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Cover

Today, more and more high-end TVs come with a large-format flat screen. Newly developed materials for screen frames over which the shadow masks are stretched (see cover picture) ensure a sharp and brilliantly colored TV picture. The materials newly developed by ThyssenKrupp Stahl and ThyssenKrupp VDM for this purpose were honored with the first prize of the ThyssenKrupp Innovation Contest 2002.
The second prize was awarded to Rothe Erde for an innovative analysis process for large-diameter antifriction bearings in connection with customer-specific companion structures.
Defontaine's new concept for flywheel ring gears and flywheel systems, which go by the name of Flexwheel®, took the third prize.
In addition to these prizewinning innovations, this issue of "forum – Technische Mitteilungen ThyssenKrupp" presents further exceptional contributions to the innovation contest.

Prof. Dr.-Ing. Ekkehard D. Schulz, Chairman of the Executive Board of ThyssenKrupp AG

Prof. Dr.-Ing. Ekkehard D. Schulz, Chairman of the Executive Board of ThyssenKrupp AG

Dear readers,

The innovation contest held by the ThyssenKrupp Group this year met with a very positive response. Altogether we evaluated 63 proposals submitted from all segments throughout the world. In this issue of "forum-Technische Mitteilungen ThyssenKrupp" we present particularly outstanding innovations regarding new or improved products, manufacturing technologies and services.
For large-format, flat screen tubes, ThyssenKrupp Stahl and ThyssenKrupp VDM have developed special new frame materials characterized by their high tensile strength and a low thermal expansion that has been matched to the shadow mask material. ThyssenKrupp Defontaine reports on Flexwheel® – a new concept for the starter ring gear/flywheel system with a long service life, designed especially for stop-and-go operation. ThyssenKrupp Turbinenkomponenten presents a fully automated heat treatment line for compressor and turbine disks and ThyssenKrupp Gerlach a fully automatic forging line for crankshafts, both new technologies aimed at improving quality and reducing production costs. ThyssenKrupp Fahrtreppen is introducing its new FT 900 e-escalator series that enables quicker response times, especially with regard to servicing and maintenance, thanks to continuous online monitoring. Rothe Erde has developed a new procedure for analyzing large-diameter antifriction bearings in conjunction with customer-specific companion structures. This procedure saves a considerable amount of time and effort in the analysis process while at the same time significantly reducing costs. ThyssenKrupp HiServ reports on an innovative smoke-extraction system for tunnels that uses vortex technology and enables considerable improvements in safety. Innovations are the basis for success within our technology-oriented company. For this reason, the ThyssenKrupp Group will once again be organizing an innovation contest in 2003 to emphasize the great importance it attaches to innovation. I would like to take this opportunity to invite all employees throughout the world to enter their successfully implemented solutions in this contest.

Yours,

High-strength steel materials for flat screens

Today, more and more high-end TVs come with a flat screen. While an increasing number of LCD screens are being sold in the PC monitor sector, conventional television tube technology still offers significant advantages in terms of color quality and contrast.

ThyssenKrupp Stahl and ThyssenKrupp VDM offer interesting solutions for various flat screen tube assemblies: Take, for example, special shadow mask and screen materials. Modifications of the basic materials Pernifer 36 from ThyssenKrupp VDM and aluminum-killed steel from ThyssenKrupp Stahl are used for the shadow masks because of their correspondingly designed technological properties.

To achieve optimum properties, it is absolutely vital that the frame material is matched to the shadow mask material. High tensile strength and a low thermal expansion matched to the mask are what is required here. For the two aforementioned shadow mask steels, matched frame materials (Pernifer 42TVR and Complex-phase steel) were developed to production maturity and launched on the market. Both of these innovations are now in successful use in the volume production of high-quality televisions with flat TV tubes.

Electromechanical Leveling System (EML)

Since the establishment of ThyssenKrupp Automotive Mechatronics in October 2000, the company has been able to demonstrate its expertise in the field of mechatronic systems, especially on the Transrapid project and for the companies in the Automotive segment. It also improved its expertise in the field of mechatronic passenger car suspension systems. While working on the system, an electromechanical suspension regulation system that adjusts the vehicle level to suit the vehicle load was developed. This system also increases ride comfort and driving stability.

The solution developed by ThyssenKrupp Automotive Mechatronics for automatic leveling control offers all the features achievable with current technology. It is also a less expensive variant than the conventional pneumatic/hydraulic systems. Pneumatic compressors, hydraulic pumps and their complex wiring systems no longer need to be installed. Consequently, there is a significant reduction of the number of parts and the maintenance costs. The product also offers other cost advantages: For example, the modular structure simplifies assembly, while the fact that the system uses materials that are already used in the vehicle facilitates recycling.

Laser welding and clamping system for the body shop

In the automobile production sector, laser welding has many advantages over conventional spot welding. High welding speeds and material savings through adapted designs are solid arguments in favor of the increasing use of laser welding for body-in-white production. However, this process is of limited use for galvanized sheets because the different melting temperatures of the sheet steel and the zinc surface layer have a negative influence on the welding process and can create pores and holes in the weld seam.

The problem can be solved by a defined opening between the layers of sheet steel that allows the zinc gas that arises to escape. To this end, Thyssen Krupp Drauz developed a flexible laser welding and clamping system that combines the advantages of laser welding with the requirements for exact clamping of the steel sheets relative to one another. The modular structure of the new laser welding and clamping system permits the welding of the most varied seam geometries at speeds of up to 5m/min.

Used in volume production on flanges in the door areas, ThyssenKrupp Drauz's laser welding system has proved highly successful. However, other flange geometries can also be welded without problems.

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Page 23

Fully automatic forging line produces crankshafts with a 7.5-second cycle time

Recent years have seen an enormous rise in the demand for diesel-powered vehicles, which are generally fitted with a forged crankshaft on account of the greater durability of this type of component. This has made it necessary to increase the production capacity for forged crankshafts. To guarantee the company's technology leadership in this area, ThyssenKrupp Gerlach set up a fully automatic production line that enables a more economical production process with a higher capacity. With a cycle time as low as 7.5 seconds and a throughput time of 4.5 hours from raw material to ready-to-dispatch product, the company succeeded in increasing annual capacity to over 2 million crankshafts.

The main features of the new production line are high availability with consistent product quality. The high level of automation has shaved a massive 35 percent off production costs. Program changes do not cause problems and can be made at short notice. The aspects of occupational safety, process reliability, ease of inspection and environmental compatibility were all taken into account during the development stage.

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Chief Executive Officer & Chairman of the Board,
Dipl.-Ing. Serge Gaudu,
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Page 28

A new concept for starter ring gears and flywheel systems (DEFONTAINE Flexwheel®)

Automobile manufacturers try to meet the steady public demand for a reduction of fuel consumption and CO_2 emissions through solutions such as stop-and-go programs. As the world's top manufacturer of starter ring gears, DEFONTAINE was confronted with the task of significantly increasing the lifetime of existing ring gears. The number of possible start cycles had to be increased to at least ten times that of the starter ring gears marketed to date.

