Focus on Hygiene – Clean sheets increase productivity in sheet forming

Defect on a stamped outer panel of a car door caused by a strand of hair

Project within Sustainable production technology

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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

In the preliminary study, we intended to compile baseline information for future work in the scheduled main project. Application of the main project will be submitted in 2013.

We have investigated possible methods for measuring particles on a flat surface/plate or component, and methods to measure the defects they cause. A benchmark was performed concerning what other companies in similar industries have made concerning particle cleanliness connected to sheet metal forming and other processes with high demands on surface finish. We also investigated what there is of published articles or other aggregate information about particle effects on sheet metal forming and in other industries. An initial mapping of the particles present in the production environment has been done. The defects of different particles generated have been studied in lab environment and methodology for this has been developed.

Literature search shows that there are a lot published about particles and particle cleanliness. This, however, focuses on particle cleanliness in mechanical systems such as bearings, hydraulics, transmission, etc. Particles impact on sheet metal forming is mentioned only in a few publications, and only as a subordinate clause without any detailed information presented.

Benchmark against companies shows that there is a serious problem with particles that generate defects in formed components, giving rise to substantial adjustments and rejects. Companies are aware of the problems but have generally not taken any direct action to solve them. For mechanical systems there are specified cleanliness requirements and standards and then the companies performed more extensive analyzes concerning cleanliness, washing processes and other measures.

The study shows that the majority of particles that may occur in the production at sheet metal forming cause defects in the formed component which does not pass the inspection. This is not only for hard particles such as metal or sand but also for soft particles of organic type as hairs, fibers, insects and plant parts. A particle with a thickness of 10 µm can give an unacceptable defect.

Conventional particle analysis by washing with washing liquid, filtering the washing liquid and microscopy with image analysis is impractical for analysis of particles on the stamping machines, tools, and large plates.

There are systems for particle measurement directly on the surface but since the measuring area is very small, they are currently not suitable for measurements on large surfaces. They work well on glossy surfaces but surfaces with structure, as with most of the materials for automotive sheet, are more difficult to calibrate and get relevant

measurements from.

Defects may be detected and assessed visually before painting by spraying with contrast-enhancing fluid and inspection by side lighting. This works well but is very time consuming. There are systems for more automated inspection and quantification of detected defects. These are in use at some of the major vehicle manufacturers.

Particles collected in the participating companies' production processes by either capture them directly in shaping dies or by capturing particles that occurs airborne. Size and chemical content varies greatly among the particles found. Accuracy in finding the source of the particle also varies widely. The processes that produce the main parts of the pollution differ between companies.

The feasibility study shows that it is highly interesting to develop a methodology and implement measures to detect and eliminate particles and raise the general level of cleanliness in the complete production process, including storage, unpacking, transportation, forming, etc., at the participating companies. The project group will therefore act for a continuation of the project with an application for the main project.

2. Background

That the level of cleanliness / hygiene in a manufacturing process affects the outcome of rejection and adjustment costs and productivity is not new. Most processes require that the components and the equipment used to manufacture and assemble the components are reasonably clean from impurities. Some processes such as gluing and coating may require an essentially fat-free and metal clean surface while other processes are more forgiving and works if the surface is free from large particles and chips.

For mechanical system, such as hydraulics, transmissions, bearings, motors and fuel systems, the performance, service life and maintenance intervals are directly affected by the amount and type of particulate pollution. Extremely clean bearings may well have almost infinite life.

Particle Cleanliness is a largely unexplored area in terms of influence in forming of sheet metal parts with high surface finish requirements. What is known is that particles on the tool or sheet material cause defects on the formed parts in the form of scratches, bumps, dents or hollows. The surface finish will then be unacceptable and the item must be adjusted or discarded, which causes increased costs. In the worst case, particles can cause permanent damage to the tool, which then must be repaired. There is no available knowledge of the connection between the type and size of particles and the defects they can cause.

The importance of good particle cleanliness in a manufacturing process is illustrated in the figure below. It shows how such small contaminants as strands of hair affect the

quality of the outcome of an outer part (car door) after forming. After painting, this type of defect is often even more pronounced.

