SAMPE BENELUX STUDENT SEMINAR

Book of Abstracts

January 2010

UT-CTW-TM-10/5626

Contents

Program

Tuesday, January 12th

v.a. 12:00	Arrival & Registration
v.a. 12:15	Lunch
12:45	Opening/Introduction Sampe Benelux
13:00	Introduction Sponsors
13:30	Keynote by A. Offringa - Fokker Aerostructures

First Student Session

14:00	Lina Osorio
14:25	Diederik van Nuffel
14:50	Bianca Nellen
15:15	Coffee & Tea Break

Second Student Session

15:30	Bo Cornelissen
15:55	Eduardo Trujillo
16:20	Steven Bakker
16:45	Jeroen van de Zand
17:10	Coffee & Tea Break

Third Student Session

17:25	Kameswara Sridhar Vepa
17:50	Gustavo Guerriero
18:15	Toon van Vugt
18:40	Closure of sessions & jury consult
19:30	Dinner
21:00	Announcement of winners & Evening drink

Wednesday, January 13th

8:00	Breakfast
9:00	Departure to Ten Cate Advanced Composites, Nijverdal (NL)
10:30	Visit to Ten Cate Advanced Composites, Nijverdal (NL)
13:00	Lunch & Closure

Sponsors of the 8th SAMPE Benelux Student Event

The student event is sponsored by a number of companies:

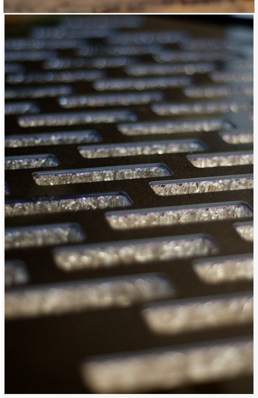
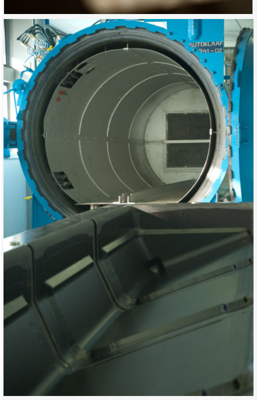
- Kok & Van Engelen http://www.kve.nl
- Airborne www.airbornecomposites.com
- Composite Technology Centre (CTC) http://www.ctcgroup.nl

The SAMPE Benelux Board thanks the support of these companies. It would not have been possible to organise this event without their support.

The organisation also acknowledges Ten Cate Advanced Composites for arranging a visit to their facilities in Nijverdal (http://www.tencate.com/) and keynote speaker Arnt Offringa from Fokker Aerostructures (http://www.fokker.com/aesp).





Composite Structures

Design, development and manufacturing of composite structures and components is the main pursuit of KVE Composites Group.

Innovation and performance

Our customers are looking for product innovations and enhanced product performance, and in many cases the use of **fiber reinforced components makes this possible**. Generally, composites are applied where **structural, thermal, weight, resonance behavior and durability** problems are encountered. The flexible and innovative mindset of KVE ensures that solutions are found for virtually every design and manufacturing challenge.

Markets

Traditionally, KVE has served the markets where composite structures are extensively used. These markets are the aerospace industry, medical technology and defense systems. Nowadays, also other industries like automotive, machine construction and civil engineering are **finding their way** to KVE Composites Group.

Design and Development

Extensive knowledge and experience is employed in the design and development of structures, technical products and systems using composites. All steps in the product realization process, ranging from **conceptual design to series manufacturing**, are executed by KVE Composites Group, whether as advisor or as turnkey project manager.

Manufacturing

Manufacturing of composites structures and components is offered from our **well equipped facilities in The Hague Ypenburg**. KVE Composites Group uses the best suited manufacturing process, ranging from vacuum infusion, resin transfer moulding, compression moulding to prepregging/autoclaving.

MRO

Employing material knowledge and process experience of composites, KVE Composite Group offers **repair services for composites and metal bonded aircraft components** from our EASA Part 145 approved composites repair facilities in Maastricht Aachen Airport.

KVE Induct

Developed at the KVE labs, the induction welding technology for carbon fiber reinforced thermoplastics is now being used for the manufacturing of aircraft components. It is an example of a very successful innovation in aerospace assembly technology.

Research

Research and Technology Development supports our engineering and manufacturing services, keeping KVE Composites Group **at the forefront of the composites industry**. We also have access to a large, international network of information from specialized companies, research organizations and universities, enabling us to integrate the right technology for the right problem.

Employment

KVE Composites Group is continuously looking forward to meet **motivated people to further strengthen our team**. Please contact us when you are interested to work in a high tech environment.

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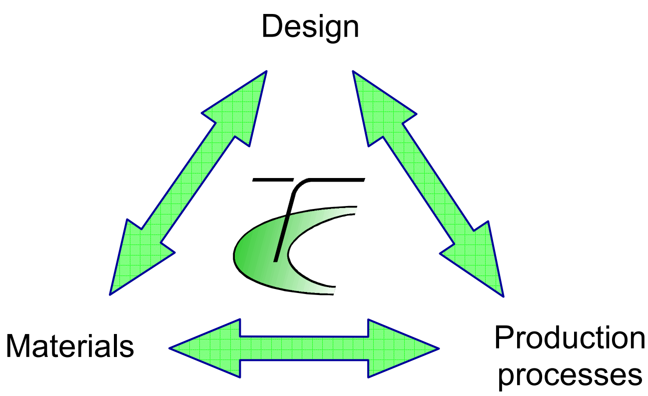
Composite Technology Centre (CTC) is a consultancy company that operates in the field of high-loaded large composite structures, mainly wind turbine rotor blades. Although founded in 2001, we are a team of engineers with experience dating back to the early 1970's.

At this moment we have a team of 15 employees, working in the different fields that are needed to design an optimal composite product:

- Design: aerodynamic and structural design using e.g. FEA (FEMAP)
- Materials: prepregs, fabrics (mainly with glass fibres) and resins, using e.g. our 100 kN testing machine
- Production processes: mainly Resin Infusion Moulding (RIM), using e.g. our infusion set-up in the workshop.



At present most of our customers are situated in China and India.
To achieve cost efficient products now and in the future, we need continuous development in all three fields. To make this possible, we work in co-operation with suppliers (like OCV and Huntsman) and research institutes (like ECN and IMA).

Techniek is voor nuchtere mensen, voor vakmensen die met beide benen stevig op de grond staan. Bij Fokker Aerospace Group en de bedrijfsonderdelen Fokker Aerostructures, Stork SP Aerospace, Fokker Services, Fokker Aircraft Services en Fokker Elmo is dat niet anders. Maar nuchterheid gaat daar samen met begeestering. Ruim 3.700 medewerkers ervaren dag in dag uit hoe inspirerend het is om voor de lucht- en ruimtevaartindustrie en de bekendste luchtvaartmaatschappijen ter wereld technische hoogstandjes te verrichten. Die medewerkers zijn op zoek naar collega's die het hoofd koel houden, maar wel graag warm lopen voor een loopbaan in de luchtvaartindustrie.