After a three-year development phase, DEFONTAINE opted for a system that provides extra flexibility when the pinion gear engages with the starter ring gear, thereby increasing its service life to between 300,000 and 600,000 start cycles: a flexible flywheel that is today known as Flexwheel®.

The comfort of vehicle occupants is another important criterion that must be considered with such new designs. To increase comfort, it was necessary to reduce the noise emission to a minimum. This was achieved by introducing viscoelastic elements into the Flexwheel®.

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Page 31

FT 900 e-escalator series

Thyssen Fahrtreppen GmbH is the first company in the world to develop a system diagnosis for escalators and moving walks with the help of the internet. To reach this goal, two technological innovations had to be realized. First of all, the 'Central Monitoring System' (CMS) software was developed. This monitors the e-escalator range and transfers all operating parameters via a corresponding internet access device to a PC monitor in a customer-friendly manner. It was also necessary to develop a new bus system. The information from the sensors that safeguard and monitor e-escalator operation is transferred to a central unit via a single bus cable. The data is then transferred to the internet access device, which manages the exchange of data on the internet. Up to eight systems can be linked up to a single interface.

The e-escalator generation is permanently monitored online, which means that it has increased availability. Error messages can be analyzed online within a few minutes. This makes it possible to send a service team to the location immediately. It also ensures that the team is provided with optimum information about the cause of the error and the necessary spares.

Thanks to the FT 900 e-escalator series, Thyssen Fahrtreppen has succeeded in significantly increasing the economic efficiency and service-friendliness of escalators and moving walks.

New pre-combustion chamber for lumpy secondary fuels

In comparison to conventional fossil fuels, there has been a considerable increase in the use of secondary fuels in the cement clinker burning process; these fuels currently have a share of almost 30 percent. The utilization of fuels such as old tires, waste oil, old timber etc. is becoming generally more difficult from a process-related point of view. These fuels, however, are appealing because of their lower price. Furthermore, refuse-derived fuels are regarded as being "CO_2 neutral". Their use in cement plants greatly helps to dispose of problematic residual materials, and this is acknowledged with correspondingly high disposal credits. Polysius AG has developed a technology in particular for the utilization of lumpy secondary fuels such as old car tires, whereby these fuels can be used – without limitations in terms of process technology or quality – to produce cement in cement burning plants with precalcination. This has been implemented by using a pre-combustion chamber that can be integrated into the cement burning process.

An important feature of this technology developed by Polysius is the combination of economic benefits and environmental advantages which, together with the relatively low cost, are regarded as key criteria for successful marketing.

Analysis of large-diameter antifriction bearings in conjunction with customer-specified companion structures

Large-diameter antifriction bearings from Rothe Erde are found as many times statically undefined coupling components operating mainly in the areas of materials-handling technology, tunnel boring technology and wind energy. They generally enable a rotating movement between two elastic constructions. The connection between the large-diameter antifriction bearings and their companion structures is normally accomplished through the use of bolts. The procedure for analyzing load distribution and the behavior of the bolted connection has until now been conducted using linear-elastic models to simulate the stiffness of companion structures and bearing rings in connection with special spring and contact elements for simulating the rolling elements. However, the creation of such finite element models is very expensive and time-consuming. Moreover, this method can not be used to take into account the non-linear behavior of the bolted connection.

Rothe Erde has developed a procedure that enables both a very economical and extremely thorough (in terms of technical mechanics) analysis of the complete large-diameter antifriction bearing-companion structure system. This procedure also makes it possible for the first time to calculate a simulation of the mutual influence of the raceway system and the bolted connection on the basis of the finite element method – for any spatial load desired. Modeling of the analysis model, which is divided into three submodels, can be conducted independently by the respective component manufacturers.

Fully automated heat treatment line for compressor and turbine disks

As an expert and experienced supplier of aircraft engine parts, ThyssenKrupp Turbinenkomponenten offers a product range featuring not only compressor blades but also a wide range of compressor and turbine disks and other disk-like products. Once the disks have been forged and machined, they are subsequently fitted with the appropriate blades by the turbine manufacturer. Disks from ThyssenKrupp Turbinenkomponenten GmbH are found in just about every civil and military aircraft engine on the market and are used in compressors as well as in turbines, where the thermal loads are high.

The highest levels of quality and strict adherence to specific component properties are required in order to guarantee a long lifespan for the compressor and turbine disks. A heat treatment line characterized by a pioneering quenching technology, a high degree of automation, and an environmentally friendly fume-extraction system has been constructed to optimize these properties. Unlike conventional heat treatment lines, the one constructed by ThyssenKrupp Turbinenkomponenten offers the possibility of ensuring defined cooling rates across the entire component surface. The basis for this ability is multiple axis oil recirculation in combination with oscillating charge motion.

Database for customers to optimize the selection of steel grades

As one of Germany's leading suppliers of industrial materials with a focus on warehousing business, Thyssen Schulte primarily addresses the needs of customers in the processing industry, most of which are medium-sized businesses. One priority in the company's business strategy is to provide customers with support and assistance in the area of materials selection and use.

The article presents and describes the innovative foundations for an electronic steel selection database that covers 400 grades of steel with an emphasis on flat products. Depending on the type of steel, up to 40 mechanical, physical and other specific materials criteria are encoded into the database. All data on the materials have been collected on the basis of practical experience over many years. Up to three criteria for the steel selection processes can be entered in instances of individual optimization problems. Also encoded in the system are the availability alternatives for each steel grade – i.e. availability ex stock/central warehouse, or as a direct sale if the material is required quickly.

This steel selection program provides Thyssen Schulte with an attractive method of offering consulting services as well as a competitive edge. Plans call for expansion of the program.

Reusable panel: Plastic composite panel with replacement film

In early 2001, the construction industry began to use formwork panels of plastic for the production of walls and ceilings. Compared to traditional plywood formwork panels, the plastic variety has several major advantages, e.g. it has a higher weather resistance and requires less effort to clean. The drawback of the plastic formwork panels that were previously on the market is that they have to be repaired by hand, which involves a lot of manual labor and therefore high costs. Hünnebeck GmbH thus developed a reusable panel whose surface can be repaired by machine. The panel in question is a plastic composite panel fitted with a replacement film. The two elements are bonded together in a mechanical process. Should the surface of the film become damaged, it can easily be removed from the base plate by machine and replaced by a new one. This greatly increases the number of possible times it can be used, in comparison with conventional plywood panels, and the quality of the concrete surface is substantially improved.

This innovation presented by Hünnebeck GmbH saves between 35 and 40 percent of cleaning and repair costs as compared to conventional plywood formwork. Furthermore, with the new system, the used material can be recycled and made into new base plates.

