

SYNTHESIS REPORT

Contract n° : BRST-CT98-5501

Title : Chassis Structures Resistant to Multiple Impact and Crash

Project coordinator: Centre of Lightweight Structures TUD-TNO

Partners: Joost Boxoen Kartsport BV
Stratime Systemes
Alchemie Ltd.
Delta Racing BV
Flanders Indoor Karting NV
IDN Concepts BV

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1. Summary

Keywords:

composite chassis structure, energy absorption, durability, safety, full scale impact tests, FEM-analysis

Abstract:

In a multidisciplinary co-operation, involving manufacturers, end-users, experts on crash, ergonomics and styling and the Center of Lightweight Structures [CLS] a composite chassis structure for a go-kart resistant to multiple impact and crash was developed.

The traditional go-kart is based on a very simple, welded steel tube frame, with a rigid rear-axle without differential. Good driving properties are obtained if the torsional stiffness is not too high. On the other hand high longitudinal bending stiffness and strength of the frame are also essential. With steel, flexibility and durability is contradictory. After driving with the kart for a few days, many impacts have often deformed the frame, and laborious adjusting is necessary. Thicker tubes improve durability, but cause poor driving properties.

With a composite design, all properties of strength, longitudinal and torsional stiffness can be tuned better. Secondly, most composite materials can absorb more elastic energy than metals. Deformations are larger, but they are fully elastic, there is no permanent deformation

Finally, there are motives of manufacturing to change the design. Assembly of the welded steel frame is a laborious man-hour consuming process. A single composite platform, integrating many functions saves parts and assembly work. Therefore a new chassis has been developed, based on glass fibre reinforced polyester. The high elastic strain level of fibre reinforced plastics, in combination with high strength and orthotropic material properties allow for a highly optimised structure. The freedom in shape of the RTM-method, providing integration of many functions, makes that for this application composite materials have a high potential.

The structural and functional requirements resulted in a tailored sandwich ring structure, in which most of the material is put along the outer contour of the chassis. The RTM technique enabled the manufacture of this complex structure which is a symbiosis of structural (moment or inertia), functional (bumper suspension), manufacturing (draw angle) and styling aspects. Also a new type of bumper system was developed which is attached on all sides of the chassis. It is based on a resilient PE foam core surrounded by a rotation moulded cover. Full scale crash tests showed an enormous improvement of the impact absorption behavior.

The project was concluded with a functional prototype which enabled driving tests. Driving properties with this model were very satisfactory.

2. Consortium

SME partners

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Joost Boxoen Kartsport, the prime proposer, is a young Belgium company with 20 employees whose core business is the development and manufacture of indoor karts. JBK is growing fast. The annual turn over almost doubles each year. The karts were first sold in Belgium, the Netherlands, Germany and France. Last year JBK started selling karts outside of Europe.

Within the project JBK was responsible for:

- the input of karting experience, market requirements and product definition
- the assembly of the kart

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Stratime is a company that manufactures composite components. One of their major techniques is RTM that enables closed mould production of structural parts such as body panels for cars.

Within the project Stratime was responsible for the manufacturing process, the manufacture of the moulds and the chassis prototypes.

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Alchemie is a company with 30 employees. They develop and produce resins, silicones, waxes and vacuum casting materials. These materials are used in the manufacture and preparation of prototypes, resin tools, patterns, models, pre-production series and other plastic or composite parts. Alchemie serves industries like automotive, aerospace, model making, sanitary ware and tool materials. It has its own laboratory for quality assurance and material testing. In the project, Alchemie brought in their knowledge of resins.

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Delta Racing is a Dutch company with 12 employees whose core business is the exploitation of an official licensed indoor kart track. In this sense Delta Racing is a model representative of the end user of the karts. During the writing of this report, Delta Racing was merging with another kart track owner, 'de Stok' in Roosendaal, the Netherlands. In the project Delta was involved with the testing of the pilot models on the racing track and they had also an important input regarding market requirements and regulations.

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Flanders Indoor Karting is a Belgium company which owns and exploits the longest indoor kart race track of Belgium. The FIK kart track is just like Delta Racing in Holland a model representative of the end users of karts.

In the project their track and test facilities were used.

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IDN Concepts BV is a small Dutch engineering office and has experience in organizing and coordinating Research and Development projects mostly related to ergonomical products. In 1993 IDN Concepts was the prime proposer of a feasibility study called the SAHEP-project which was elected to carry the EUREKA-seal, an internationally recognised hallmark of excellence of the European Community.

Since 1994 IDN Concepts specializes in the development and the production of custom made office chairs, lift seats and adjustable working chairs, mostly to be used in the health care sector. Within the project IDN was responsible for the ergonomical design, such as chair, steering wheel and pedals.

RTD-performer

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The Centre of Lightweight Structures TUD-TNO is a joint venture between the Delft University of Technology (Faculty of Aerospace Engineering) and the TNO Institute of Industrial Technology. Legally CLC is part of the TNO Organisation.

The CLC has a large expertise in the field of advanced materials, lightweight structures, structural calculation, product development, durability and full scale testing. The laboratory has built an international reputation through various innovative product developments in sectors of transport, civil engineering and consumer goods.

TNO is the Netherlands Organisation for Applied Scientific Research, a fully independent R&D organisation with a staff of about 4600 and a total turnover of more than 350 million ECU a year. TNO's primary tasks are to support industry, the authorities and other groups of the community in technological innovation, and to assist clients in solving problems, look at www.CLC.tno.nl

In the project the CLC was responsible for:

- structural concepts of the chassis and energy absorption systems
- detailed design of the chassis, including calculations by FEM
- insert design
- choice material and manufacturing process
- tests on strength, stiffness and durability and implementation of results
- overall project coordination

subcontractors:

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denHartog & Musch is specialised in product innovation, concept generation, human factors engineering and the 3-D visualisation of complex design structures.
In the project the office carried out the over all design and styling of the kart as well as the adaptation of the chassis geometry to all other parts of the kart.