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AIRBORNE

Airborne International
Airborne develops and produces advanced composite products, for a variety of markets. It turns innovative know-how into industrialised production, through integrated Design and Build programmes. Airborne operates state-of-the-art engineering and production facilities, and is dedicated to quality, customer satisfaction and cost-efficiency. In the rapidly evolving world of composites, Airborne is committed to develop new game-changing technologies, in materials, processes and product design.

Airborne consists of the following business units:

Airborne Composites Netherlands
Design and Build of advanced composites

Airborne Composites Spain
Design and Build of advanced composites

Airborne Composite Tubulars
Thermoplastic composite tubulars for the oil & gas industry

Airborne Technology Centre
The Airborne Technology Centre is founded to develop the new, differentiating composite technologies for future new business for Airborne. It reflects the ambition of Airborne to be a Technology Leader in composites.

The following five Research themes are defined:

Thermoplastic composites
Thermoplastic tape placement, in-situ consolidation, autoclave/oven consolidation, welding

Injection and preform technologies
RTM and VARTM, automated preforming techniques, fast curing maerials
Smart structures

Integration of sensors and/or active materials, nano-composites, self-healing
Simulation

Composite mechanical behaviour, simulation of process-induced effects
Automation

Automated Fibre Placement, fiber steering, Continuous Winding process, machining of composites

Microstructural And Mechanical Characterisation Of Bamboo (*Guadua Angustifolia*) Fibres

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Keywords: Bamboo fibres, Fibre microstructure, Mechanical properties

Thanks to their good mechanical properties and low density, bamboo fibres represent one of the best alternatives among the natural fibres. In other words, specific mechanical properties of bamboo fibres are comparable to those of glass fibres.
Guadua angustifolia is the most important bamboo specie of South America and one of the giant bamboos in the world. Their potential and possibilities are being studied in the frame of the project "Development of Bamboo fibre composites".

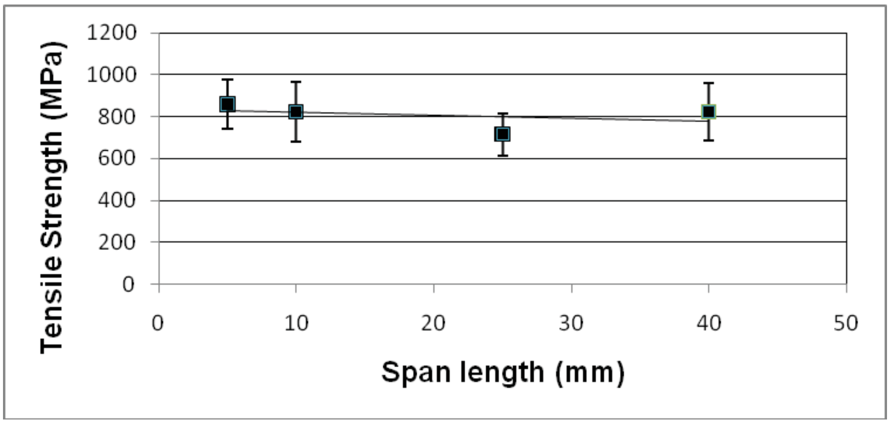

Figure 1: *Tensile strength of technical bamboo fibres at different span lengths.*

Mechanical properties of technical bamboo fibres have been studied with values of strength of 800 MPa and E-Modulus of 40 GPa, proving the excellent tensile properties of this material, Fig. 1. For this reason, our efforts are focused in making this fibre suitable for its use as reinforcement in composite materials. To achieve this goal the study of the morphology and microstructure of the elementary fibre and the technical fibre (Fig. 2) is a necessary step as part of the understanding of their performance under tensile stresses and their performance as reinforcement in a polymeric matrix.

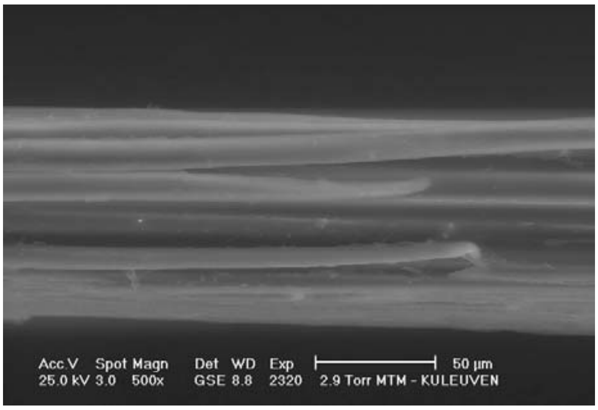

Figure 2: *Surface morphology and diameter of* Guadua angustifolia *extracted technical fibres.*

The relation between the bamboo fibre morphology and microstructure with the mechanical properties are being studied as well as the failure modes under tensile stresses as one of the stages in the development of bamboo fibre composites.

An Experimental Study On Repetitive Slamming Wave Impact On Deformable Composite Structures

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Fibre-reinforced polymers (FRP) are applied more and more in marine constructions, e.g. sailing yachts, catamarans and high speed crafts. The use of FRP involves important advantages in comparison with more convenient materials (e.g. steel) in marine applications. Corrosion resistance, limited maintenance, a long life time, low weight and sometimes a lower cost are the main motivations for ship constructors to use FRP.
Untill a few decades ago, marine composite structures were designed very stiff and quasi rigid, to resist the slamming wave impact. Slamming wave impact, seen as the most important load that marine structures encounter, is characterized by high local peak pressures (up till 10 bar and more) with a very short duration (typically millisconds). Figure 1 shows the water slamming on a speed boat. Nowadays, due to the continuous striving for less material and less weight, the structures have evolved to thin-walled and deformable components. At one hand, this deformability leads to a reduction of the peak pressure during water impact which is basically a good thing. But at the other hand, fatigue damage (e.g. delamination) and final failure can be induced in the composite structure due to repetitive deformation as the structure encouters repetitive wave impact.

Figure 1: *Speed boat slamming on the water surface.*

Figure 2: *Experimental test facility.*

In this research, an experimental test facility has been built to investigate the influence of the deformability of the composite structure on impact pressure and damage growth. Automation of this test facility makes it possible to perform repetetive tests without manual intervention, and to control the impact velocity. The facility consists of a stepladder which is fixed at one end to a rotating shaft which, on its turn, is connected to an electric motor. A controlling unit regulates the motor and ladder motions. At the other end of the stepladder, a test object is attached which is forced into a water bassin as the ladder turns downwards. Figure 2 shows a picture of the test facility.

To create an initial idea about the influence of the deformability of the composite structure on impact pressures, tests with a full rigid cylinder and a hollow deformable cylinder have been performed and compared. In both cases the pressure signals showed a very high and short pressure peak. In contradiction with the prospections, the average peak pressure measured for the deformable cylinder was comparable to the the peak pressure measured for the rigid cylinder (5.17 bar versus 5.35 bar). However, conclusions can not be made since there is too much scatter on the results (standard deviation: 2.31 bar versus 1.51 bar). Too low sampling rate of the data acquisition system (51 kHz) might be the cause for this scatter. New results with higher sampling rate have to be carried out to draw conclusions from the slamming tests.