Safety in underground transport systems thanks to smoke extraction systems from ThyssenKrupp HiServ

The number of tunnel fires resulting in huge levels of damage has increased significantly over the past few years. The constantly rising numbers of heavy trucks traveling in tunnels represent a particular risk in this regard. The most immediate danger in a tunnel fire is smoke. People trapped by smoke cannot flee the scene of the disaster in time, and fall victim to the toxic gases. Conventional technology does not offer a sufficient means of extracting the toxic smoke quickly enough and in a targeted manner. If, in addition, the fire itself is not contained, the result will be long and costly repairs to the tunnel and the closure of this transport artery during this period.

ThyssenKrupp HiServ has been working for many years on technologies for extracting toxic gases of industrial processes and methods of rapidly extracting smoke to keep escape routes free of smoke in case of fire. The company, a specialist in the thermodynamic and technical ventilation design of air and smoke extraction systems, has developed a new smoke-extraction system whose core element is a vortex hood. Taking its cue from nature, the system generates a cyclone-like flow of air that displays an extremely uniform suction effect. The ceiling pipes used to transport the toxic gases are equipped with vortex hoods on both sides, whereby integrated dampers activate the individual hoods as needed. The system is thus capable of extracting smoke and heat directly at the location of the fire within seconds, thereby substantially reducing the resulting damage.

Dr. rer. nat. Wolfgang Zacharias,
Head of Automotive Business,
Triaton GmbH, Dortmund
Page 63

Triaton.Castrum Sequence – The control center for just-in-sequence module production in the automotive supply industry

Supply chain management has been a key element in the automotive supply industry for quite some time now. In response to the challenge presented by customers who want vehicles that are even more individualized, automakers are now increasing the number of model and equipment variants. Consequently, the vehicle-specific delivery of system components to final assembly lines is becoming an ever-more complex process. So it is not only an issue of "just-in-time" delivery any more; the idea is to get the right equipment variants to the final assembly belt in the right order (i.e. in the sequence of installation).

To support such "just-in-sequence" logistics processes, Triaton GmbH has developed solution modules under the name "Triaton.Castrum Sequence". The individual modules support various functions, such as the sequenced delivery schedule for the automaker's production release system, the compilation of vehicle-specific production data, and plausibility checks to maintain the vehicle sequence. The Triaton solution is geared toward lean logistics processes and fully automated manufacturing processes, enabling the smallest lot numbers to be produced at a minimal stock level.

Users appreciate not only the system's functionality but also the round-the-clock support provided by Triaton GmbH.

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Dr.-Ing. Thomas Heller
Dipl.-Ing. Günter Stich

High-strength steel materials for flat screens

The winners of the ThyssenKrupp Innovation Contest 2002 (Fig. 1)

1 Overview

Steel and ferro-nickel alloys are found in TV tubes in the form of:

- Shadow masks
- Screen frames
- Shield covers
- Bimetal springs
- Implosion protection frames

(Fig 2). Each of these components places specific demands on the material used to make it. The extensive expertise of ThyssenKrupp Steel in this field, as represented by the companies ThyssenKrupp Stahl, ThyssenKrupp VDM, Wickeder Westfalenstahl and ThyssenKrupp Nirosta (TKN), has a range of interesting products for use in the manufacture of TV tube components.

ThyssenKrupp Stahl and ThyssenKrupp VDM develop materials to make shadow masks. Such materials are melted and rolled into hot strip, which is then rolled by Wickeder Westfalenstahl into cold strip in thicknesses of between 0.1 and 0.25 mm. Various modifications to the basic material Pernifer 36 from ThyssenKrupp VDM plus an aluminum-killed steel from ThyssenKrupp Stahl display just the special technological properties required for both formed and stretched shadow masks (Fig. 3). A 0.2-mm-thick Pernifer 36 strip manufactured by ThyssenKrupp VDM is also used to produce so-called diaphragm frames, which hold the formed Pernifer 36 shadow masks in shape.

Bimetal springs are made of strips of Pernifer 36 or Pernifer 48 from ThyssenKrupp VDM welded to a CrNi steel from ThyssenKrupp Nirosta. They compensate for temperature-related movements of the shadow mask.

At the heart of a TV tube is the electron gun (Fig.4). For use with this highly complex component, ThyssenKrupp VDM has developed the material variants Pernifer 40 So 2 and Magnifer 50 GP, both of which have special properties. They are used to make stampings as well as bent and deep-drawn components which are used to focus the three electron beams in the TV tube.

The purpose of the shield cover (Fig. 5) is to prevent the electron rays from being influenced by any magnetic fields, e.g. the earth's magnetic field. The strip from which shield covers are made is produced by Wickeder Westfalenstahl.

Screen frame with shadow mask (Fig. 3)

Electron gun (Fig. 4)

TV tube components made of FeNi and steel (Fig. 2)

2 High-strength steels for flat screens

Today, more and more high-end TVs come with a flat screen. Here, conventional tube technology still offers significant advantages – e.g. better color quality and enhanced resolution – over LCD screens, which are still predominantly used for PC monitors. The problem with modern flat screens is that the screen mask (also referred to as the shadow mask) is not subject to deep drawing, which normally provides stability. The screen frame must therefore ensure that the pre-tensioned shadow mask is held in place without distortion when subjected to the different loads during manufacture and operation. This places particularly high demands on the material used to make the frame. The materials used for the frame and the sha-

Shield cover (Fig. 5)

dow mask must be carefully matched so as to ensure optimal performance of the system as a whole.

3 Use of FeNi alloy

Pre-tensioned shadow masks made of Pernifer 36 display extremely low thermal expansion. However, this calls for a strengthened frame made of a material with similar low thermal expansion. This led to the development of the new material Pernifer 42 TVR, a ferro-nickel alloy that can be precipitation-hardened and is suitable for use as a frame material for the pretensioned shadow masks of large-format, flat screen color TVs. The chemical composition of Pernifer 42 TVR is such that following the precipitation-hardening heat treatment of the already manufactured frame, the mechanical strength is almost twice as high as that of the original strip after solution annealing (Fig. 6). In its hardened state, Pernifer 42 TVR fulfils all the specifications required. Depending on the size and type of TV, the frame is made out of strips between 1.2 and 3.0 mm in thickness. In particular, the material must meet two requirements. A process to blacken the shadow mask and frame involves temperatures of 550 – 640 °C. Similarly, in the heat treatment used to harden the seam between the two halves of the tube, temperatures rise to 450 – 480 °C. To ensure that the shadow mask still remains under tension once the mask-frame assembly has cooled down again, the thermal stability of the material used to make the frame must be so good that there is minimal creep elongation under such conditions. At the same time, thermal expansion of the frame must be less than that of the shadow mask so as to prevent the latter from becoming overstretched during heat treatment.

The advantages of the frame material Pernifer 42 TVR are its good processability, high thermal stability and low thermal expansion, making it ideal for use in combination with shadow masks of FeNi 36, which displays especially low thermal expansion.

Working in close cooperation with the Thomson company, the Pernifer 42 TVR alloy was developed in just nine months before receiving certification for this application in the year 2000, since when it has been used in volume production.