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TNO- Road Vehicles is a sister division of TNO-Industrial Technology. One of their expertises used in this project is crash management of road vehicles. Theoretical analysis and computational calculations of crashes (Madymo software) as well as full scale crashes in real practice can be carried out.
In the project TNO-Road Vehicles made crash simulations of the existing (steel) kart and the first composite concepts, they tested the energy absorption properties of the new bumper system and finally they carried out full scale crash tests with the first pilot model of the kart.

3. Technical Achievements

3.1. INTRODUCTION

Karting is a fast growing sport in Europe, the US and East Asia. The vehicle of this high thrill activity is characterised by its low-cost and simplicity. In fact the kart is not more than a steel tube frame with a seat, driving devices and a 'lawn mower' engine.



Fig. 1 : conventional recreational go-kart frame

Originally practised by a small group of hobbyists, it is now a recreation where people with different skills, young and old, enjoy themselves. This asks for a new approach. The kart-tracks are now a recreational business where safety should have the highest priority.

Secondly, for a track-owner the karts are the source of income, they are exploited 10 hours a day, seven days per week. In other words, the structure should be durable, resist dynamic loads and heavy crashes.

At present the chassis is a frame, built up out of a large number of steel tubes welded together, see figure 2.

Assembly is an laborious man-hour consuming process. This steel tube frame however, is not durable enough.

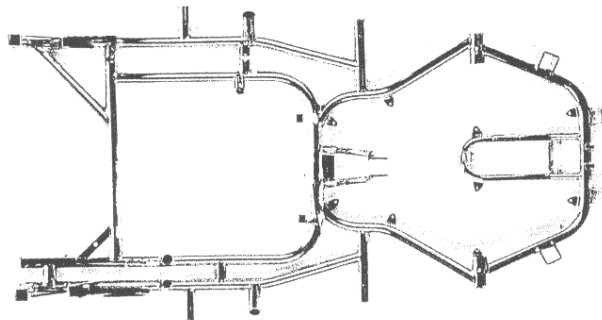


Fig. 2: steel tube go-kart frame

In recreational go-karting the chassis is involved in many collisions, causing unwanted deformations. Many maintenance hours are required to keep the go-kart in service. Thicker tubes improve durability, but cause poor driving properties because of lower flexibility.

Torsional flexibility is required in curves. The kart has a rigid rear-axle without differential which means that the rear wheels have the tendency to drive straight on. In

order to take a curve, one of the wheels (the inner rear) should be lifted a bit, while the front wheels keep their grip.

So, flexibility without permanent deformation is required. And this is one of the main fundamental differences between fibre reinforced plastics and metal. In the stress strain curve of composites and metals it can be seen easily that the ability of absorption of elastic energy is far better for composites because yield strength is better, while stiffness is lower.

The possibilities of composites were recognised by one of the bigger kart builders in Europe. In a two years R&D program, the Centre of Lightweight Structures [CLS] developed a composite chassis structure with the kart builder, experts on crash, ergonomics and styling and (end-)users. The program was funded by the European Commission and was called CHARMIC, an acronym of Chassis structures Resistant to Multiple Impact and Crash.

3.2. OBJECTIVES AND REQUIREMENTS OF THE COMPOSITE CHASSIS

The go-kart has grown from a hobby vehicle into a serious consumer product. In spite of that, requirements on production and durability and standards on safety did not keep in pace with that. The objective is to develop a new kart chassis improved on following items:

- **Safety.** During a crash the acceleration of the driver should be as low as possible.
- **Durability.** The life cycle of the present kart is restricted to only 1,5 to 2 years because of frequent crashes on the crowded racetracks that often result in deformation of the chassis.
- **Ergonomical and biomechanical properties.** Adjustment of seat, steering wheel and pedals to different sizes of people is a must.
- **Economic production.** The construction of the present kart is an assembly of many parts and joints. A more integrated body structure would decrease the cost.
- **Driving properties.** Also recreational, amateur drivers are becoming more critical on the driving behaviour of the kart in fast curves. Secondly, the steering must be light to become less tiring.

When the objectives described above are translated into a structural design of a composite chassis, one can list the following structural requirements that have to be fulfilled:

- **Torsional flexibility**
Experienced drivers have tested different karts with steel frames and it turned out that frames with a relatively high torsional flexibility (but not too high) have good road-holding in a bend. This torsional stiffness is used as the reference for the new composite frame.
- **Longitudinal stiffness**
This is required to withstand vertical loads. When driving up a hill, the acceleration of the driver may not cause too much bending, since the chassis is hanging only 4 cm above the ground.
- **Frontal impact**
The present kart has a plastic (PE) cover which is attached to the steel frame by bolts with some small rubber rings, so in a collision almost all energy is absorbed by

the steel frame. This induces high loads and high accelerations on the driver. In the new concept an energy absorbing bumper system is preferable. The shape and strength of the chassis had to be designed in accordance with the bumper. Assuming a frontal crash of 20 km/h and an available stroke of 150 mm to absorb the energy, the frontal load will be up to 40 kN

- **Side impact**

The present kart has a rotation moulded side protection, that can absorb a considerable amount of energy. Also a 10 mm thick PP graze plate that distributes the loads surrounds the kart. So, absorption of impact energy at the side is a smaller problem than on the front side

- **Other load introductions.**

The chassis is subjected to many different high loads introduced by parts such as seat, engine, brakes, steering wheel, roll-bar, axle bearings and last but not least the front wheel suspension. Critical case for this is a sharp bend at high speed and driving up and down a steep slope.

