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2013-04712 : Efficient Production of Structural Composites for Moderate Volumes

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1. Summary

Composites are considered to have a central role in the solution of a number of challenges in the automotive industry where primarily the struggle to reach the statutory CO2 targets. Most available technologies for composites means, however, increased costs mainly due to material costs and long cycle times. Unlike these, the patented X-TECH™ technology is successfully developed to meet the cost target for applications suited to the automotive industry high volumes (> 50,000) where efficient production technology combined with high utilization of materials also gives weight reduction of up to 50% .

X-TECH™ is a technology that is based on a reinforcing skeleton of continuous fibers overmolded with a thermoplastic matrix. The current project has developed the development and manufacturing processes for the production of structural composites in volumes where the injection is not economically viable by utilizing the possibilities of PUR-RIM (reactive injection of polyurethane). Target volumes in the project have been 1000-10000.

Within the project, the technical production aspects evaluated as the important adhesion between reinforcement skeleton and matrix by different surface modifications. Properties, processability and costs were weighed to evaluate the best solution. To build the material models for developing simulation methodologies conducted a series of tests. The developed simulation methodology correlated by evaluating a simple test body.

Finally, verified both the development and manufacturing processes through the development of a demonstrator spongiform a cargo guards to a passenger car. Prototypes were developed which were tested both statically and dynamically in the form of standardized crash tests.

There developed protective grille met all technical requirements and reduced the weight by around 30% against the existing production grid. Additionally, composite solution, a design freedom which provides completely new opportunities to use the component as a design element in the interior of the car.

The project was a collaboration between Klippan Safety, INXIDE and Swerea SICOMP. Klippan Safety is a provider of security items for both heavy and light vehicles while INXIDE is the owner of the X-TECH ™ technology that develops and manufactures composite solutions for volume production. Swerea SICOMP is one of Europe's leading research institute for polymer composites.

2. Background

Automotive industry

The recent years' focus on humanity's environmental impact has led to a variety of countermeasures to, among other things, reducing vehicle fleet fuel consumption. In particular, fuel consumption has been found to be significant with regard to the CO2 emissions and global warming. In numerous reports, particularly from the automotive industry, but also from the aerospace industry, it is claimed that the only way to meet future European emission requirements paradigm shift from metallic materials, primarily to polymer composites. The above is confirmed by a number of partnerships and the creation of joint ventures between the vehicle and carbon fiber manufacturers. Examples include collaboration between Lamborghini and the Huntsman, the BMW and SGL, GM and Teijin, Daimler AG and Toray Industries, Ford Motor Company and Dow (and AKSA), KraussMaffei and Dieffenbacher, and more.

The crux of this development is rapid and fully automated production processes, as well as less expensive carbon fiber. The main process parameters from the manufacturing point of view will consequently be the lowest possible temperature and process pressure and the shortest possible cycle time. The current trend is automation and fine-tuning of existing processes unfortunately often has its roots in the aerospace and marine markets. For example, focus on BMW RTM normally used in production runs at up to 10 000 pcs / year. RTM (from the English Resin Transfer Molding) is a process in which a pump press the resin into the tool. The bets that BMW has done currently allow an upscaling of the RTM to nearly 35 000 pcs / year. However, it seems likely that a scaling beyond 100 000 pcs / year will encounter ogenombryggbara technological barriers. Another example is the cooperation between the Lamborghini (VW) and Huntsman based on SMC. SMC (from English Sheet Moulding Compound) is a hot-pressing method for manufacturing truck fronts, bath, small boats, to smaller details like electrical panels and connectors. Even where we can expect a technology barrier at ca. 100 000 pcs / year because of the material selected: thermoset polyester. The material requires chemical reaction during the production process, which inevitably leads to long cycle times

Fig. 1 Cross-section of the BMW i3 with a complete composite cabin

Another trend in the automotive industry is the individualization and customization of vehicles to individual customers. This means that the body of the vehicle will be standardized around the high volumes, and that the customization will be by means of a small series of customized components.

