric plasma has been developed into small, light units that can be placed on robot. With results from the Peru project the method would also be eligible for a use in the aftermarket industry, for example replacement of windshields.

3. Objective

The objective of Peru project was to

• Examining the strength and long-term properties of the plasma-treated paint and adhesive systems.

• Find process windows for plasma treatment of paint and verify these results against the current and future paint- and adhesive systems (including tape).

• Preparing for implementation of atmospheric plasma, including environmental assessment, FMEA and business case.

• Create a network of competences concerning plasma, process and analysis.

4. Project realization

The FFI project Peru 1:st of January 2012 to 31th of December 2013 can be summarized with the following activities.

Soil reduction
The first task was to ensure that the plasma could reduce dirt. Two types of soils were studied, TEFO - cebum (artificial fingerprints) and release agents for plastics. Analysis shows that the amount of dirt can be reduced.

Surface analysis
To find good analyse techniques to study surface effects several different methods were compared with multivariate data analysis to see which methods of analysis correlates. Surface energy measurement and XPS measurements show such a correlation .

Process parameters
Based on various materials and surfaces were optimal parameters emerged from a surface energy perspective. To ensure minimal dissemination of results the plasma was driven by robotic programs. The speed and distance between the surface and the plasma nozzle was varied. Two plasma devices with different power were studied.

Occupational exposure measurements
The plasma produces ozone and nitrogen gases that can be hazardous. In the demonstrator cell controlled measurements were done, this to provide data on how ventilation should be designed . Two plasma devices with different power were studied.

Demonstrator and Implementation
During the project a plasma production cell was built at one of the project participating companies. This production cell was used as a study cell for the performed FMEA and was a source of information for a business case for a plasma station windshield bonding.

Business intelligence
As the project went on for two years , a new business intelligence concerning plasma equipment was made in the project's final phase.

Project Management
The project has had quarterly reconciliations within the project management team. On these reconciliations, project finance and objectives were followed up. Risk assessment was done on these reconciliations to identify if anything disrupted the project.

5. Results and deliverables

The project has increased the understanding of plasma cleaning and the surface transforming effects. The plasma may reduce dirt as fingerprints and release agents that may otherwise interfere with adhesion of the adhesive

The project have also shown long-term effects of plasma treated surfaces. Humidity and climate affect the surface energy negative.

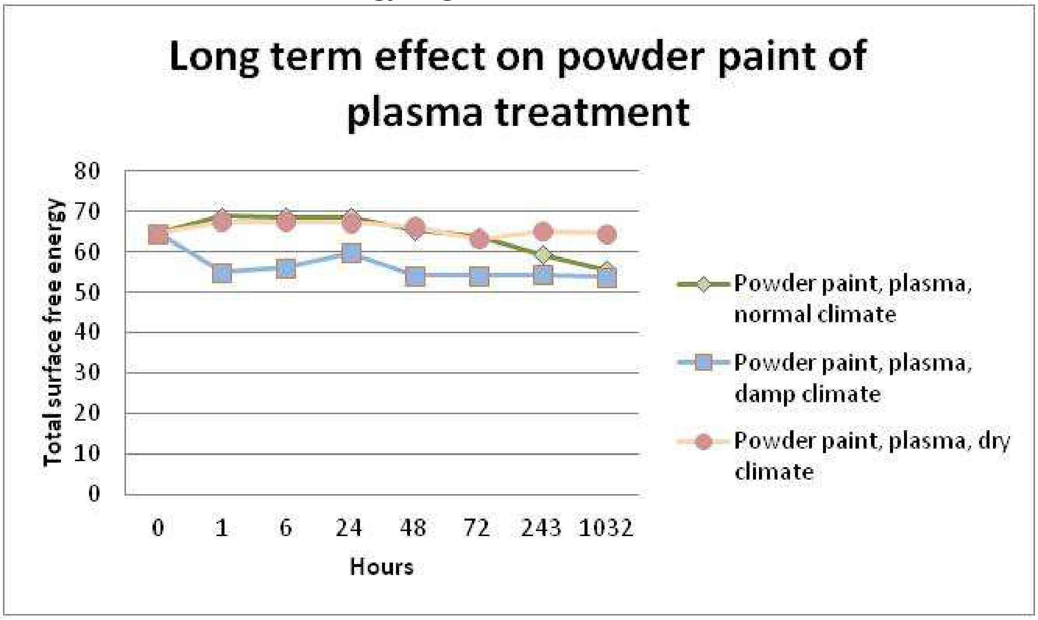

Figure 1 Change in Surface energy based on the time and relative humidity.