- **Durability.**

High peak loads as well as frequent lower loads must be considered. The complete load spectrum during 5 years (around 150,000 km) determines the required (fatigue) strength level of the chassis.

3.3. Concept Design of the Chassis

Main objectives that were relevant for the shape and general layout (conceptual design) of the chassis were the driving properties (torsional flexibility) and the way impact energy is absorbed.

The mechanical properties of composites are for both objectives in favour to those of metal, since the ability to absorb elastic energy is higher which can be seen in the stress-strain curve below: The absorbed energy without any plastic deformation is given by the hatched area in fig. 3.

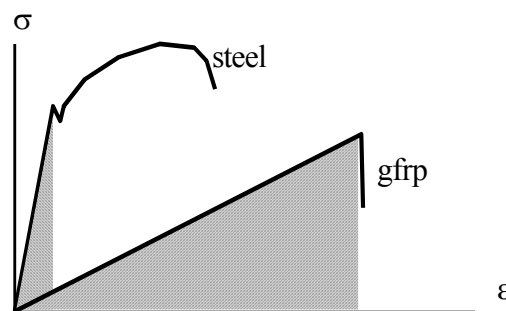


Fig. 3 Stress strain curve steel and composite

The present steel frames can be built very flexible and it then has excellent driving properties, but these frames are very vulnerable. Any collision should be prevented. When defining the global shape of the chassis, it should be considered that stiff elements are required to provide longitudinal stiffness, impact protection and different load introductions. On the other hand torsional stiffness should not be too high in order to provide good driving behavior. Torsional flexibility can be obtained by making the chassis 'waisted'. The waist of the chassis has a smaller width and therefore less differential bending stiffness.

With this in mind, a number of conceptual designs of the chassis were made, in which the use of sandwiches, beams and solid laminates and their dimensions were varied. Other motives that determined the choice of concept were the attachment of essential parts to the chassis like the engine and bumpers and the fact that a driver with its chair has to fit on the chassis. The shell type of structure is then preferred above the beam kind of structure since the bottom panel in the shell concept protects the driver's feet, and a shell type of structure is cheaper to manufacture than a beam structure. Following structural concept was chosen:

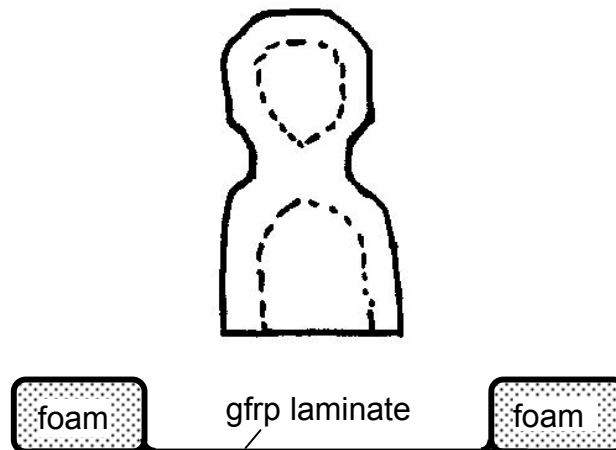


Figure 4. Concept design of the chassis

The cross-section of the beams is a symbiosis of structural (moments or inertia), functional (bumper suspension), manufacturing (draw angle) and styling aspects. The bottom plate is a solid laminate web, that is shaped for a seat position as low as possible and contains form elements for easy placement of the seat and guiding elements for lengthwise-adjustable pedals.

The chassis concept should incorporate possibility to deform in order to provide length along which energy can be absorbed. It is obvious that chassis deformation only is not enough and would cause too high accelerations on the chassis and driver. Additional bumper systems have to be added in order to increase stroke and to decrease forces. The design of the bumper is described in section 4.4.

3.4. STRUCTURAL DESIGN OF THE CHASSIS

Strength and stiffness properties of the chassis have to be calculated. Objective is a frame with the same diagonal stiffness and bending stiffness as a well-driving, flexible steel tube frame. Secondly, in the critical load cases, stresses have to remain below the critical design stresses.

3.4.1 Design process

In the development of the go-kart use was made of results of theoretical crash analysis and tests as input for structural analysis. The design process is visualised in the flow diagram of fig.7.