X-TECH™

For several years, research has been done on the EPFL (Ecole Polytechnique Fédérale de Lausanne) in Switzerland with the aim of identifying and developing manufacturing technologies for composites to be tailored for the automotive industry requirements images relevant costs, volumes, performance and the environment.

The technology (X-TECH ™) developed based on creating a förstärkningsskellett (X FORMTM) consisting of continuous fibers overmolded with a thermoplastic matrix material. Overmolding can be made by a variety of methods, but usually by injection molding or pressing. The shape of the X-FORMTM are tailored component load cases and optimized to follow the load paths and therefore pick up and distribute the load in an energy efficient manner.

TECH ™ X-thus combining the benefits of properly positioned reinforcing elements usually used for low volume production by over molding process for high volumes. The high utilization of the material properties in combination with the efficient production provides components with the potential for both weight and cost.
INXIDE created in Switzerland in 2008 to launch the X-TECH ™ and 2011 Fouriertransform invested in INXIDE to industrialize the technology. The company has a number of successful pre-development project demonstrated the cost-effective weight saving of up to 50% of the load and the energy-absorbing components! Among other things, received INXIDE with Hyundai Kia and Hanwha L & C the prestigious JEC Innovation Award 2013 for a bumper beam of X-TECH ™ that was 30% lighter than comparable GMT solution (Fig. 2).

Fig 2. The bumper beam of X-TECH ™ for cars

In contact with customers INXIDE recognized the need to offer X-TECH ™ applications in much lower volumes than what the technology was primarily intended. Complex articles in the injection molding requires expensive tools which gives the cost is only achieved at volumes up to several hundred thousand. At lower volumes become the investment cost is too high to be able to offer competitive solutions.
An important factor in the process to provide the desired properties in an X-TECH ™ component is to ensure that X-FORMTM: one is fixed to the casting. With the proposed method with RIM over-molding comes easier fixing to be used, which additionally provides the ability to produce articles with Class A surface, which has hitherto not been possible.

PUR-RIM (Reactive Injection Molding of Polyurethane)

Plastics, and particularly composites, typically made by different variants of injection methods, in which liquid materials are mixed and introduced into a tool or the form in which the material may react and / or solidifying, see Fig. 3. Within this group there are a number of processes which most can be used to prepare both composites and core material. In this context, RIM (Reaction Injection Molding) is a generic term for a process in which usually two components are mixed in an antechamber, and then injected into a mold cavity and which react to a solid product. Common to these processes is that they cause low emissions of volatile substances, thus contributing to an environmentally friendly production. Furthermore, different types of posts made easy with this method; for example, metal, metal brackets, fixings and foams in the production of double-skin or sandwich into the device. In particular, this feature helps to enable the combination of X-FORM□ and PUR-RIM. Interesting for PUR-RIM is that the method is suitable for both large (> 50 000 pcs / year) and small (about 1000 pcs / year) production volumes. On the one hand allows Purs fast reaction times (5-30 seconds) large production volumes. On the other hand, allows the low process pressures and temperatures relatively biliga tools, resulting in low investment costs and economical even with small production volumes. In summary, the major advantages of PUR-RIM cycle times down to a few minutes, even for large parts of 1 m2. This means that RIM can compete with conventional sheet metal stamping. The low viscosity makes large complicated structures can be manufactured. Clamping force is only a fraction of that used in injection molding of an equal detail, allowing cheaper tools.