The project has shown that there is optimum on process parameters. The plasma may under-or over-treat the surface with adhesion problems as a result. Process window for the plasma can be considered as stable area on speed and distance. This must be determined based on each and specific surface.

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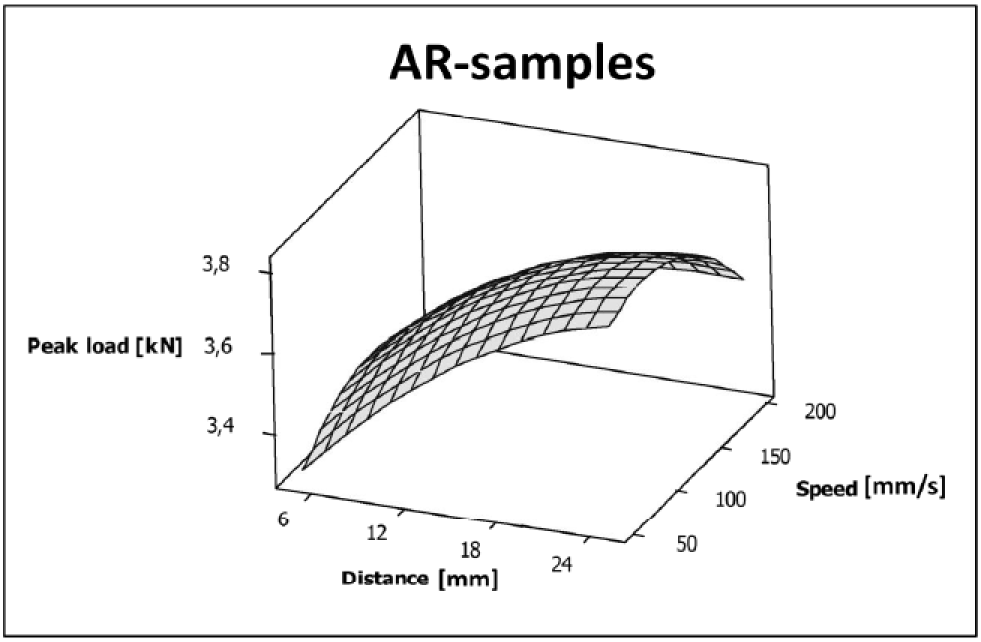

Figure 2. The shear strength based on the process parameters, distance and speed.

The project has evaluated surface analysis methods to describe and measure the change in the surface caused by the plasma. Of the methods examined, it was found that XPS could detect a surface transformation where it is more oxygen in the surface after plasma treatment and that the carbon content is reduced. These XPS measurements correlated to surface energy measurements, which measures the polar contribution increased after plasma treatment .

The project has prepared for implementation with the experience of production cell of participating institutions and manufacturing companies and formed the basis for the implementation study. A process-FMEA for a windshield application cell were made.

The plasma creates ozone and nitrogen gases therefore occupational hygiene studies of how high levels that are formed in a production cell were made. The results show the safety distance from the equipment which you have to be in, in order to not exceed the limits. In this study, two equipments with different power were used. General results were that the levels are below the maximum approved level approximately one meter from the production cell. These results are important to have when new production cells are designed .

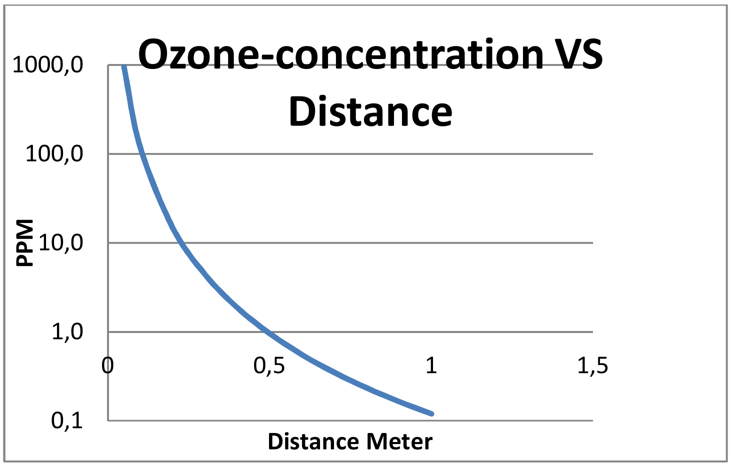

Figure 3 The ozone concentration v.s

5.1 Delivery to the FFI-goals

The following describes how the project contributes to one or more objectives that are relevant to the specific program as Peru project signed in.