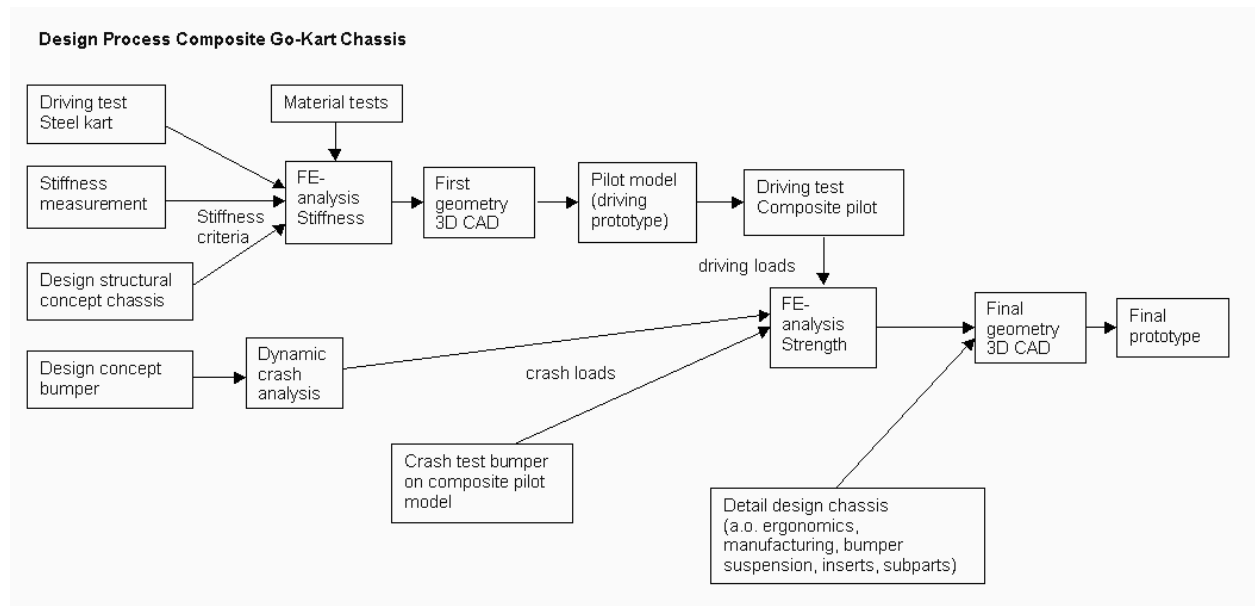


Fig. 7: schematised design process

3.4.2 First geometry and FE-analysis

Based on the structural concept the simplified geometry of the kart chassis was modeled in 3D CAD. This model was used as initial geometry model for the FEM-analysis, and modified to fit the stiffness requirement. The design torsional rigidity has been derived from measurements of a steel kart chassis with very good driving properties.

Within the FEM analysis the torsional flexibility of the platform is tuned by reducing the width at the midsection of the platform, and the height and width of the sandwich beams. The fibre orientation in combination with cross sectional area balance the torsional rigidity (cross sectional area and shear modulus) and the bending stiffness (moment of inertia and Young's modulus). Design stress data were derived from samples of the material as was used for the construction of the driving prototype.

FEA load case 1: torsional rigidity

The test set up, used for the measurements, is simulated in the FEM-model. A load of 40 kg is applied on the left front wheel, and the resulting maximum deflection of the front wheel suspension is taken as a criterion.

The sandwich chassis will be modeled as a hollow box, thus neglecting the contribution of the core. This simplification leads to a slight underestimation of the stiffness of the panel of approximately 20%. A modeled deflection of 12mm was taken as a target.

The first geometry was found to be too rigid. Tailoring of the chassis, or reducing the beam height at the waist, resulted in a weak center section. It was found that a tapering of the beam at the midfront was very effective: the deformation was spread more evenly, whereas before it was more concentrated at the waist of the chassis.

Fig 8 shows the effect of the tapering.