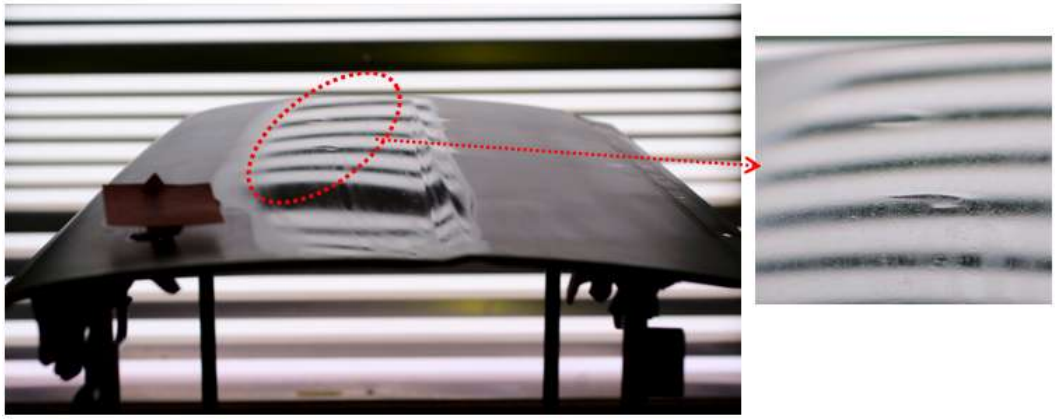

Figure 1. The figure shows a rejected outer panel (car door) which has been formed with two strands of hairs placed on the stamp. The defects are visualised by the light. The detail has a blanking liquid applied, which simulates varnishing.
The stripes are a reflection phenomenon which is caused by the illumination.

3. Objective

The pre study aims to compile baseline information for future work in the project. The study will analyze potential methods for measuring pollutants/particles on a flat surface/plate or component, and methods to measure the defects they cause. The study will also investigate what other companies in the same or similar industries have made concerning particle cleanliness in connection to sheet metal forming and other processes with high demands on surface finish. Since our opinion is that there is not much of published articles or other compiled information available for sheet metal forming, it is important that we also look at the experience from other industries.

The overall objective of the study is to prepare for further studies in the main project:
• Explore the possibility to measure particles and the defects they can cause in sheet metal forming, in a controlled manner, and try out suitable lab tools and methods.
• Collect samples of the particles, size and type, found in an industrial environment.
• Ensure that the main project gets the right focus and that we are not only doing things right, but also the right things. If there are simple steps to eliminate certain sources of error, we need not put as much effort into them and can concentrate resources on other parts to get a cost-effective project.
If the conclusions of the pre study show that there is potential for cost-effective measures to take control of particle cleanliness at sheet metal forming and improving the productivity, the project team will act for a continuation with the main project.

4. Project realization

The work of the pre study was conducted according to the following work packages:

WP1 Benchmark

1. Mapping of general measurement methodology and occurrence of different types of particles in production processes and how to measure them on components and sheets.
2. Synergies with other industries with similar production processes, mainly in sheet metal forming, but also in other areas where particles can be expected to cause problems. One example is foil lamination for furniture industry.
3. Summary and documentation of results.

WP2 measurement methodologies

1. Investigation of measurement technique for particles on components in lab tests.
2. Mapping of measurement systems and associated measurement methodologies for measuring defects in formed parts from production.
3. In laboratory tests verify lab tools and measurement methodologies with pre-defined particles.

WP3 Mapping

1. Initial measurement of particle cleanliness for selected manufacturing processes at the participating companies.

Below are some selected illustrations from the project. The results from the pre study are described in the summary.

Figure 2. Particle analysis with image processing and particle counter PartSens.

Figure 3. ABISoptimizer for detection and measurement of surface defects.

