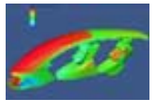
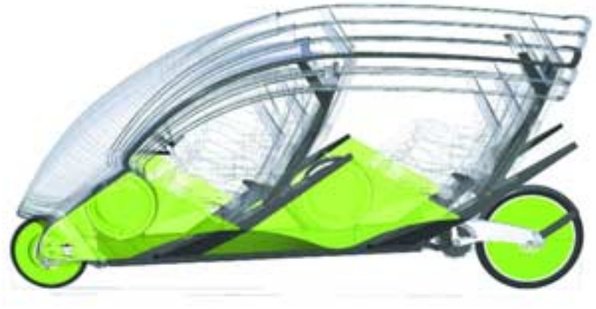
ABOVE: The latest computer model of the Läufer: ten pre-production vehicles will be built next year

BELOW LEFT: A solo can be created using many parts from the tandem, thanks to modular design

BELOW AND RIGHT: Computer modelling investigates aerodynamics (right) and models various sizes of rider (below)





It's a sad fact that human powered vehicles are embraced as a means of transport by only a small proportion of the population. This can be explained thus.

◆ Firstly, most human powered vehicles (HPVs) do not offer sufficient weather protection.

◆ Secondly, an agreeable speed can only be kept up on a gradient with great effort, while precious energy is transformed into useless heat while braking.

◆ Third, multi-purpose HPVs are associated with an ascetic attitude, rather than having strong, positive emotional connotations of success and speed.

To tackle some of these obstacles, the conceptual outline of an innovative human powered vehicle was developed as a pre-degree student project at Darmstadt University of Applied Sciences in the summer of 1998.

The design study was followed by a conceptual review. Can a two-wheeled vehicle of that length (3.5m) be safely controlled, and what steering geometry is best? Does the size-adjustment work? Does the aerodynamic target seem realistic? The essential features of the design study were confirmed and optimised, completing the first stage of development.

The project then took on a life of its own, with an interdisciplinary student task force working steadily to bring the design to fruition. As well as aiming to develop an innovative product, the project is also pioneering a new, modern form of study. Motivation comes from the project's common goals – and not from formal guidelines. The team is entirely self-organised when it comes to the distribution of tasks, internal information flow, and the acquisition of knowledge and sponsors. The basic ideas behind the project soon seemed to become widely accepted and enthusiastically supported.

The 'headline' target is to build a vehicle which, with an output of 130 watts per rider, can achieve a constant travelling speed of about 40km/h (25mph). This is to be achieved through optimisation of its aerodynamics, and an electronic power management system.

The vehicle was built up for the first time in March 2000 for the Hanover Industrial Fair, with the generous support of over 20 partner companies, using industrial production methods. The central elements of the frame were made of carbon fibre-reinforced plastic and CNC-milled aluminium. The CAD models were generated using the CATIA system.

Our current work involves replacing the complex aluminium parts with die cast aluminium. The carbon fibre components are being optimised for less weight and easier manufacturing. The outer shell is also being analysed further to enhance its aerodynamics.

At the moment, about 45 partner companies in many related fields are supporting the student project. An additional five-student engineering team was recently set up at the Munich University of Technology to develop peripheral components including luggage packs, a rear view mirror, a stand for the vehicle, and the lights and signals. Another three-student mechatronics task force is looking at the electronic power management and the data communication system.

ERGONOMICS

On single-seated cycles you can often do without long-travel leg-length adjustment. Quality bicycle frames are often produced in several sizes, and some are custom-built to fit.

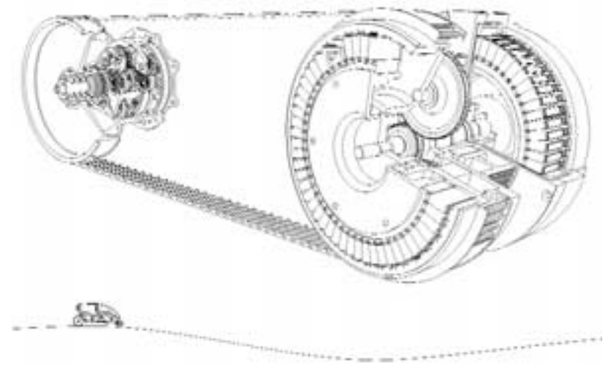
But on a tandem vehicle, a flexible way to accommodate differing riders is essential, because not only must the riders' individual heights be catered for, but their relative statures must also be taken into account. Furthermore, a vehicle for long-distance riding will often not always be used by the same people. The Läufer is designed to fit riders from 150 to 200cm (4'11" to 6'7") tall.

Because it is the most highly-loaded part of the design, the drivetrain is rigidly connected to the chassis. The seat adjustment, by sliding along the angled beams, ensures that each rider is able to achieve not only the correct distance from the pedals, but also the correct height above the ground. In this way riders of all sizes can sit with both feet on the ground and so stabilise the vehicle when stationary.

The partial fairing provides good weather protection without feeling claustrophobic or overly restricting ventilation. There can be problems seeing clearly through transparent fairings, especially in the rain and at night, but we hope that the strongly curved shape will make water run off quickly. One of our Munich students is working further on keeping the rider's view clear: one possible solution seems to be a hydrophilic coating, another idea is a wiper combined with a hard coating. We will have to see what is best.

PROJEKT LÄUFER

A most impressive HPV project is underway at the Darmstadt University of Applied Sciences in Germany. Michael Kirsch from the Projeckt Läufer team explains what they're up to.