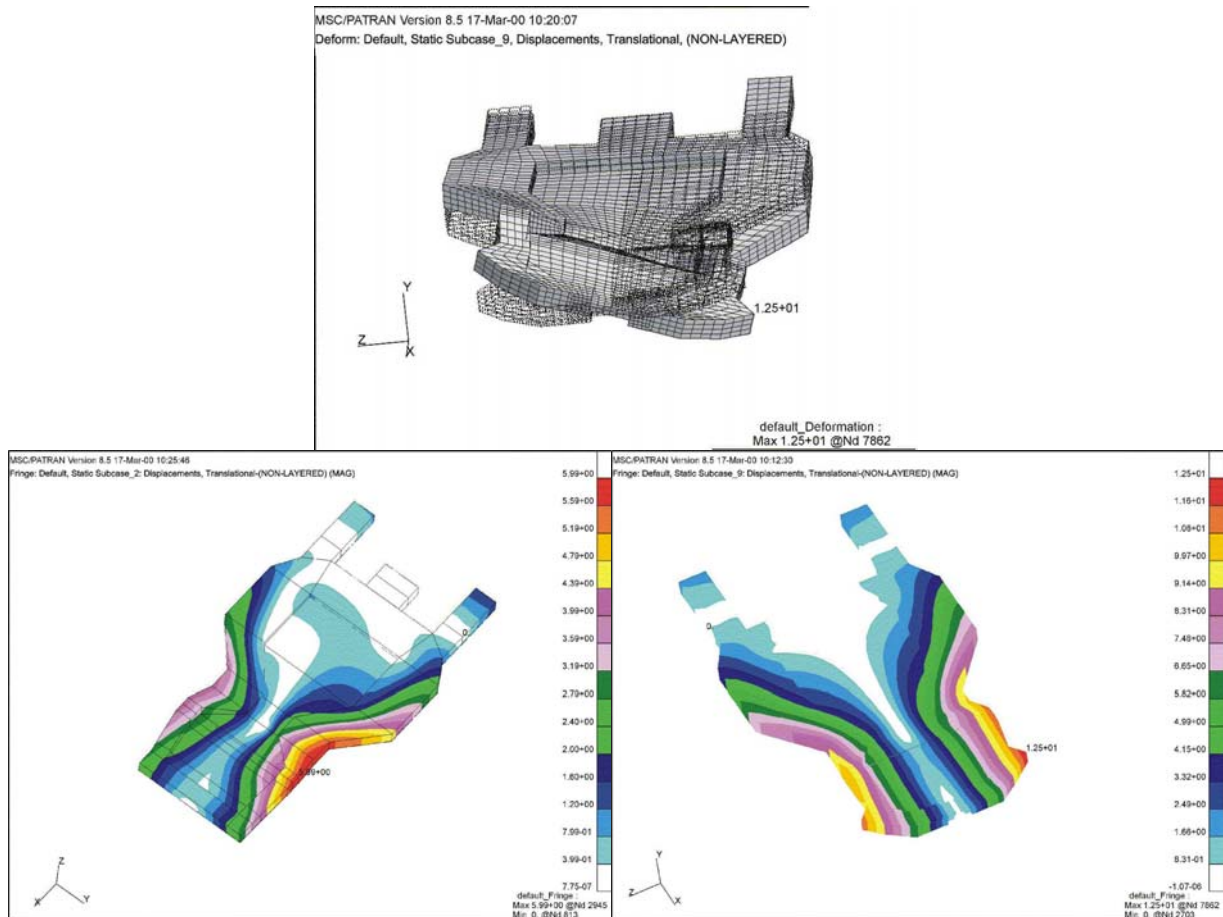


Fig 8: Deformation of the chassis without and with tapered section at the mid front beam

This way, the stiffness of the chassis was reduced effectively, without reducing the strength of the areas of high loads, i.e. the waist area and the wheel suspension. Other load cases investigated consider the deformation of the chassis when a person enters the go-kart and steps with one foot on the side beam. They were found to be not critical.

The resulting geometry is shown in fig.9 and 10 .The same 3D CAD model as was used for geometric input for the FE-analysis was used for production drawings for mould construction for the manufacturing of a driving prototype.This model does not yet include details regarding styling, ergonomic features or bumper attachment.

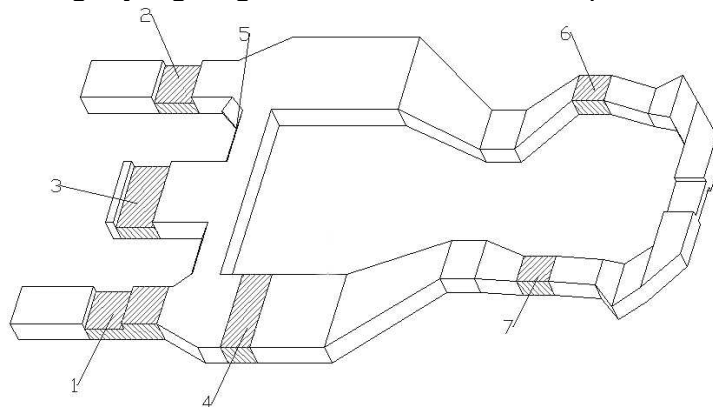


Fig. 9 geometric model with main inserts

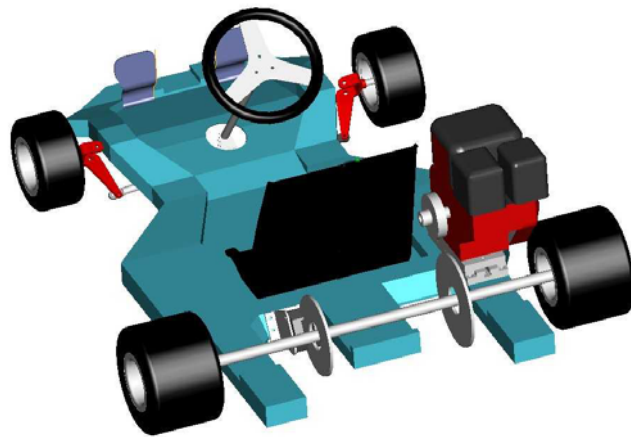


Fig 10. 3D CAD model

3.4.3 Pilot model and drive tests

A pilot model was produced with RTM. This model is used to investigate the driving properties (design verification) and to measure the actual driving loads, to be used in load case 2 of the FEA.

The driving loads are derived from driving tests on a representative go-kart circuit. The track included a large number of sharp curves and a viaduct, causing high loads especially on the front wheel suspension.

During the driving test, the loads on the chassis were measured using strain gauges and a datalogger. Highest loads were found to occur at the waist and at the frontwheel suspension. A spectrum of the driving loads is shown in figure 11.

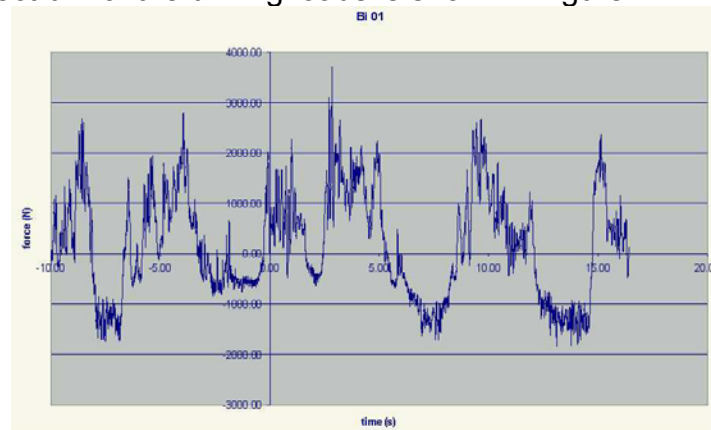


Fig. 11 typical load spectrum



Fig.12 go-kart with strain gauges

The peaks are the high loads when taking a turn. The occurring strains were compared to the torsion test measurements, and the FE-analysis. From this an estimate of the load on the front wheel is made. The maximum strain levels are around 0.2, which indicates that fatigue is unlikely to occur.

3.4.4 Bumper design and Dynamic Crash analysis (Madymo)

For the drivers safety it is important to keep his accelerations as low as possible during a collision. Secondly, it is preferred that energy is dissipated, and not elastically returned by spring back. If the kart would bounce back directly, accelerations would take longer and there would be a bigger risk of head injuries. There are several ways to dissipate energy without permanent deformation or failure, i.e. by friction, by hysteresis of material deformation or by hydraulic/pneumatic valves. A proven concept based on friction can be a cylinder with an oversized rubber piston. Energy absorption through hysteresis can be obtained with resilient foams.