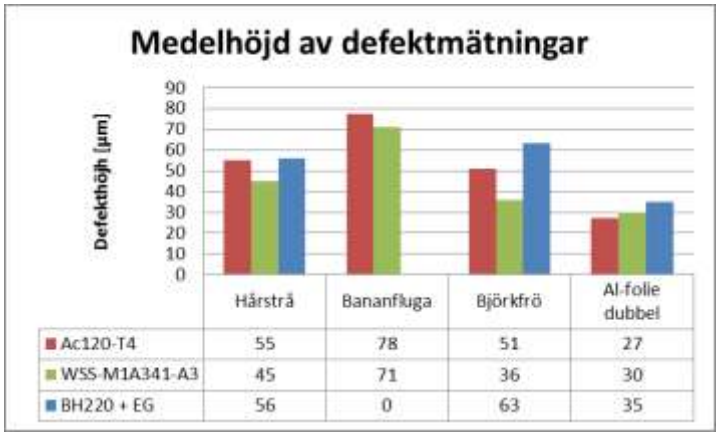

Figure 4. Measured defects caused by various particles.

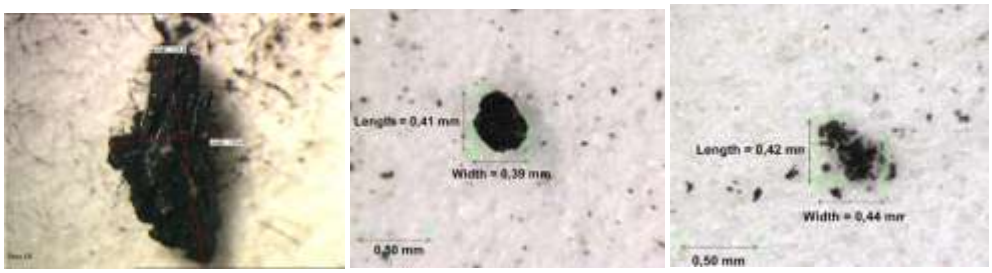

Figure 5. Examples of particles collected on a filter from the press line.

5. Results and deliverables

5.1 Delivery to FFI-goals

The project was a feasibility study. The objectives of the sub program will mainly be met in the planned main project. The study has shown that there are significant opportunities

to improve competitiveness by developing methodologies and take control of particle cleanliness for sheet metal forming. The project will strengthen research and generate new knowledge in an area that has had no coordinated research activities.

Results from the project will directly lead to production improvements at the participating companies. The outcome will be highly relevant for other manufacturing industries, not only in sheet metal forming, but also to a large extent other industries where particles can cause problems in the production or for the products. Examples include injection molding of plastics, lamination, manufacture of hydraulics and transmissions, bearings, etc.

The main project aims to develop methodologies and instructions to take control of particle cleanliness. The results will be disseminated widely for industrial applications and used in production education. Overall, the project group consider that the main project will meet most of the objectives of the specific program.

6. Dissemination and publications

6.1 Knowledge and results dissemination

The project was a pilot study and the only proposed dissemination of project results outside the project team is this Open report. The pre study is intended to result in a larger main project in which methodologies and guidelines for increased productivity through improved particle cleanliness are produced and distributed both within and outside the project team.

6.2 Publications

The project has resulted in a comprehensive final technical report plus seven internal interim reports as follows:
Final technical report
Appendix 1 Benchmark Literature search
Appendix 2 Benchmark Companies
Appendix 3 Measurement of particles
Appendix 4 Measurement methodologies for particles on surfaces
Appendix 5 Mapping of measurement systems and associated measurement methodologies for measurement of defects on formed parts from the production
Appendix 6 Verification of laboratory tools for the evaluation of particle impact
Appendix 7 Mapping of particles in selected production processes

7. Conclusions and further research

The pre study has resulted in the conclusion that it is of significant interest to develop methodology and implement measures to detect and eliminate particles and raise the general level of cleanliness in the production of sheet metal forming. In this way, productivity is increased and production costs can be reduced and thus the competitiveness can be strengthened.

The project team will therefore act for the continuation of the project with a new application for the main project. We believe that all sheet forming with high requirements on surface finish have problems with particles. We therefore intend to involve also some companies outside the automotive industry in the main project. This we believe can broaden and enhance the impact the project may have on the Swedish industry.

8. Participating parties and contact persons

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