The Läufer's electric-assist transmission uses motor/generators on the intermediate driveshaft to 'even out' the gaps between the Rohloff's gears

SPONSORS AND SUPPORTERS

The support of university professors and industrial companies is no less than essential. We, the students, would not be able to pay for a single windscreen or carbon fibre shell. We would also have a hard time getting through our studies without our professors' support. It is a fact that the project might die should any of our main sponsors or university supporters retire.

This is why I would like to especially thank our main two sponsors and the three Professors who have been supporting us from the early days:

Die Wethje GmbH, Kunststofftechnik:
Usually involved in Audi and BMW automotive racing projects, they support us in all areas of plastic technology. The head of the company, Mr Reinhard Wethje, contributes to our design process with thirty years of experience in carbon fibre.

Schröter Modell- und Formenbau:
The Schröter company is also involved in automotive racing projects. They support us in CAD/CAM and make the majority of our moulds for the die-cast and carbon fibre components. In the near future they will handle the whole die-cast process. Their chief executive, Mr. Maximilian Lörtzl, contributes to our die-cast design process.

Prof. Dr.-Ing. Herbert Birkhofer:
A committed tandem bicycle traveller and the first professor to support the project, ever since 1998 when two mechanical engineering students, Christian Hessling and Michael Gräff, asked him for help. Prof. Birkhofer is head of the Faculty of Machine Elements and Engineering Design. He also introduced industrial design to the project, sending his students to the industrial design faculty of Darmstadt University of Applied Sciences.

Prof. Tino Melzer, Industrial Designer MA:
Together with Prof. Birkhofer, he supported the initial design study early in 1999, involving two industrial design students, Max Neumeyer and myself. His teaching gave the vehicle a visionary yet realistic outlook.

Prof. Dr.-Ing. Reiner Anderl:
Committed to computer-integrated design, Prof. Anderl joined the project in December 1999. He pushed to make the *Läufer* a completely computer-designed product. Today it seems hard to imagine designing the *Läufer* without CAD.

DRIVE SYSTEM

With a conventional tandem, moderately fit riders can attain average speeds of around 35km/h. Under similar conditions we are aiming for 40km/h, not as some computer-simulated value, but as a constant touring speed, made possible by a low-power hybrid drive system.

A clean (no grease) toothed belt runs from the 'pedal rings' to an intermediate shaft. From here, a second belt drives the rear wheel's hub gear. This is a 14-speed Rohloff Speedhub, with a range of 500%, which covers the desired speed range.

The intermediate shaft contains a planetary gearing system, which incorporates three 'energy converters': electronically-regulated motor/ generators, with a maximum power of 600W.

As well as providing assistance on hills, the control system allows the gear-change steps in the rear hub to be 'evened out' by the system to give the effect of a continuously variable transmission. It does this by acting as a sort of 'slipping' or 'gaining' clutch: losing or adding a few revolutions per minute to the output pulley so that the gear ratio perceived by the rider seems to change smoothly and continuously.

The motor/generators can also be used as dynamos, to win back energy from braking.

CHASSIS

The chassis is built from monocoque hollow carbon-fibre composite structures, made by joining together laminated half-shells. In this way the basic structure can be manufactured using simple jigs and with little finishing work. The spars onto which the hollow sections are bonded also fulfil secondary functions, acting as guides for the seat adjustment or as attachment locations for parts of the fairing. All components of the core chassis are solidly bonded together. The component parts can be built up into chassis for either a single or two-seater.

In comparison to most contemporary recumbents the carbon-fibre parts have very large enclosed volumes, giving this comparatively long vehicle sufficient stiffness.

Our weight goal for the pure HPV is about 35 kilograms. The electric-assist unit will add an additional 15 to 20kg. With a travelling weight of up to 250kg (captain, stoker, vehicle and baggage) the regenerative braking should be quite effective. The frame structure with main tube and the four seating wings weighs about 9.5kg.

STEERING

We're developing hydraulically-actuated steering for the *Läufer*: there are two main reasons for this. First, the long seat travel means that we must also offer a corresponding range of handlebar movement, to ensure a comfortable riding position for all sizes of rider. The second reason arises from the one-sided front suspension, which is used (instead of a fork) to achieve a shorter wheel base. With the one-sided arm there is no need to accommodate a headset in front of the captain's pedal ring.

Both requirements could not be satisfied with any usual mechanical steering linkage. What we need is a more flexible solution, and hydraulics seem like the answer. We are presently collaborating with Magura and with Dura Industrie, who offer a ball-based flexible actuator.

THE FUTURE

As I write we are working on a redesign to incorporate some new features. This will be finished by early 2002, and by summer 2002 we will start building a pre-production series of ten vehicles.

At the moment, the *Läufer* is a university project with the clear objective of producing a state-of-the-art HPV, stuffed with technology, to demonstrate a new generation of rideable human powered locomotion. All of our sponsors support this project philosophy.

The student project is planned to end up with the pre-production series. Ten vehicles seems a good number to gain real-world experience and to show that production is feasible. From that point on, the future of the project is a matter of costs and markets, just like any other product:

So what's a *Läufer*? It refers to the German word for runner: a long distance athlete rather than a sprinter. *Läufer* is also the German word for a bishop in chess: it moves along diagonal lines. Fast, but not in a conventional way!

CONTACTS

More details can be found on the website:
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