For the kart bumper simplicity and low-cost are required, therefore it was decided to use the resilient foam concept. A foam filled box structure was designed as shown in fig. 13. The PE-box will be made by rotation moulding, for the prototype the box was welded out of PE-sheets.

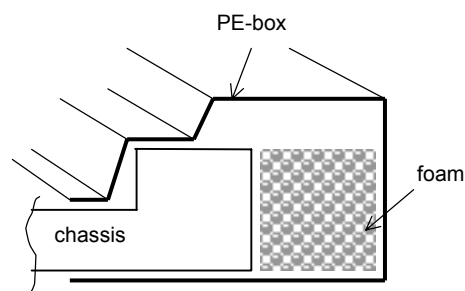


Fig. 13 Bumper concept

To further study the effect of the bumper on the response of the go-kart and the pilot, use was made of dynamic crash software: Madymo, a multi-body simulation program. The improved bumper system resulted in less jump-up of the chassis and lower peak accelerations of the pilot.



Fig.14: Madymo- frontal impact analysis

From this model, the peak loads acting from the wall on the chassis were derived and used as input for the FE-analysis. An impact of 20 km/h against a solid brick wall was taken as a reference. With the optimised bumper, a compressive peak load of 40 kN

was found. This load case is equivalent to a collision at much higher speed (40 km/h) into a flexible track side wall , such as a wall of tyres.

In this model an infinitely rigid chassis is assumed. The effect of the flexibility of the chassis was derived from the FE-analysis, and corrected for in the bumper deformation. The performance of the bumper was tested for both the side bumper as the front bumper. Fig. 15 shows the bumper prototypes in the test setup for the side impact test.



Fig. 15 side bumper impact test and bumper prototypes

The bumpertest was done with a second geometric pilot model. Both the side and front bumper were tested. The kart chassis was mounted on a carriage, and launched by a spring mechanism at a speed of around 25 km/h. Near the impact wall the chassis (with balance weight) is ejected, such that it can move freely. High speed camera's, load cells and strain gauges were used for data collecting.

The response of the chassis is used for model verification of the Madymo analysis (accelerations and loads on the chassis) and the FE-analysis (occurring strain levels at maximum frontal load). The chassis did sustain the test successfully.

3.4.5 Strength analysis : 2nd FE-analysis

For the same geometric model, a more detailed strength analysis was performed, using loadcases derived from the tests and crash simulation.

Load case 2: driving loads

A single vertical load is applied to one of the front wheels, whereas the other three wheels are kept in place. The occurring strains must be below the fatigue level of 0.4. The force on the front wheel was derived from the driving tests. Fatigue was found to be not critical. Still, fatigue tests will be performed to prove the durability of the chassis.

Load case 3: impact

The loads on the chassis are derived from the Madymo analysis that was used for the design of the bumper. From the bumpertest, a peak value of 47 kN was found. This load case is the ultimate load for the strength analysis of the chassis. Due to the curved shape of the front of the kart, high bending moments are introduced at the wheel suspension. At this area high normal stresses are found. Which is seen in fig.16:

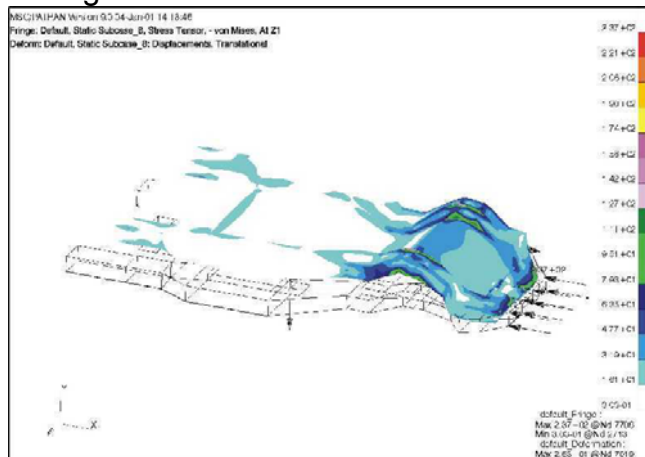


Fig.16: frontal impact: von Mises

It is noted that the high stresses are partly due to the simplified geometry and inaccuracies in the model. In the real product, round offs will reduce peak stresses. Also at the front wheel section a strong insert is present for introduction of the vertical wheel loads, which is not included. To improve the strength of the chassis at the front wheel suspension the beam height at the front section will be increased. Such local increase in stiffness will not affect the driving properties. Secondly, the front beam of the kart will be elevated. This way, the front bumper will be supported more symmetrically, and the bending moment on the beam of the front wheel suspension is effectively reduced.

3.4.6 Insert Design

Crucial aspect of a composite structure is the way in which high loads are introduced. The first step in the design is to define the magnitude and direction of the loads and to decide which path in the composite structure will be followed in order to realise a reliable load introduction.