4 Use of low-alloy steel

While planning to establish a plant to produce TV tubes in Germany, Panasonic was on the lookout for a suitable steel grade to produce screen frames. An aluminum-killed steel is used to make the corresponding shadow masks.

In the first instance, the steel used for the screen frames has to be able to deal with the conditions arising during manufacture (Fig. 7). As already noted above, particularly significant in this respect are the high temperatures involved when blackening the screen frame and hardening the seam between the two halves of the tube. The material for the frame used to support the shadow mask must guarantee that the latter remains perfectly flat and distortion-free both during and after

Chemical composition:

Ni	Ti	Nb	Al
43%	2.4%	0.4%	0.3%

Mechanical properties:

Condition	annealed/bendable	hardened
Yield point R_p 0.2	340 MPa	840 MPa
Tensile strength	650 MPa	1150 MPa
Elongation	35%	10%
HV hardness	160	340

Creep elongation:

<0.05% Test conditions: 1h at 600° C with 350 MPa load

Thermal expansion coefficient	Frame Pernifer 42 TVR	Shadow mask Pernifer 36
CTE(20-100°C) (10^{-6}/K)	3.8	1.1
CTE(20-300°C) (10^{-6}/K)	5.1	5.4
CTE(20-500°C) (10^{-6}/K)	9.1	10.3

Pernifer 42 TVR: specification profile and properties (Fig. 6)

Manufacturing processes of a flat screen frame with pre-tensioned shadow mask (Fig. 7)

such treatment. Trials have shown that hot-rolled Complex-phase (CP) steel is well able to meet such specifications and therefore offers an interesting alternative to the low-alloy steels conventionally used for this purpose. CP grades belong to the family of multiphase steels. The properties of these sophisticated materials are attained by combining microstructural constituents of varying hardness. CP steels consist of an extremely fine, predominantly bainitic matrix, dispersed with small martensitic and, if necessary, ferritic islands (Fig. 8). Micro-alloying with titanium and specially adapted temperature control during hot rolling produces the exceptional qualities of this steel. Despite displaying a tensile strength of more than 800 MPa at the mill finish stage, the MnSiCrTi-alloyed CP hot strip of about 5 mm thickness is still cold-formable and weldable. There is increasing demand for CP steel grades in the automotive industry, where they are now used to manufacture crash-relevant components.

This high initial strength and advanced temperature control during hot rolling deliver the properties that make this type of steel well suited to fulfilling the specifications required of screen frames for large-format, flat screens. During the production of such frames – a process involving cold-forming and heat treatment – fine precipitation further increases the strength to approx. 1,000 MPa without any loss in toughness. In other words, the production process is used to enhance the properties of the steel. Thermal stability and creep properties both meet the specifications required (Fig. 9).

Thanks to this combination of properties, the CP steel used to make the screen frames ensures that the pre-tensioned shadow mask remains completely flat and distortion-free in a fixed position during the entire process of manufacturing a TV tube. In turn, this guarantees that electrons from the electron gun are directed to exactly the right hole in the shadow mask, thereby producing a picture with superb color quality and enhanced resolution.

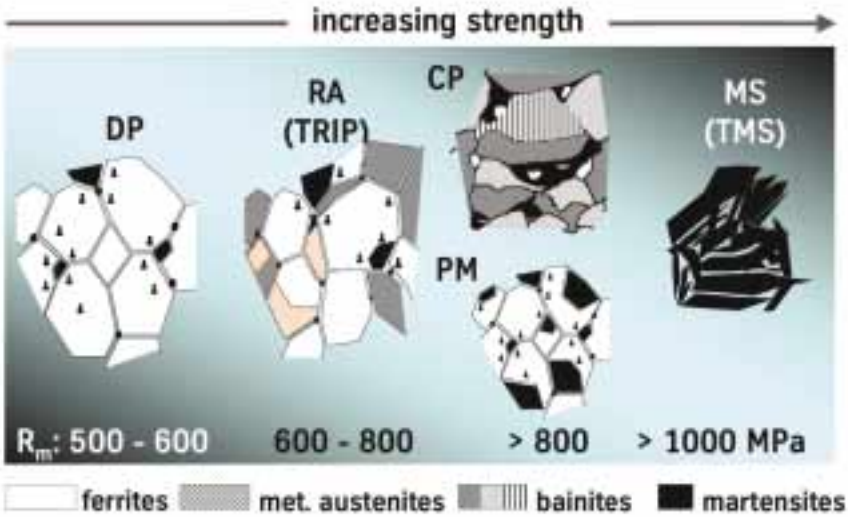
The material's high strength in comparison to rival steels means that it can also be used in the future to reduce the weight of the screen frame. Moreover, it may well be possible to dispense with the cold rolling phase currently required.

In the market for high-end TVs, there is a clear trend toward flat screens. Thus, the production of the corresponding screen frames offers substantial market potential for high-grade steels.

In the meantime, mass production of 120,000 TV tubes a month has commenced at a new plant in Esslingen. The CP steel described above is used to make the angles of the screen frames. For every TV tube, some 1.5 – 2 kilograms of CP steel are used, which amounts to as much as 240 tons a month. Other manufacturers of flat screens have also expressed an interest in the material.

5 Summary

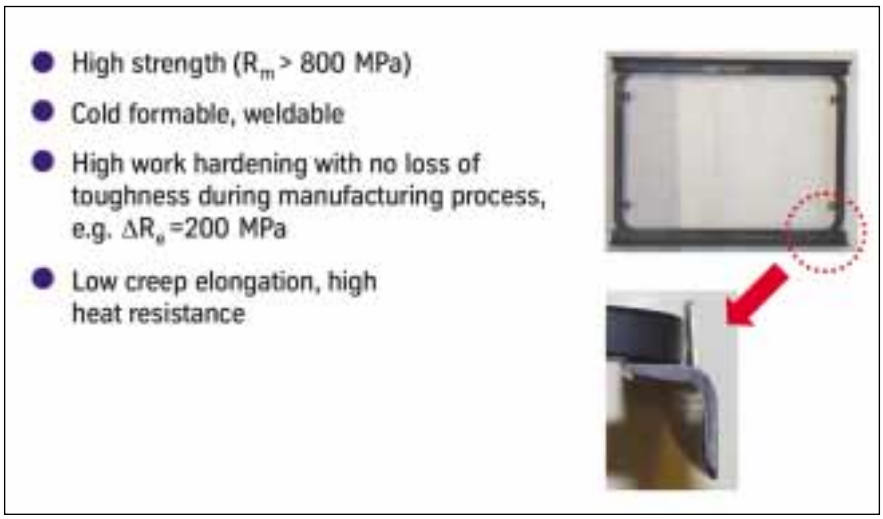
In today's market for high-end TVs, there is a clear trend toward large-format, flat screens. Steels of very high strength are required to produce a screen frame capable of supporting the load exerted by a pre-tensioned shadow mask. In order to ensure top picture quality, the materials used for the shadow mask and screen frame must be carefully matched.