Manufacture Of Composite Sub-Structure Repairs For Aircraft Structures

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For the Royal Netherlands Air Force (RNLAF) the F-16 replacement and NH-90 helicopter will be the first all-composite aircraft. When these aircraft become operational a Structural Repair Manual (SRM) is the guideline for repair, which limits itself to small damages at undisturbed surfaces. In-house knowledge on composite repair needs to be obtained by the RNLAF.
The fighter-like F-16 replacement consists of a highly loaded monolithic structure contrarily to the helicopter which consists of a less high loaded sandwich structure. For the fighter-like structure stealth capability and repairing a high temperature BMI system make it very difficult to design repairs without access to all data. The helicopter-like structure does not have stealth capability, does not need to be completely flush, is not made of a BMI system and more data is available to base the repair design upon. The last advantage leading to the decision to focus on the helicopter is that the NH-90 becomes operational within the Netherlands in several months.
Looking at a helicopter design this air vehicle roughly consists of two components; a tail and a fuselage. The tail panels are only accessible from the outside with limited access from the inside. Fuselage panels are always accessible from both sides. The most difficult case from repair point of view was selected for this thesis, i.e. the generic benchmark panel based upon the tail structure. This generic benchmark panel consists of two sandwich structure sections chamfered down at the ends and in the middle to attach an L-shaped rib.

Figure 1: *Aircraft Battle Damage Repair*

For the damage to repair it is stated that when a through penetration of the complete structure can be repaired sufficiently, a non-through damage would not lead to any additional problems. The damage was therefore chosen to be a through penetration of all structural components. A one inch hole with on both sides half inch cracks was applied at the most unfavourable location; through the rib foot and web and all components of the sandwich structure.
The location of this damage falls beyond the scope of the SRM leaving the operator with only two options: repairing the aircraft directly in-field with a fast, simple Aircraft Battle Damage Repair (ABDR) or repairing the aircraft in the

controlled environment with a sophisticated depot repair. ABDR can be performed on different levels related to the situation the aircraft is at. For this thesis ABDR repair indicates the situation in which the aircraft is in-field but with some time to place a patch.
The goal of the ABDR repair is restoring strength in order to bring the aircraft back to an environment in which it can be repaired properly with an expedient or depot repair. For the ABDR repair an aluminium patch is designed and riveted against the damaged area. Again availability of time and severity of the situation defines whether improvements (i.e. adhesive film and crack stop holes) are applied. This repair showed first damage propagation during test at 230 [kN] which is higher than the first damage occurring in an unrepaired panel which was observed at 190 [kN]. For final failure the value for the unrepaired panel is 225 [kN] and for the ABDR repaired panel no final failure occurred but it is expected to be close to 300 [kN].

Figure 2: *Depot repair*

The depot repair is a restoration of the original structural components and their load paths based upon restoring strength and stiffness for the remaining lifetime. For the depot repair first the damage is removed and the area is prepared by means of step sanding. After this the rib is repaired by means of a doubler after which the sandwich structure is repaired. This repair showed no damage propagation and finished the test at 300 [kN], the end of the test bench' range.
Comparing the xy-strains of both repairs show equally good repairs for the ABDR and depot repair in terms of global stiffness. No stress concentrations are created and no load is redistributed around the damaged area. Strain levels very close to the crack tips are higher but the global strain level indicates that the ABDR patch is not attracting load. In terms of strength the depot repair definitely outperforms the ABDR repair. Would the ABDR repair be redesigned to offer equal strength, then this would result in a stiffer patch. Note that this is the result of a static tensile test and does not give any result for fatigue behaviour.
Evaluating the repairs both seem to be cost effective; scrapping the component or consulting the Original Equipment Manufacturer (OEM) are the other options. For direct use several steps still need to be taken; the repairs need to be tested according to a qualification programme agreed upon with the international design organisation or national design organisation (the Military 21 design organisation) and airworthiness authority (in this case the Military Airworthiness Authority).
During the further process it is advisable to follow techniques which appear in damage removal and repair. Such techniques involve laser damage removal, the use of a Scarfing Tool for Automated Repair of Composites (STARC) but new techniques may become available in the near future making the repair process quicker, easier to perform or less technician dependent.

Tow Mechanics: Improving The Accuracy Of Deformation Modelling

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The mechanical properties of a continuous fibre reinforced polymer are determined to a large extent during the forming phase. The continuous fibrous tows deform geometrically. Knowledge of the tow orientation and tow deformation behaviour is essential to obtain the desired product quality in terms of e.g. strength and impact performance. Modelling efforts have so far been focused primarily on the macro (fabric) and meso (tow) scale [1,2]. A physically based model of tow deformation which includes information on the filament (micro) level can improve the accuracy of existing draping and forming simulation software.
A set of five mechanisms is determined to describe the deformation of fibrous tows:

1. **Tension:** A load is applied in axial direction with respect to the local tow or fibre axes.
2. **Compaction:** A load is applied perpendicular to the longitudinal axes of the tows or fibres.
3. **Bending:** A moment is induced in a tow or fibre section (the case of tow bending behaviour is described in previous work [3]).
4. **Twist:** Torsion due to a relative rotation between two locations is applied along the longitudinal axis on the tows or fibres.
5. **Shear:** A load is induced by a relative displacement of two parallel planes, which remain parallel during and after the displacement.

Friction plays a role in all the mechanisms, with effects on macro, meso, and micro scale. The determination of the involved friction coefficients of the tows and fibres with respect to each other and mould materials such as tooling steel is necessary to accurately predict the tow deformation in the dry and impregnated fabric. Current research in this project is focused on determination of the frictional properties on meso and micro scale.
The friction coefficient on meso scale is determined experimentally by means of a fibrous tow specimen (glass or carbon fibre) on a rotating drum. This capstan type experiment relates the friction coefficient μ to the tensile forces T_0 and T_1 in both ends of the tow specimen, which is wrapped around the drum under pre-tension over an angle of π radians, see figure 1.
Preliminary results (see figure 1) are obtained by using Amontons' law (1). The test was performed for a combination of a 12k carbon fibre tow and a PVC cylinder rotating at 12.8 min^{-1} (reference measurement);