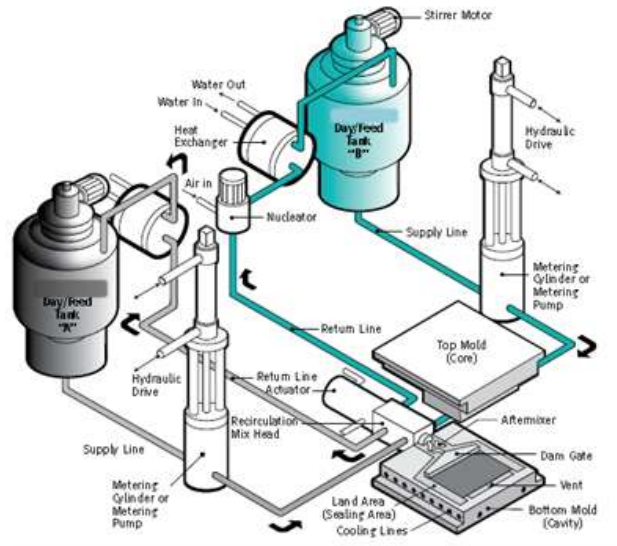

Fig. 3 Typiskt RIM process

In this perspective, the project will address the problem from the other direction. Instead of relying on traditional costly and slow processes, we assume X-TECH ™ process can be scaled up in production volumes over one million pcs / year. The challenge with X-TECH ™, however, is the high investment costs required for large-scale production capacity, which means that the X-TECH ™ can not be used for the smaller custom-made products. A possible solution appears to be that of casting the X FORMTM with polyurethane (PUR) instead of using the polypropylene / polyamide. This is likely somewhat poorer mechanical properties, but in return, low investment costs, while the possibility for large production volumes, which in turn opens the door to both large and small series, provided the material can be adapted to the prevailing load case.

3. Purpose

The project aimed to identify the development of methodologies and production process to ensure quality and cost-effective development of solutions with the current technology concept.

The specific objectives of the project worked with were:

- a quality-assured process for cost effective manufacturing of components of the combination of X-TECH ™ and RIM in volumes of 1000-10000 articles
- material models for the efficient production of components with a technology solution
- and manufacture, testing and correlating a demonstrator - in this case a cargo guards for a car
- a production set-up for series production

4. Execution

The project worked with the primary objective to verify the results of the project on a demonstrator that can be used for the further marketing of the technology and the project's industrial partners.

To reach the primary was conducted structured work which the main elements of the project

- Effect of surface modification to ensure adhesion between the reinforcing skeleton and matrix material
- Material characterization of the basis for the material model
- Structure of the simulation model and industrialization for effective development
- Development and manufacture of cargo grid demonstrator
- Testing and validation of the cargo grid and reconnect the test results for further optimization of the material model and simulation methodology
- Cost analysis of an industrial approach

The participants in the project had significant complementary skills. As the project's Academy party utilized the Swerea SICOMP the basic materials testing, analysis and theoretical construction of materials modeling. Industrial Parties focused on prototyping, engineering, industrialization (both development and production processes), as well as validation.

5. Results

The central objective of the project was the creation of a development and production methodologies to ensure quality production of components and systems technology. The challenge was (technically) to cost-effectively combine a thermoplastic based reinforcement skeleton (X FORMTM) and an over-molding material which is normally not compatible and (analytical) build material models for efficient and accurate simulation.

A test series was designed to evaluate ytmodifieringskoncept to ensure adhesion between reinforcement elements and matrix material based on polyurethane. With the utilization of the findings was carried out a series of tests to characterize the material combination. The purpose of the material characterization was to partly get an insight how the material combination behaved in comparison with the X-TECH ™ normally behaves with a thermoplastic that overspray and both have as a basis for building up of material models.

Material models developed and correlated with the material characterization and testing with a simple test body.

A cargo guards to a Volvo XC70 used to evaluate the developed methodology. The partition grille used today are based on steel pipes that are welded together and painted. The current concept is an entirely new design freedom and purpose of the demonstrator was to develop an attractive cargo guards that meet all requirements and are also lighter than the current design. Cost-wise, the protective grille to be at parity with the existing solution.

Fig. 4. The cargo barrier developed within the project

The developed design was produced in a small series. Articles produced was used for static and dynamic testing. The dynamic test was done by crash tests on Klippan Safety's own test facility. The impact test showed that the design and concept partly capable collision requirement and partly to the material models that are created have a high degree of regularity to the practical test.