Structure hardening of multiphase steels (Fig. 8)

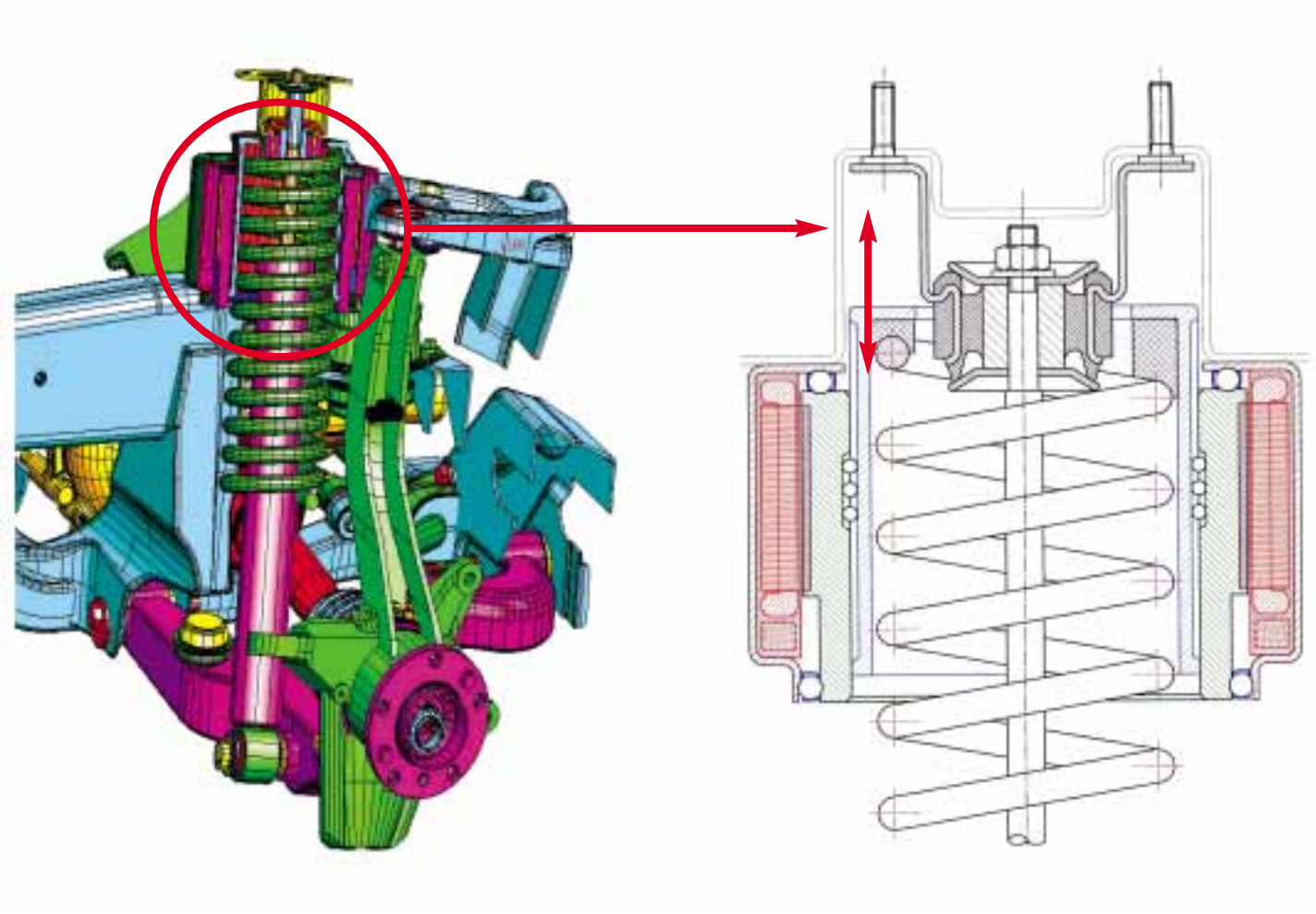
ThyssenKrupp Steel has developed special steels for screen frames used in conjunction with two different shadow masks (steel + FeNi (Invar®)) and successfully brought both products to market. The two solutions were awarded joint first prize in the 2002 ThyssenKrupp Innovation Contest.

Material properties of CP steel (Fig. 9)



Dipl.-Ing. Siegfried Ellmann
Dr.-Ing. Friedrich Löser

Electromechanical Leveling System (EML)



Suspension strut with integrated actuator (Fig. 1)

1 Overview

ThyssenKrupp Automotive Mechatronics was founded in October 2000. ThyssenKrupp Transrapid holds a 49 percent stake in the company, ThyssenKrupp Automotive Systems the remaining 51 percent.

The Transrapid project was a perfect opportunity for the employees at ThyssenKrupp Automotive Mechatronics to demonstrate their expertise in the development and manufacture of mechatronic systems. The first batch of the Transrapid vehicles is currently being manufactured in Kassel.

The transfer of this know-how to the field of mechatronic suspension systems for passenger cars has given rise – in cooperation with ThyssenKrupp Automotive Systems, ThyssenKrupp Bilstein and ThyssenKrupp Federn – to a number of production orders from German automobile manufacturers. This collaboration has helped to improve the ThyssenKrupp Automotive group's systems competence in this field. Such work also produced the project described below: the Electromechanical Leveling System (EML), an electromechanical suspension control. A patent application was filed for the new system and was granted by the German Patent Office on May 16, 2002.

2 Functional characteristics

Some vehicles today already use systems to adjust the height of the spring-mounted body. These systems employ hydraulic control cylinders or air springs as actuators, and hydraulic or pneumatic units – driven by an electric motor or the engine – to generate the requisite pressure.

The aim of the EML project was to devise a comprehensive electromechanical system to adjust the height of the vehicle body which would enhance functionality economically and efficiently.

The system works in the following way: integrated in the upper end of a suspension strut is an electric motor (Fig. 2), which adjusts the upper spring collar and therefore the level of the vehicle body. The rotational motion of the electric motor is converted into a linear motion by means of a screw drive. A central design feature of the system is its use of high efficiency modules, which enable the system to be used in vehicles where the power of the onboard electrical network is limited.