• The Peru project has contributed to the continued competitive automotive industry in Sweden, by studying new methods of production within the plasma to reduce costs in today's production. Knowledge of a new process enables knowledge to introduce plasma increased not only the project's focus, " Direct Glassing " but to component manufacturing by subcontractors.
• The project has led to industrial techniques and skills by having a wide consortium that worked together and gladly shared their knowledge and experiences to each other. The project has increased the knowledge of different process layout, materials knowledge and analysis of surfaces.
• The project has supported research and innovation environments between institutions and manufacturing companies. One result of this is an approved continuing projects with an extended project team to cover the gaps identified in the Peru project.
• The project has work to ensure that new knowledge was developed and implemented , and that the existing knowledge is implemented in industrial applications by demonstration cells built up and that an implementation preparation in the form of environmental assessment , FMEA and business case have been presented in the project.

6. Dissemination and publications

6.1 Knowledge and results dissemination

To effectively create functional surfaces with a dry pretreatment locally, will reduce the production cost and partly avoid the use of chemicals that occupies a large and costly manufacturing area, and be able to reduce chemical use and disposal.

Plasma has in the last year got a lot of attention when the desire awakens to understand the method and its capabilities. This increased interest is because more new material is coming into the manufacturing.

Peru-The project has participated in national conferences to talk about the results and there got and interest from audience.

Peru-The project has created a follow-up project in the framework of the FFI. "Joining of Float. VINNOVA Dnr:2013 - 04691

To the new EU-Call 2015 there are planned activities where plasma before joining is used.

These new projects and awareness of plasma method will accelerate the introduction of the method.

6.2 Publications

Ten technical reports have be produced within the Peru project.

1. Process optimization of plasma treatment on painted and plastic surfaces
Authors: Åsa Lundevall, Ola Albinsson and Sofia Wilhelmsson (Swerea IVF)

2. Cleaning of organic contamination with plasma treatment and CO2 snow jet.
Authors: Åsa Lundevall, Ola Albinsson (Swerea IVF)

3. Pre-treatment of automotive clear coat using atmospheric pressure plasma
Authors: Sofia Wilhelmsson (Examensarbete Chalmers Tekniska Högskola)

4. Plasma treatment on glass
Author: Åsa Lundevall (Swerea IVF)

5. Health- and workplace risk assessment
Authors: Ragnhild Bruhn, Nils Lindskog (Volvo Global Truck)

6. Company specific evaluation
Authors: Åsa Lundevall, (Swerea IVF) Jens Peter Jenzen (VCC), Thomas Larsson och Andreas Sjögren(Thule Sweden AB), Dan Jönsson och Patrik Hagel (Scania CV)

7. Demonstrator PERU Projekt Plasmabehandling av Trim Panel Corner
Author: Karin Segerdahl (Volvo Global Truck)

8. Presentation, XPS analysis
Author: Lars Matsson (Volvo Global Truck)

9. Business Case
Author: Åsa Lundevall (Swerea IVF)

10. FMEA
Author: Åsa Lundevall (Swerea IVF)

7. Conclusions and future research

The project has shown that plasma can reduce dirt and create surfaces that are beneficial for bonding and coating.

The project has demonstrated the possibility of implementing the plasma in the automotive industry.

During the Peru project, new questions came up regarding how plasma can increase adhesion on glass. This resulted in a now granted project in the FFI-program "Joining of Float glass", VINNOVA Dnr:2013 - 04691. In this new research project, the project group was expanded to bring in new expertise in glass manufacturing and glass research and product knowledge about adhesives.

8. Participating parties and contact person

VCC
Peter Porsgaard, Mikael Sporrong, Jens Peter Jenzen, Louise Sigström, Sofia Willhemsson (Master Thesis)
VGT
Karin Segerdahl, Hans Fors, Peter sällström, Lars Enqvist, Ragnhild Bruhn , Nils Lindskog
Scania
Marcus Liljeqvist, Dan Jönsson, Björn Lennartsson, Grethe hallberg, Christer Bodén
Agaria
Jonas Axelsson
Thule Sweden AB
Thomas Larsson, Andreas Sjögren
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Lars Matsson Staffan Johansson
Swerea IVF
Ola Albinsson, Åsa Lundevall, Johan Åkerman
Chalmers
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