$$\mu = ln\left(\frac{T_1}{T_0}\right)\frac{1}{\pi} \tag{1}$$

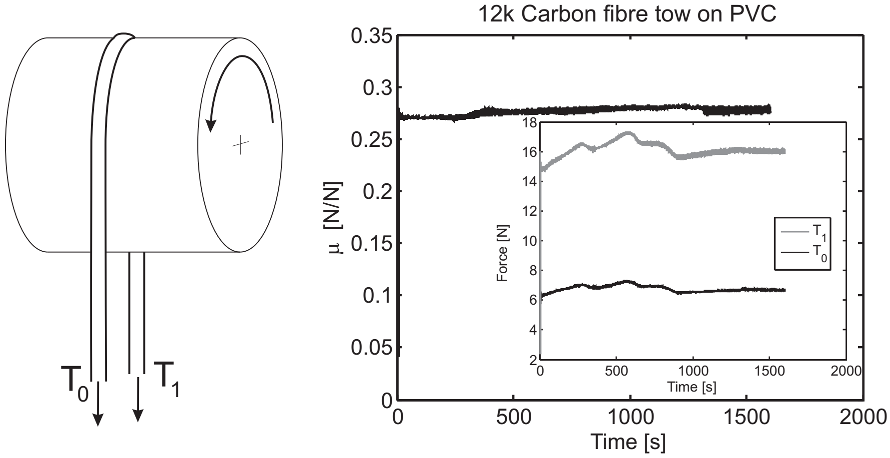

Figure 1: Outline of the capstan friction experiment and preliminary results

The dependence of the coefficient of friction on the rotational speed of the drum and the applied pre-tension on the tow specimen are subject of investigation. Robins et al. [4] performed Capstan friction tests with single carbon fibres (among other materials) and did not find a dependence of the friction coefficient on the rotational velocity of the drum. Nevertheless, this independence has to be verified for tow specimens as well, since the behaviour of those materials is not necessarily the same as that of the individual fibres. The sizing with which the tows are treated for better handling and adhesion to the matrix can play a significant role in the determination of the measured friction coefficient. The use of eq.(1), based on Amontons' law, implies a contact area independent friction behaviour. This assumption will be verified for the fibrous tow friction coefficient.

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Bamboo Fibre Thermoplastic Composites For Structural Applications

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Natural fibres are becoming a real alternative for the transport sector thanks to their green nature, low density, and in some cases better specific mechanical properties (normalized to material density) than glass fibres. Thermal conductivity of natural fibres is low; therefore they make a good thermal barrier. Low cost, inexhaustible supply and good environmental performance, make natural fibres possible substitutes to synthetic reinforcing fibre materials, especially for polymer matrix composites. In spite of these advantages, their performance with thermoplastic polymers has not been good enough and more scientific research is needed to bring natural fibres to the market of structural components. Bamboo fibres represent one of the most attractive natural fibres because of their availability and excellent mechanical properties; in this project, long bamboo (Guadua angustifolia Kunth) fibres are studied to be used as reinforcement in both continuous thermoset and thermoplastic composite materials (Fig.1).

Figure 1: *Unidirectional bamboo fibre composite with thermoplastic matrix.*

Single fibre properties show that the specific E-Modulus can compete with glass fibre and the specific strength is only 10% lower, these good properties are the result of a novel mechanical extraction process developed at K.U.Leuven that preserves the intrinsic properties of the fibre (Fig. 2).

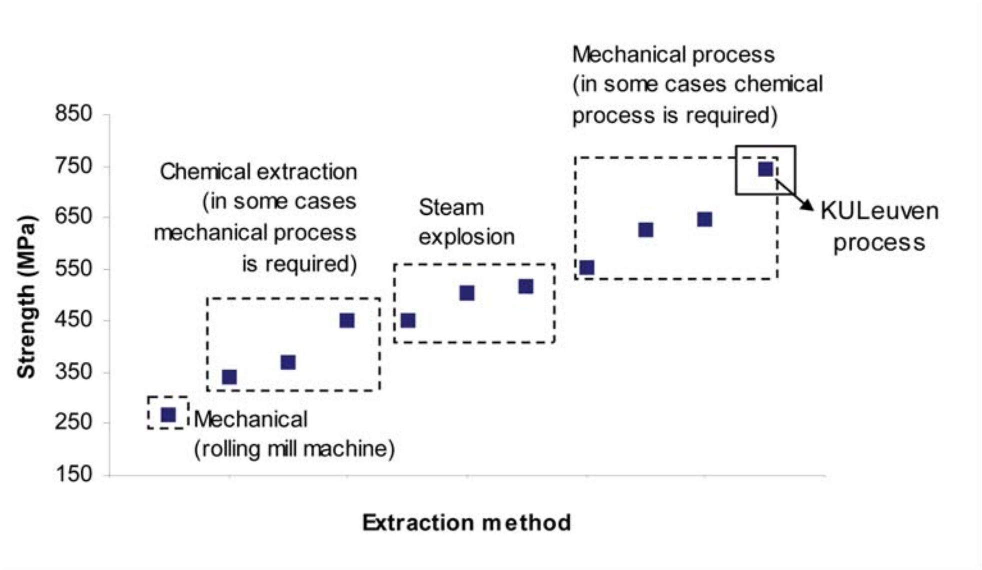

Figure 2: *Strength values vs extraction method for single bamboo fibres.*

In spite of these properties, it was found that thermal degradation occurs at a relatively low temperature. For UD bamboo/thermoplastic composites, several variables such as temperature, time of exposure to the consolidation temperature, pressure and polymer type and rheological behavior are studied in order to optimize the composite properties. The partial results show a very promise composite in comparison to other natural fibre thermoplastic composites.

Using Microtomography And Numerical Predictions For The Investigation Of Failed Composites

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Materials comprised of two or more different materials with the properties of the new material being better than that of the components are called composites. The application of composite materials in the aerospace industry is growing rapidly. The materials are known for having outstanding mechanical properties per unit weight, giving possibilities for lighter aircraft, leading to higher efficiencies.
With the presence of composite parts in aircraft the possibility of accidents involving composite failures is created. Unfortunately the knowledge and experience regarding failure analysis of composite structures is lacking behind. Failure analysis is strongly dependent on techniques originally developed for metals, like fractography, investigating the fracture surface. The problem is that in composites much information at the fracture surface is destroyed during failure, making the failure analysis more difficult. Especially the discrimination between static and fatigue failures is difficult.

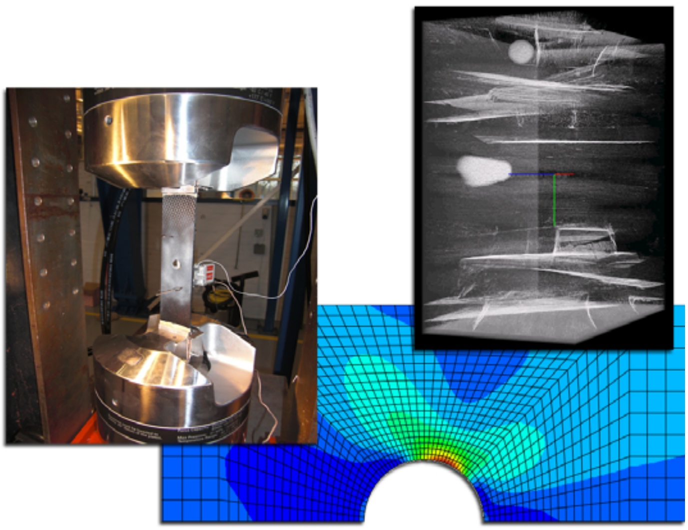

Figure 1: *For this work a threefold approach is used, consisting of mechanical testing, numerical modeling and investigation by microtomography.*

An opportunity lies in the fact that the failure not only affects the fracture surface, but a larger volume, that is not destroyed by the failure propagation. In this volume damage is present in the form of microcracks in the matrix. The present development of microtomography as an industrial tool for high resolution volume investigation makes it possible to observe matrix damage in the form of microcracks during a failure analysis.