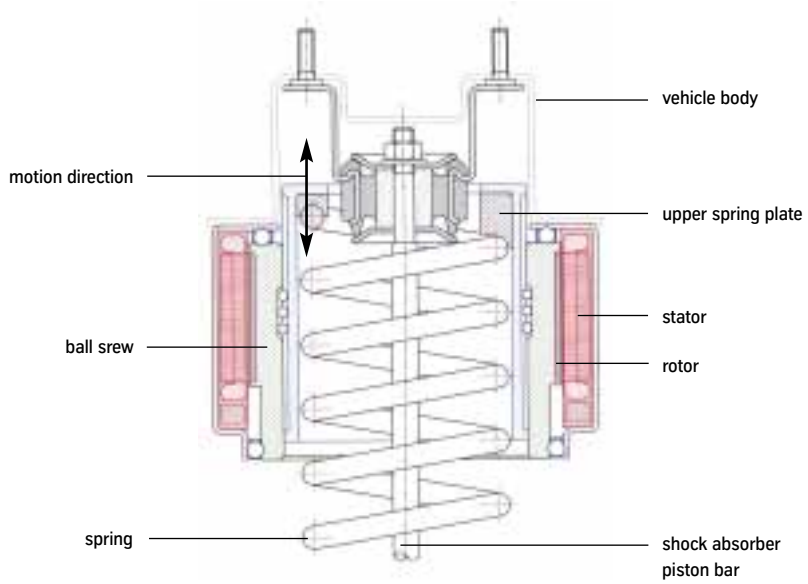
The motion of the body is registered by a control unit connected to acceleration sensors, height sensors and information from the vehicle bus (Fig. 3). Electromechanical actuators fitted to each suspension strut convert electrical energy into linear motion. A master control unit regulates the body level in line with the current driving situation and the driver's wishes.

3 Customer benefit

The benefit to the customer consists essentially in enhanced driving stability, comfort and vehicle functionality.

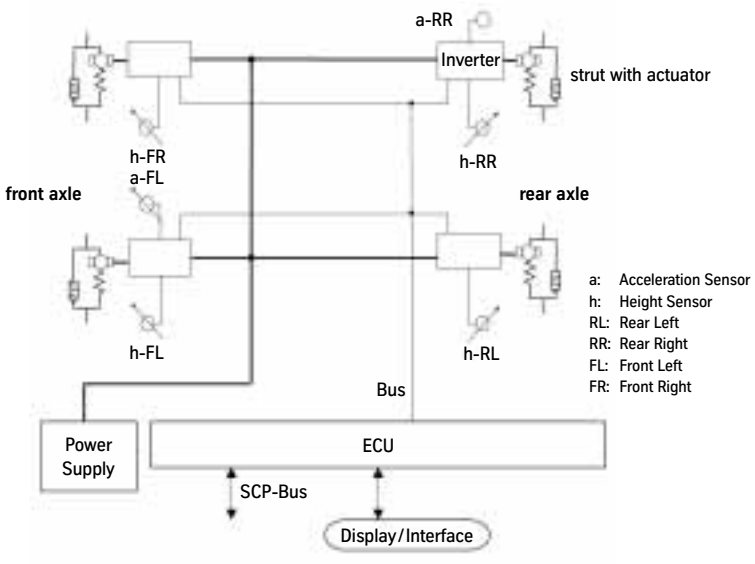
- **Enhanced driving stability**
  Sudden changes in the vehicle's dynamic driving state, such as an overly rapid lane change, can push a vehicle beyond its stability threshold, causing it to understeer or oversteer. A dynamic redistribution of the wheel loads raises the stability threshold and thus boosts vehicle safety.

- **Improved vehicle comfort**
  Cornering, accelerating or braking changes the horizontal position of the body. Automatic leveling at each sus-



Actuator (Fig. 2)

Block diagram of the Electromechanical Leveling System (Fig. 3)



pension strut keeps the body horizontal. This reduces uncomfortable body motion during braking, cornering and when driving on uneven road surfaces.

- **Greater functionality**
  Loading passengers or objects into a vehicle changes the height of the body. This is compensated for by an automatic system that keeps the body in its original position independent of the load. In turn, this prevents undesired side effects such as dazzling headlights, increased fuel consumption due to added wind resistance, diminished ride quality and reduced ground clearance.
  In addition, ground clearance can be adjusted either automatically in line with the vehicle's speed or manually according to the driver's wishes.

4 Cost savings

Cost savings are generated both in vehicle manufacture and subsequent operation.

- **Reduction in parts**
  In contrast to hydraulic and/or pneumatic systems, EML converts electrical energy into linear motion. There is therefore no need for a hydraulic pump or pneumatic compressors along with the complex system of transmission lines that they require.

- **Ease of assembly**
  The modular design brings cost benefits when integrating the system in the vehicle. Beyond actually mounting the unit itself, all that is required is to plug in the electrical connectors.

- **Maintenance**
  In contrast to conventional systems, EML does not use hydraulic or pneumatic reservoirs, transmission lines or actuators. Maintenance requirements will therefore be substantially reduced.

- **Recycling**
  Given that EML employs significantly fewer individual parts, recycling costs are reduced.
  The use of the same materials already used in the vehicle (e.g. for electric motors, transmission, control units) means that no additional procedures are involved in recycling the various components.

5 System development

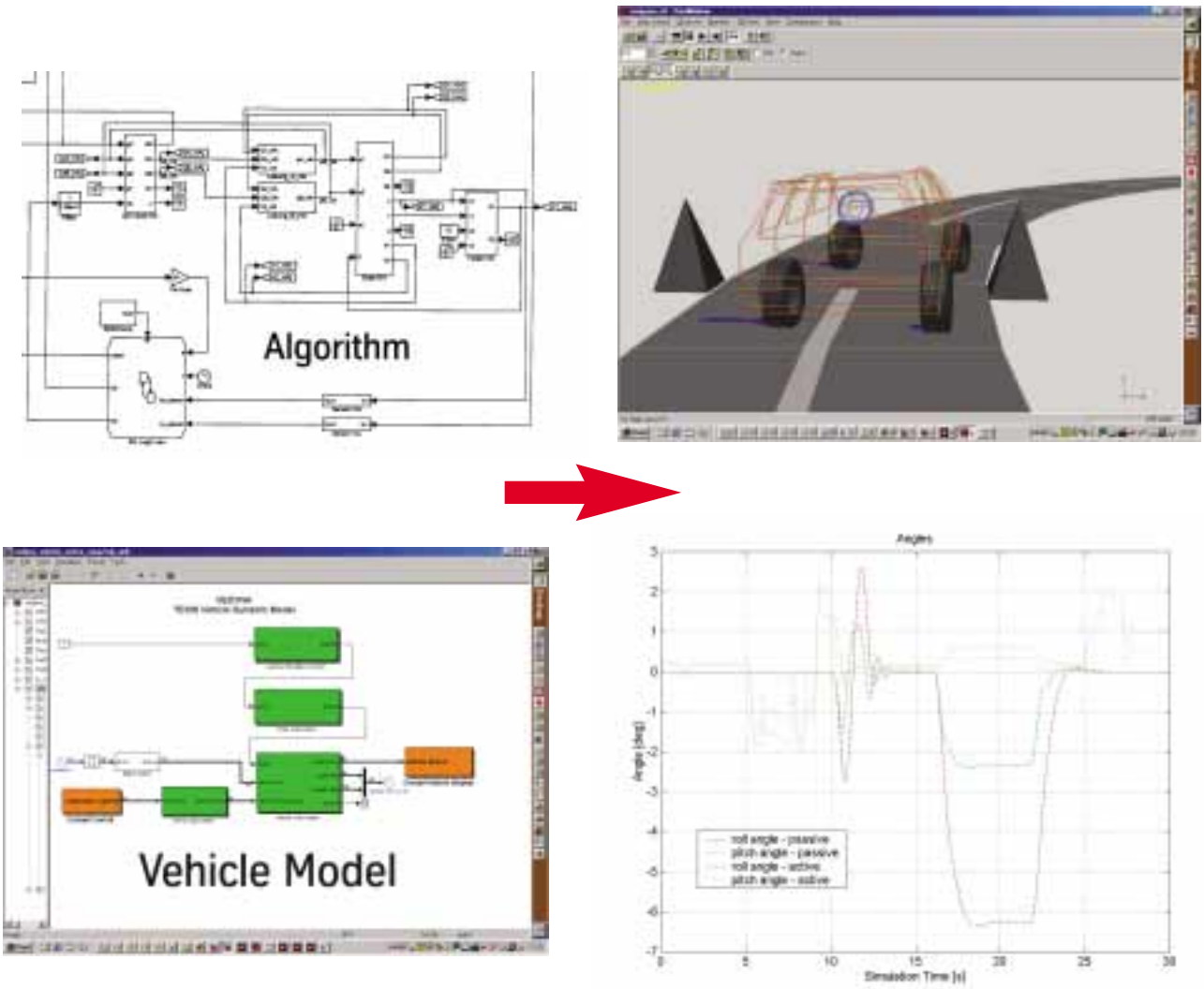
The development of mechatronic systems demands an integrated approach. This means focusing on not only the actuators but also the control algorithms and the total suspension dynamics. To this end, a simulation model is constructed on a computer in order to validate the system as a whole (Fig. 4).