In case of a composite shell structure with sandwiches incorporated, following considerations are important when introducing loads:

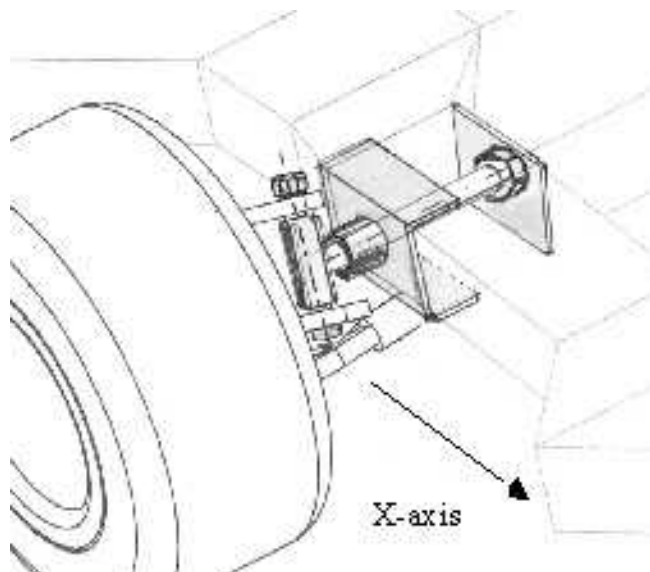
- Laminates should be subjected to loads in their plane only. In this way, high bending moments in the laminate are prevented. It is obvious that fibres are preferably oriented in the direction of the principle stresses, which means a +/- 45° orientation in case of shear.

- In plane load introduction should take place along a certain length or surface of the laminate in order to prevent high local compression and shear stresses in the laminate.
- Loads perpendicular to the laminate should be carried by flanges (laminates perpendicular to the shell) or by the core in case of a sandwich. Here it is also required to introduce the loads along sufficient surface.
- A bonded joint should carry shear loads only, peel stresses should be prevented.
- A hole in a composite laminate can carry bearing load but only under certain conditions:
 - 1) The laminate around the hole must have a quasi-isotropic orientation.
 - 2) The hole must be reamed to a perfect fitting to prevent high local compression stresses. This can also be done by an injection with resin after assembly
 - 3) The laminate should be clamped in order to prevent brushing (local failure under compression)
 - 4) The distance between the hole and the edge of the structure are another hole must be at least 3 times the diameter of the hole.If these conditions cannot be fulfilled, an insert is required. In a sandwich this can be for example a solid block of wood or metal that replaces the foam core. In case of a single laminate one would choose for a metal ring or flange bonded to the surface in order to transfer loads through shear instead of bearing.

Especially the front wheel suspension is a part of the chassis where high, dynamic loads occur. Its design is mainly determined by the vertical load with its resulting moment along the X-axis.

The vertical load has to be transferred from the wheel and the stub axle to the outer vertical flanges of the composite beam structure, while the moment is carried by both the inner and outer flange.

From a manufacturing point of view it is preferred to keep the foam core in one piece, therefore it was decided not to use a solid block in the beam as an insert. Instead, two steel parts were used for load introduction. One steel C-profile bonded around the outer vertical flange of the beam, and one internal steel plate besides the inner vertical flange. See figure 17.



3.5. MANUFACTURING

3.5.1 choice of technique

The foreseen series production of up to 10,000 pcs. is determining for the technology. Techniques like SMC (sheet moulding compound), GMT (glass mat thermoplastic) and RTM (resin transfer moulding) would be suitable.

Both SMC and GMT are techniques where a prepreg is moulded under high pressure. SMC uses a thermoset resin while GMT is thermoplastic. Typical products are shell structures with limited 3D geometry. Product area is often restricted to around 1 m² since heavy pressing machines are required. The flow of the prepreg has to fill the mould, therefore fibre volume content (V_f) is restricted to 25%.

If sandwich sections and/or inserts have to be integrated, and if a certain mechanical level is required, RTM is a more appropriate technique. Applied pressure is low (up to 8 bar) the product size can be larger and no pressing machine is required. The technique is not as fast as the pressing techniques, since fibre reinforcements are often put into the mould manually. But the V_f of the composite can be higher (up to 40% with fabric, up to 30% with CSM).

From the beginning it was likely that the chassis needed many inserts and a high mechanical performance, so RTM was the first choice of technique.

The chassis is a construction of laminates, foam cores and inserts. With RTM, the foam core and inserts are manufactured in advance and are then placed together with the dry fibre reinforcements into one of the two moulds. The set of moulds is then closed and resin is injected. For small series (prototyping) the foam core could be manufactured manually, but in series production it is economical to injection mould the foam pieces. So, in that case a separate set of moulds is required

3.5.2. Process development and mould design

Some manufacturing aspects had to be taken into account and determined the chassis design:

- Mats of chopped strands (CSM) are applied to improve the permeability.
- The shape is smooth and drapable with fabric and dischargable from the mould.
- Sharp corners must be avoided in order to place fibre reinforcements easily into the mould. Sharp corners had to be rounded off.
- The foam core and inserts were designed in a way that the foam core of the complete chassis is in one piece only. It means that only one injection mould for the foam is required.

Below, pictures are shown of the material placement and the RTM mould set:



Fig. 18. material stacking



Fig. 19. RTM mould set

The applied pressure during injection is around 4 bars. With a product size of 1,2 x 0,8 m it means that the moulds have to be stiffened thoroughly. This stiffness is obtained through the grid of steel flanges.

5.3. *process*

After glass reinforcement, inserts and foam core are placed, the moulds are closed and clamped together by bolts at the edges. The top mould is provided with a number of threaded holes, that can be used for both injection gate as well as overflow gate. The resin is injected into one of the holes and the other holes are checked carefully upon overflow. If an overflow gate releases resin, it is closed with a bolt. To obtain a regular filling of the mould without any entrapped air an injection strategy has been determined, which means injecting the mould at specific places for a specific time. This action is shown on the picture on the right.

After all overflow gates show resin, the injection is ready, and all holes are closed with bolts. The injection process itself takes not longer than around 5 minutes.

After that the mould is placed in a oven for a few hours (depending on the resin type) in order to cure the resin.