The objective of this research is to investigate whether microtomography with or without finite element modelling is a complementary tool to find the cause of fracture during post-mortem analyses. It is investigated whether there is a difference in damage behaviour observable by microtomography for composites failed under different loading and environmental conditions and whether microtomography can be used to validate a finite element model based on damage. For this research carbon fibre/epoxy and carbon fibre/PEEK under static and fatigue loading are investigated for their behaviour at room temperature and at 100°C.
A difference in damage behaviour between a static-loading and a fatigue-loading history is observed by microtomography for unaged woven carbon fibre/epoxy and carbon fibre/PEEK tested at ambient temperature or at 100°C. Furthermore a difference between an ambient temperature and a 100°C loading condition is observed for unaged woven carbon fibre/epoxy tested in fatigue. Since damage is observed by microtomography for unaged carbon fibre/epoxy tested under static or fatigue loading at room temperature, carbon fibre/epoxy tested under fatigue loading at 100°C and carbon fibre/PEEK tested under static or fatigue loading at room temperature or at 100°C, microtomography can be used to facilitate the validation of a finite element model based on damage for these materials and conditions.
Putting it all together it can be stated that microtomography can be used directly to distinguish between unaged woven carbon fibre/epoxy and carbon fibre/PEEK loaded statically and loaded in fatigue at ambient temperature or at 100°C and can be used in combination with a finite element model based on damage to validate a stress analysis in order to find the cause of fracture during failure analyses in the cases where cracks can be found.

Automated Double Cantilever Beam test system – A two-axis moving camera setup controlled by image analysis for crack recognition

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Composite materials are increasingly being used in structural components in industries where weight and demanding mechanical properties are important design criteria. To meet these high industrial standards the research and development in composite materials is a significant part of the industry. With the development of new materials and production methods, the need for mechanical testing will be inevitable to define the mechanical properties of the composite material. The most common type of failure in laminated composite materials is the separation of individual layers; delamination or interlaminar fracture. The experimental determination of the interlaminar fracture toughness is generally done by the Double Cantilever Beam (DCB) test, for laminated composite materials first developed by Wilkins et al. [1].
The standard configuration of DCB specimen is shown in fig. 1. Load blocks are bonded onto the surface of the unidirectional laminated specimen, to secure the application of the load in a straight line. The initial delamination is introduced in the specimen by positioning a thin film at the mid-plane of the composite laminate during the production process. On one side edge of specimen a white paint is applied to ensure a high optical contrast between the laminate and the growing crack front.

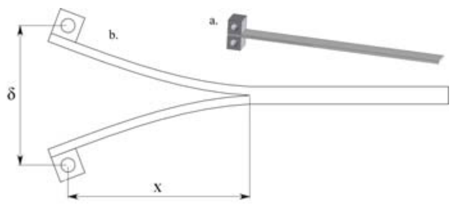

Figure 1: *Three dimensional view (a) and schematic diagram (b) of a DCB specimen.*

When executing a DBC test, following the common standard ISO 15024 [2], multiple parameters have to be recorded for the determination of the fracture toughness, GIc. Two data lines for the load and displacement of the specimen are directly extracted from the tensile testing machine and are relatively easy to record during the experiment.

A third parameter is more complex to determine, this is the distance from the load line to the crack tip, the delamination length, x (fig. 1). This research is focused on the identification and position of the crack tip.
The delamination length is currently determined at a limited number of points (typical 10-15) on the specimen by an observer moving a microscope along with the crack tip during the experiment. In the situation where no moving microscope is available the delamination length is measured in a post process at multiple pre-marked points on the specimen. Both manual methods have disadvantages; in the accuracy of the determination of the crack length, require a skilled observer and are time-consuming. To exclude the manual observation of the delamination length and thereby increase the accuracy and repeatability

of the test an automated test system is designed.

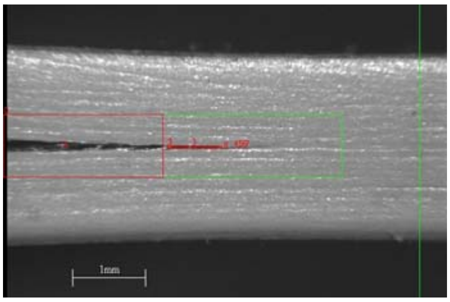

Figure 2: *Acquired and processed image of a DCB specimen at the crack tip.*

The hardware of the system consists of a CCD camera mounted on a two-axis linear actuator controlled by a stepper motor for each direction. This setup is mounted behind the tensile tester perpendicular to the mounted specimen. With the macro zoom lens fitted on the camera a meso-scale image of the side edge of the specimen is acquired with an image size of approximately four millimeters in height, see fig. 2 for a typical acquired image.
The processing of the acquired images is done real-time in the NI Labview platform at a rate of one frame per second. In this cycle the individual image is converted to a binary image by a threshold operation and a Region Of Interest (ROI) is defined. Within the ROI an object detection is executed, combined with the set boundary conditions for ia. minimal object size and contrast ratio, multiple dark objects are identified. In fig. 2 the red objects are numbered within the green ROI square. The object with the largest x-coordinate is selected as the location of the crack initiation. The coordinates of the crack tip are used to update the camera position every cycle. The delamination length is obtained by the current camera position and the crack tip coordinates in the acquired image.
Experiments with the operational system have been performed with thermoplastic composite (CF/PEI) laminates with good results. A significant improvement is made compared to the manual analysis; the interlaminar fracture toughness is determined at every data point (1Hz) and is not limited to a number of manual observations. The automated system has been compared to a manual analysis for a single specimen, first automatically tested and post-processed manually. The automated system has a tendency to underestimate the delamination length, caused by the conversion to a binary image in the first step of the process. This is related to the limited number of available pixels of the used camera compared to the height of the crack opening at the tip. The height of the crack-opening near the crack tip is possibly less than one pixel and therefore information is lost by the threshold operation.
Continuous research will involve performing automated DCB experiments on thermoplastic laminates, the acquired data will be used to improve and quantify the system. The automated DCB test system should contribute to the reliable and time efficient execution of delamination toughness experiments in academic and industrial environments.

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Numerical Investigation And Comparison Of Slamming Loads On Rigid And Deformable Cylindrical Structures

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Keywords: Slamming, rigid cylinder, deformable composite cylinder, fluid-structure interaction, Arbitrary Lagrangian-Eulerian (ALE)

Since the inception of the composite materials in the field of marine applications, there has been an ever increasing demand for more cost efficient, and low weight composite structures. Design of Wave Energy Convertor(WEC) is one of those fields where it has become very important to make the structure deformable to control the cost as well as material usage. Deformable composite structures not only reduce the cost and weight of WECs but also help in controlling the local peak pressures that are induced on the structures due to slamming loads. Figure 1 shows very high local peak pressure incident on a rigid cylinder that lasts only for a short duration of time. As a part of this study, numerical simulations of slamming loads on both rigid and deformable cylinders have been performed using both explicit and implicit methods to quantify the variation in the peak pressures incident on WEC. Numerical simulations include fluid-structure coupling using an in-house code for coupling between black box flow and structural solvers and commercially available Arbitrary Lagrangian-Eulerian (ALE) code. Figure 2 shows the pressure contours with the pressure peak moving along the cylinder surface.