At the same time, this model also serves as the basis for discussions with the customer regarding specifications. Using this method, any necessary changes can be implemented rapidly.

The next step is to convert the results of the design process into prototypes and then verify them on the test bench and in test vehicles. Following successful verification, the requisite hardware and software is put together in specimen assemblies suitable for volume production. Finally, tests are conducted to examine the system's resistance to environmental influences and its operational stability.

Throughout the entire system development phase, any necessary design modifications are carried right through to simulation level. This enables comprehensive verification of both the model and the actual system. The various tools used facilitate an efficient implementation of this process.

System development (Fig. 4)

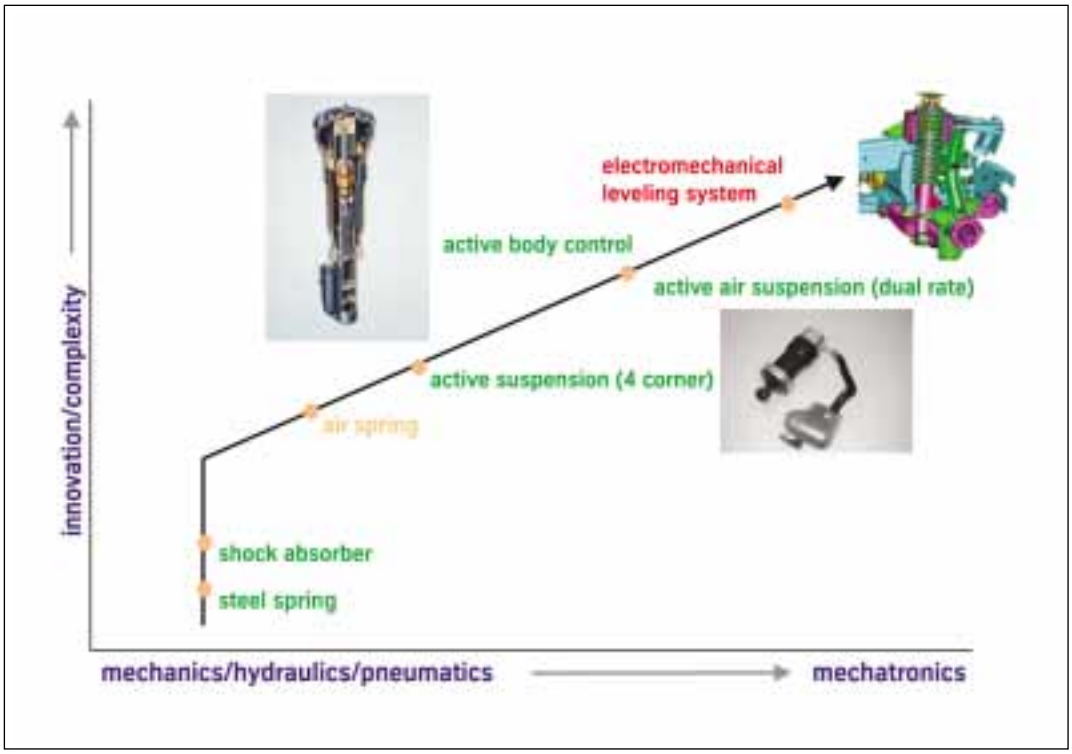


6 Outlook

Today, active systems are increasingly being used to upgrade the "passive" suspensions found in conventional vehicles (Fig. 5).