3.5.4. *assembly*

The composite chassis structure can be assembled easily with other parts to a complete kart. Compared to the present assembly with a steel frame there are three important advantages:

- 1) Less man-hours required for assembly
- 2) The composite chassis is cheaper than the steel one
- 3) The composite chassis has a well-defined shape, whereas the steel frame has large size tolerances caused by the welding during its manufacture.

Pictures of the complete assembly of the first prototype are shown below:



Fig. 21: assembled pilot model



Fig. 22: racing pilot model

3.6. RESULTS WITH THE PILOT MODEL

The first pilot models of the composite kart have been tested on the go-kart indoor track and in the advanced crash test facilities of TNO Automotive, Delft, The Netherlands. During rides on the track, driven by experienced go-kart racers, it was concluded that the driving properties were very satisfying. The longitudinal stiffness was enough while torsional stiffness was not too high. The kart had a good grip during in the bends. Durability and stiffness preservation of the chassis are also satisfying so far. After a few hundred driving hours, the torsional stiffness of the chassis was measured. This test showed no loss of stiffness of the pilot model chassis so far.

The bumpers were tested separately in a crash laboratory. The front bumper was attached to the composite frame and this was put on the drive train of the crash simulator. The chassis and bumper collided with the wall at a speed of 25 km/h. The chassis sustained the test without any damage.

The mechanical behavior of the bumper, especially the compression characteristics of the foam blocks and the acting forces on the chassis were investigated. It turned out that it corresponded to the calculated expectations very well.

4. Exploitation plan and follow-up actions

Below the exploitation plans of each partner is described.

Joost Boxoen Kartsport

The kart builder JBK is already selling karts in several European countries, Japan, China and the USA. JBK will commercialise the new product on a world wide scale. A kart with a higher durability will decrease the number of requested karts. However, this will be compensated by a larger market share of JBK. A higher market share is expected since the new kart will be far more economical for the kart track owners (see below 'kart track owner').

Besides a larger market share, a higher profit margin is possible.

There are now around 1200 indoor kart tracks in Europe. The average kart track has about 30 karts driving. With a life cycle of 1,5 to 2 years of the present (steel) kart this each year 20,000 new karts are needed. World wide around 23,000 karts are sold. JBK sells now about 10% of these.

The market expectation is that there will be around 50,000 karts driving in the world.

The new karts will have a life cycle of about 5 years. This means that 10,000 new karts a year are required, from which JBK aims to sell 25%.

A new kart could be sold for 3000 €, the present kart for 2250 €.

The turn-over for karts sold within Europe would therefore increase from 4,500 k€ to 12,000 k€. Besides this, the profit margin is higher. A rough estimation based on the results with the pilot model has shown that the cost of a kart based on the new chassis will probably be 10% higher.

lease concept

The composite kart is more durable. The kart builder can benefit from this, if a lease concept is set up, where the karts are owned, inspected and repaired by the kart builder. Better control on quality is possible, this will result in a higher safety of the kart. With the new durable composite kart JBK has plans for kart lease contracts. This could diminish exploitation costs for the kart track owner. It will also bind the kart tracks to the JBK organisation.

Kart track owners (Delta, FIK)

The new composite kart chassis and its efficient production process will lead to a less costly product. Exploitation costs will diminish due to less maintenance cost. With a price of 3000 € and a life cycle time of 5 years, kart tracks could save a lot of money. Current karts cost about 2250 €. The average life cycle time is 1.5 to 2 years. The costs of a kart per year is now about 1250 €. The participants have set the maximum price of the composite karts at 3000 €. The minimum life cycle time is set at 5 years. The costs of the composite kart will be no more than 600 €.

An average kart track which has 30 karts could save well over 20,000 € per year.

IDN Concepts

IDN Concepts will invest in the manufacture of the kart seats.

They will also investigate the application of composites in other products.

Through this project IDN concepts has gained a lot of know-how on lightweight engineering with composite structures. Together with the CLC, IDN will investigate the possibilities to start similar R&D projects for technical aids to be used in the health care sector. Many of the aids for disabled people need to be lifted frequently in common use. Examples of such aids, such as the Elevato lift seat (a technical aid for elderly and disabled people who have difficulties with standing up from a chair), wheel chairs, home care beds and buggies for disabled children in the age of 5 to 12 years old.

Other companies, that manufacture and sell these kind of products, will be contacted to see if they are interested in joining an R&D project such as this one.

Stratime

Stratime will for the moment act as manufacturer and supplier of the composite chassis for JBK kartsport. A hall with production line will be prepared in the factory in order to

fulfil the series production. This product fits in their strategy to become a major supplier of large composite structures made in RTM for the automotive market.

CLC TUD-TNO

For the Centre of Lightweight Structures this project was a perfect example to show that they are capable in carrying out large comprehensive developments of lightweight structures. All essential steps were involved; conceptual structural design, FEM calculations, manufacturing technology, prototyping and testing. The experience and know-how of both mother organisations (TNO and Delft University of Technology) were used in an optimal way.

Follow-up action

A first spin-off of Charmic has already been initiated; IDN Concepts, Delta Racing and CLC have launched a plan to develop a new type of racing car. This car will have the performance and appearance of a formula car, but it will have the 'low-budget', non-professional but serious racing amateurs as their target group.

5. References

To be published at the 10th European Conference on Composite Materials (ECCM) in Brugge, Belgium on 3 - 7 June 2002:

"Composites in primary structures: Endurable and crash resistant bottom platform for a go-kart" by Ir. W.D. Brouwer and Ir. E.Tromp, Centre of Lightweight Structures TUD-TNO