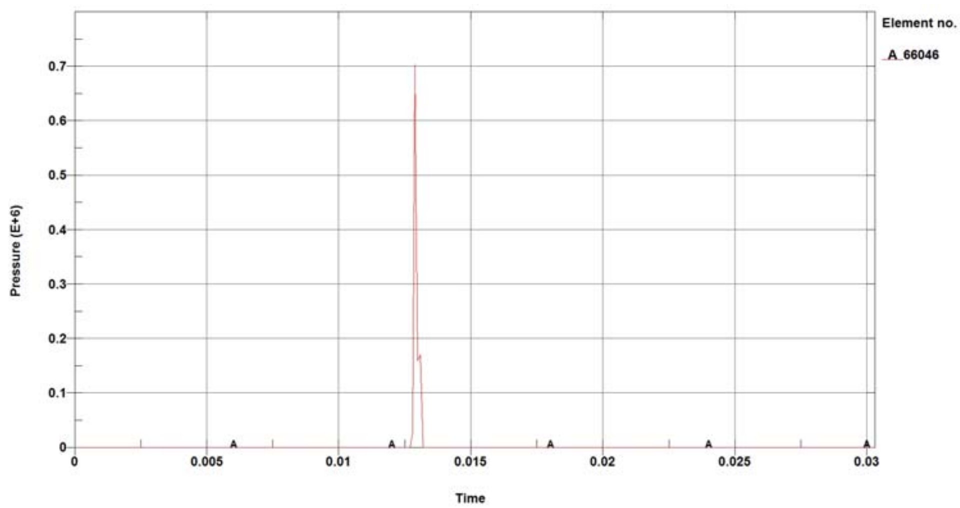

Figure 1: *Pressure Vs Time plot for the element with highest pressure peak.*

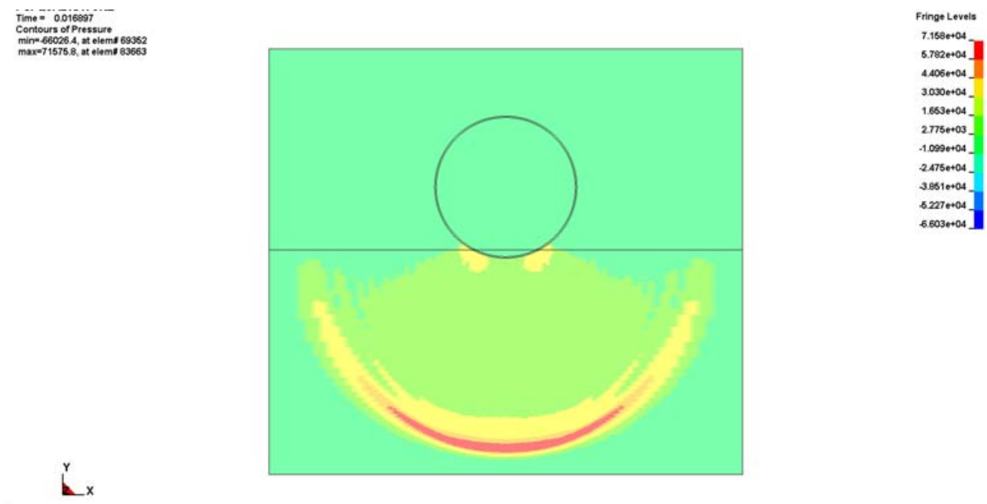

Figure 2: *Pressure contour at a given time step.*

Self-Reinforcing High performance Polymer Coatings For Aerospace Applications

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Keywords: Liquid crystalline polymers, thermoset, adhesion, chemical resistance, thermal spray.

Commercial Liquid crystalline polymers (LCPs) are known for their outstanding properties compared to other high performance polymers. These properties include superior fracture toughness, dimensional stability, chemical resistance and barrier properties over a wide temperature range [1]. These properties are mainly due to the formation of a highly ordered mesomorphic phase; a phenomenon known as self-reinforcement. Commercial LCPs have been applied in (for example) bulletproof jackets and high precision injected parts for electronic devices. As LCPs are chemically inert, the adhesion strength when adhered to a metal layer is usually quite low. Therefore, they have been unacknowledged as coating materials. Vectra^{TM} is one of the most studied thermoplastic LCPs. Several authors have focused on the enhancement of its adhesion for applications like packaging or as printed circuit boards [2], with limited results. In addition, they can only be dissolved using hazardous acids, and thus, coatings can not be applied from solution. Therefore, melt processing or powder coating techniques need to be considered.

Novel liquid crystalline thermosets (LCT) consist of low molecular weight Vectra A type backbones (oligomer) terminated with reactive aryl-ethynyl groups. Like traditional thermoplastics, these LCTs can be melt-processed within a wide temperature window. Further heating above the cure onset temperature induce chain extension and crosslink chemistries compatible with the liquid crystalline mesophase, which fix the structure and form a tridimensional polymer network [3].

Our objective is to develop a coating process suitable for these new high performance LCTs, and to study their performance in relation to specific requirements from aerospace applications. LCT coating layers with a thickness of 25μm and 80μm were applied on grid-blasted Aluminum by melt pressing the polymer inside a mold. Thermal, topographic and tribological properties of these coatings were investigated. The effect of moisture and aggressive environments on the mechanical and physical properties of the coating was also studied and compared to the performance of commercial LCPs. The findings show that these LCTs exhibit the chemical resistance of traditional LCPs, but with high adhesion strengths similar to those of structural adhesives.

In addition, our research also focuses on the application of LCT coatings by thermal spray, a versatile coating technique compatible with industrial production lines.

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Energy Release Rate Concept Validation On Delamination Behaviour Of A CFRP Wet Lay-Up Scarf Joint Repair

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Today, aerospace composite structures seem to be certified according to approaches similar to safe life, using no growth concepts, which means a significant drawback in terms of optimal design and structural weight. To fully explore the potential of these types of materials, similar damage tolerance approaches as being developed for metallic structures should be developed for composite materials. Another driver to obtain knowledge and understanding of fatigue and damage tolerance properties of composite materials should be safety. Without understanding and the ability to predict the damage growth mechanisms of a material, proper safe application will not be possible.
Recently, a generic concept has been proposed to predict delamination growth which is based on the Energy Release Rate (ERR). The first validation activities on fibre-metal materials show promising results. The purpose of this study is to show that this generic ERR based concept is also valid for composite applications. Hereto a specific composite application has been selected for which the validation will be performed.
The selected application is a 2 dimensional representation of a CFRP wet lay-up scarf joint repair. That is a joint between a pre-impregnated plain weave carbon fibre fabric 180°C curing epoxy system and a wet lay-up system of identical fabric with a room temperature curing epoxy. Both laminates have lay-up $[[\pm 45,90]_3]_S$ and the repair plies are applied such that all plies end at the scarf interface surface.
To predict the delamination behaviour of the selected application an analytical ERR based model is proposed which will be validated experimentally. The relation between delamination growth (dadN) and the effective ERR (ΔG_{eff}) has been determined by experiments with mode I and mode II type specimen. For mode I the standard DCB test has been used. Mode II has been tested using a tensile type test at which two butt-jointed plates are connected by symmetrical application of continuous plies at both sides at which the initial delamination has an H-shape.
It will be shown how the proposed approach agrees with the experiments. With this approach one should be able to predict delamination behaviour requiring an analytical ERR model and relatively simple mode I/II tests only.