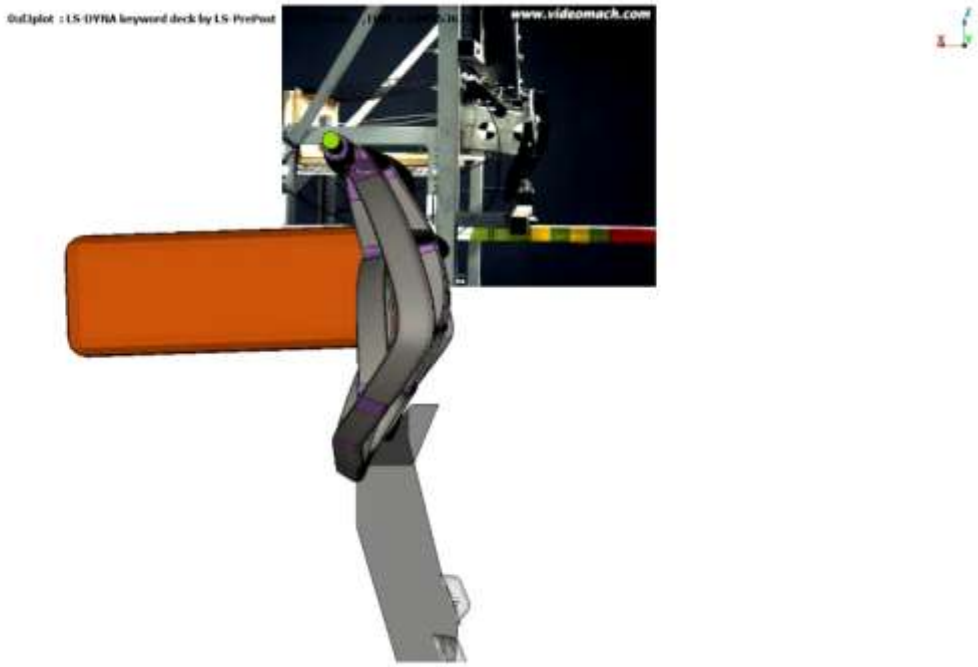

Fig. 5. Visualization of conformity between the test and simulation

The partition grille had a weight saving of almost 30% and a cost-neutral business case of the volumes.

An important production technological challenge that tested the fixation mechanism to ensure the positioning of the reinforcement skeleton. This was done by various types of clips which were taken up to the production of demonstrators. The concept worked very well for prototypes, but as a series of wise approach needs fixing mechanism developed further.

5.1 Contribution to FFI-goals

The proposed technology solution supports the FFI program objectives by

- The demonstrator has successfully demonstrated weight savings potential with technology concept in which a weight saving of 30%. This contributes to weight saving of CO2 reduction.
- Technology concept create cost-effective solutions when:
    - X-FORM: one manufactured in a robotized production cell
    - The reinforcement and matrix materials used optimally
    - Low tool costs linked to the RIM process

This gives the project's Tier-1 provider will be able to obtain a competitive advantage

- X-TECH™ technology offers an efficient energy absorption through the use of reinforcement material properties and thus may be security related articles developed within the current volume range. This has also been demonstrated with the developed cargo barrier.

Technology solution supports the objectives of Sustainable Production by the project will work with:

- development of innovative, environmentally friendly and safe products
- automated production
- industrialization of the technology

Technology solution contributes to the sub-program roadmap by:

- technology concepts developed for a production process and system solution that supports cost-effective manufacturing of innovative lightweight solutions are also suitable for energy absorption.

6. Dissemination and Publications

6.1 Transfer of knowledge and dissemination of results

The partition grille has been used in a variety of exhibitions and conferences to present the results. Hardware with crash test videos are powerful tools for increasing the credibility surrounding the technology.

6.2 Publications

At this writing, preparing publications regarding:

- The effect of surface modifications of adhesion between the X-FORM^{TM} and matrix materials, and the evaluation process
- The process of materials characterization and transfer to the structure of materials modeling and simulation methodology

7. Conclusions and future research

Projects have shown that the X-TECH technology with the PUR-RIM to manufacture structural composites in between high volume and commercially viable. Development methodology developed can be directly implemented into new projects. Prototype production has also solved the necessary technical production issues in order to take the next step to optimize the production process to achieve further efficiency and thus increase competitiveness.

The technology needs further development regarding industrialization to increase competitiveness. This applies above all to further enhance regarding efficient production processes and surface modification.

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8. Participating partners and contacts

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