Route Ermelo – Nijverdal

Addresses

Conference centre Dennenheul
Paul Krugerweg 45
3851 ZH Ermelo

Ten Cate Advanced Composites
Cambellweg 30
7443 PV Nijverdal

Route description

- Leave the conference site and turn right twice to reach the main road (Putterweg, N303.
- Turn left on the Putterweg.
- Continue to the second roundabout and take the first exit of the roundabout (Leuvenumseweg, N796).
- Follow this road to the end and take the first exit at the roundabout (N302, Flevoweg).
- Follow the N302 till you arrive at the highway A1/E30. Take direction Deventer/Apeldoorn.
- Follow the A1/E30 up to exit 27 (Markelo, Holten-Oost). Turn left in the direction of Holten.
- At the next junction, turn right in the direction of Rijssen (Rijssenseweg, N350).
- Follow the N350 into Rijssen untill the large roundabout and take the second exit (turn left) in the direction of Nijverdal/Hellendoorn (N347, Morseweg).
- Follow the N347 in the direction Nijverdal/Hellendoorn (few roundabout and 1 leftturn).
- Shortly after the second roundabout in Nijverdal, the round bends to the left: turn right here into the Rijssensestraat. This is the third street after the roundabout (Rijssensestraat).
- Turn right at the end (Constantijnstraat).
- Go straight at the traffic lights (G van der Muelenweg).
- The second street to the right is the Campellweg. Follow this street to the entrance of Ten Cate Advanced Composites.

Complete Route

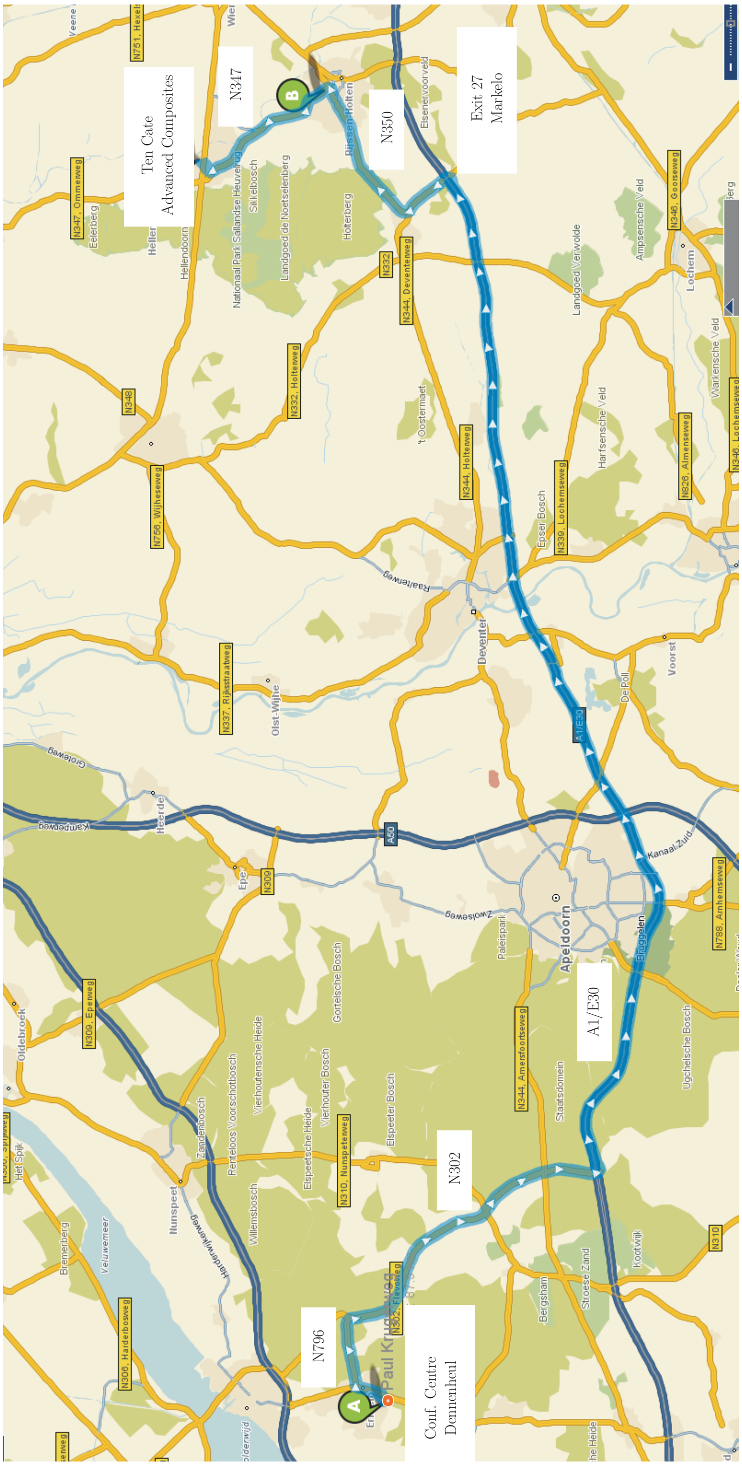

Figure 1: *Complete route Ermelo – Nijverdal.*

Detail Ermelo

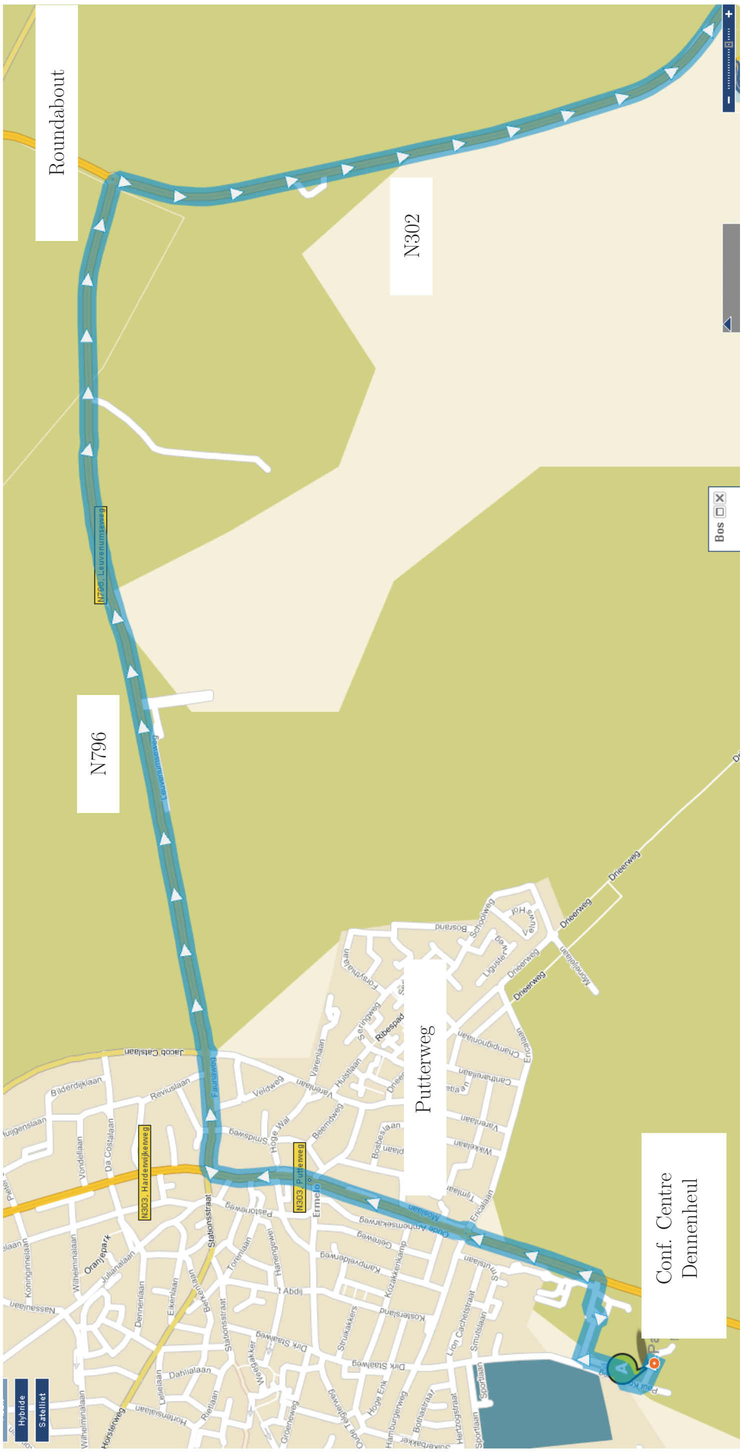

Figure 2: *Detail of the route in Ermelo.*

Detail Nijverdal

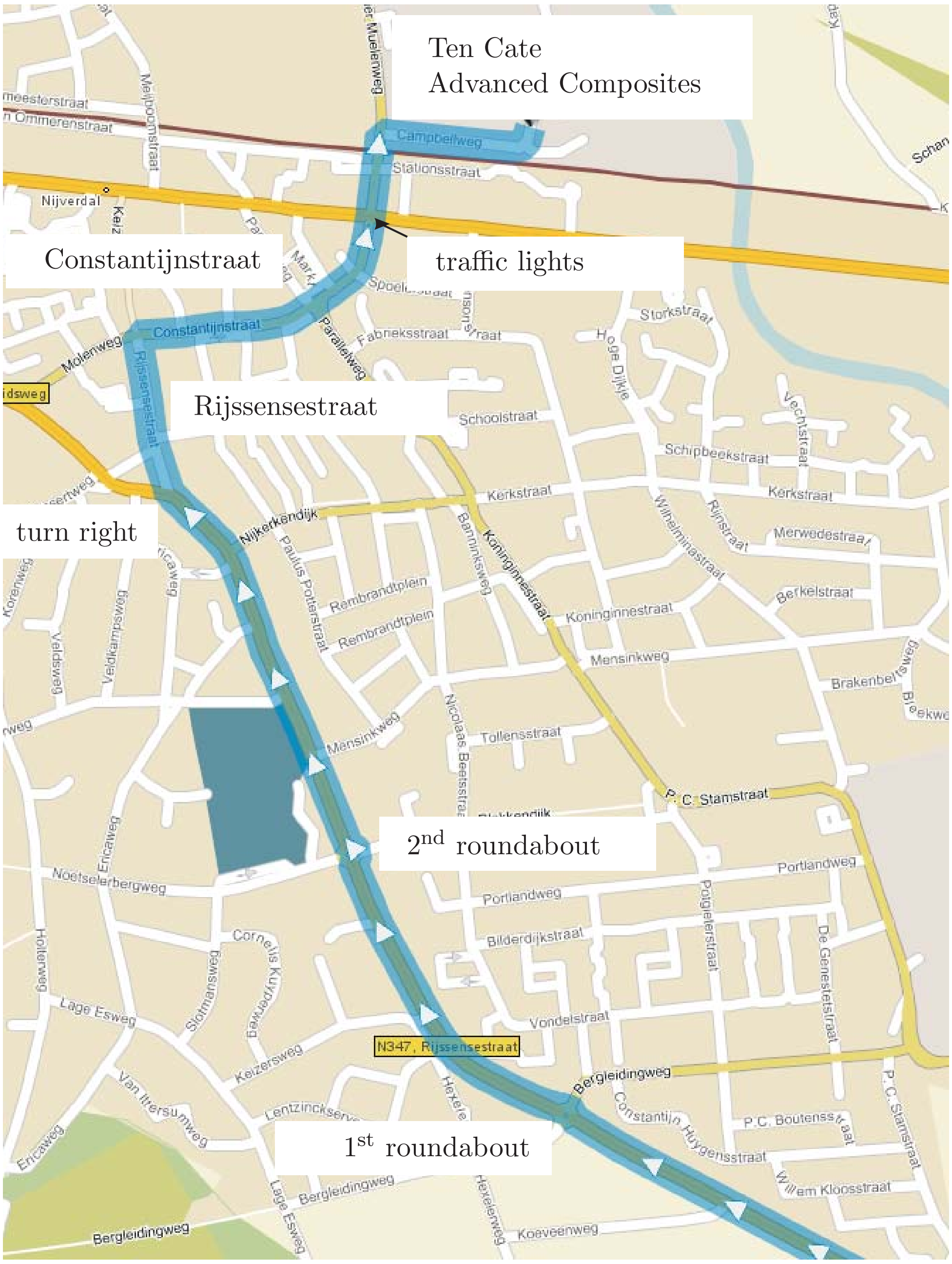

Figure 3: *Detail of the route in Nijverdal.*

Winners

The jury of the 8th SAMPE BENELUX Student Meeting is pleased to announced that the prize for the best presentation is awarded to:

Gustavo Guerreiro

Delft University of Technology,
Faculty of Aerospace Engineering
Structural Integrity and Engineering Mechanics

He is invited to represent the Benelux at the SAMPE EUROPE Student Conference preceding the 31st SAMPE EUROPE International Technical Conference. His abstract can be found on page 33 of this Book of Abstracts.

Secondly, the jury has decided to propose:

Eduardo Trujillo

Katholieke Universiteit Leuven
Department of Metallurgy and Materials Engineering

as a candidate for the JEC award. If granted, he will also participate in the SAMPE EUROPE Student Conference. His abstract can be found on page 25 of this Book of Abstracts.

The jury congratulates the winners and wishes them good luck at the SAMPE EUROPE Student Conference.

Richard Loendersloot

On behalf of the SAMPE BENELUX Student meeting jury:
Adrie Kwakernaak
Ariean Koelewijn
Jeroen de Vries
Marcus Kremers
Peter Joosse
Arnt Offringa