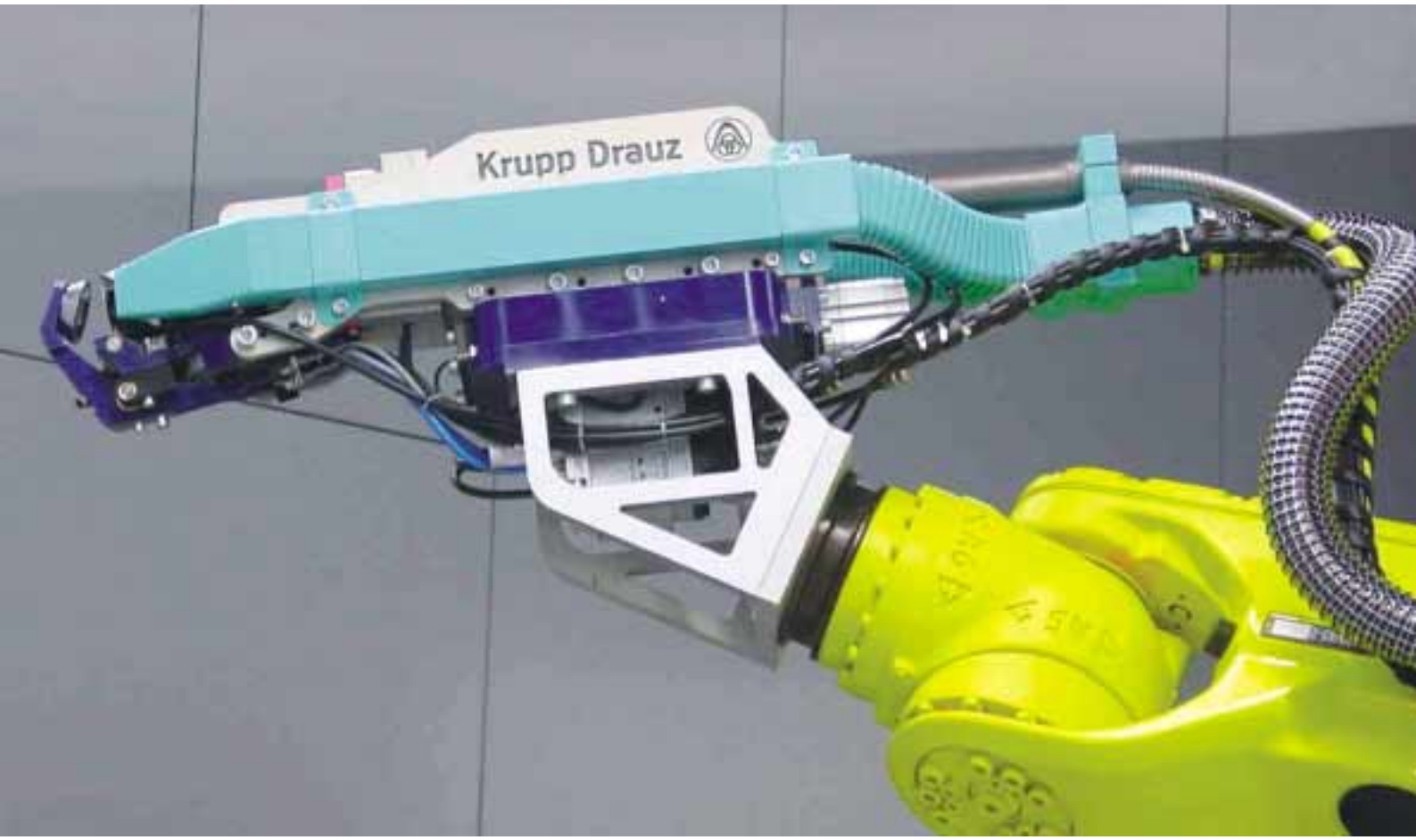
In place of steel springs and hydro-pneumatic shock absorbers, we are now seeing the use of air suspension systems, which are operated as switchable actuators by electronic control units. A further enhancement in functionality comes with the use of hydraulic systems. Future strategy in this field will be to combine the separate mechanical, hydraulic, pneumatic and electronic systems in mechatronic systems that couple electronic and data-processing systems with the electromechanical actuator. In turn, it will then be easy to integrate a number of mechatronic systems within one overall vehicle control system. In this manner, enhanced functionality will be coupled with further benefits such as reduced costs, increased availability and improved safety. The Electromechanical Leveling System represents an important contribution to this process.

Innovation in an automobile through mechatronics (Fig. 5)



Dipl.-Phys.-Ing. (FH) Andreas Möckel
Dr.-Ing. Holger Günther
Dipl.-Ing. Mirko Jansche

Laser welding and clamping system for the body shop



The LSK laser welding and clamping system (Fig. 1)

1 Introduction

Over the past few decades, spot welding has been the favored joining method for the production of bodies-in-white. The advantageous properties of this welding process, e.g. robust technology, insensitivity to interference, easy operation, insensitivity to geometric tolerances, have led to its virtually total domination of welding in the body shop. Vehicle development has been adapted to meet the needs of spot welding, and the designers know all the typical process characteristics.

Even initial problems resulting from the introduction of coated body panels to protect against corrosion were quickly overcome. The development of more rigid vehicles was a reaction to the trend toward, and the desire for, greater protection in the event of accidents. Some joints could no longer be made using spot welding, and the use of MAG weld joints, which were rarely used for thin steel, increased. However, the heat input in each component is relatively high. This means that geometric distortion of components, which has a substantial negative effect on the quality of the finished product, is unavoidable. The aim of manufacturing warp-resistant weld structures with low heat input and high process speed can be achieved using laser welding (Fig. 2, Fig. 3). The availability of high-performance lasers paved the way for the use of laser welding in the body shop.

2 Laser welding in the body shop

The principle of laser welding is fundamentally different from that of spot welding. For spot welding, the two sheets must always be positioned between two electrodes. Resistance heating generates the required heat of fusion. This means that the joints must always be designed to allow access from both sides. With laser welding, the energy required for melting is focused on the surface as “light”. The high energy density of the created “light beam” causes immediate melting. High welding speeds with low total joint energy can therefore be achieved. The intermittent spot welding process can be replaced by a continuous laser welding process, thereby considerably increasing productivity in the body shop. However, the requirements regarding the positioning of components and permissible component tolerances are much higher for laser welding.

3 New clamping concepts

With the flange-like cross-sections that often occur in the production of bodies-in-white, the sheets to be welded are pressed together by the application of high pressure by the tool itself (spot-welding gun) in order to achieve an effective transfer of energy to the component. The pressing together is part of the procedure. This is not the case with laser welding. Initially, the laser beam “only” provides energy. Fixtures are needed to position the components close together and clamp them. If no additional material is used for welding, gaps of less than 0.2 mm are required to create firm joints. This is the first difficulty involved in using laser welding. It also means that closer tolerances will have to be observed in the future when producing bodies-in-white. This means that new clamping concepts are required for various joint geometries.

Another problem hinders the more widespread use of laser welding. The use of coated sheets gives rise to quality problems. The reason for this is the highly different melting temperatures of the parent metal (steel) and the coating material (zinc). During the laser welding process, a so-called vapor capillary is created. The edge of this vapor capillary is surrounded by molten steel. The zinc that is present as coating material is then in the gaseous phase. This gaseous zinc leads to uncontrolled splashing of the molten steel and,

Laser welding process (Fig. 2)

Example of a laser-welded seam (Fig. 3)

as a result, creates pores and holes in the weld seam. The necessary tensile strengths can therefore no longer be achieved. This effect can be prevented by creating a gap of a maximum 0.1 mm between the pieces to be joined. The demands made on clamping technology therefore not only relate to the strong pressing together of sheets but also to creating a small gap. The laser welding head for robot applications developed by ThyssenKrupp Drauz solves this problem.

4 Strategy and concept of the laser welding and clamping system (LSK)

The development of the laser welding and clamping system by ThyssenKrupp Drauz couples the functionality of a spot-welding gun with the advantages of laser welding. This means that the clamping of the joint geometry and the welding can be combined in a single tool. The application of roller clamping technology (Fig. 4) is advantageous not only for the continuous laser welding process but also to guarantee continuous clamping. When using this technology, many requirements relating to wear, temperature loads and soiling must be taken into account.

The zinc degassing between the sheets is accomplished using different types of spacers. So-called burls are currently being used for volume production. Burls are raised bumps in the components that create a gap between the pieces to be joined. They are created when the sheet steel parts are pressed. This process is very cost-intensive and can not always be applied to all components because the direction of forming does not always coincide with the direction of the burls.

Roller clamping technology used on a component (Fig. 4)

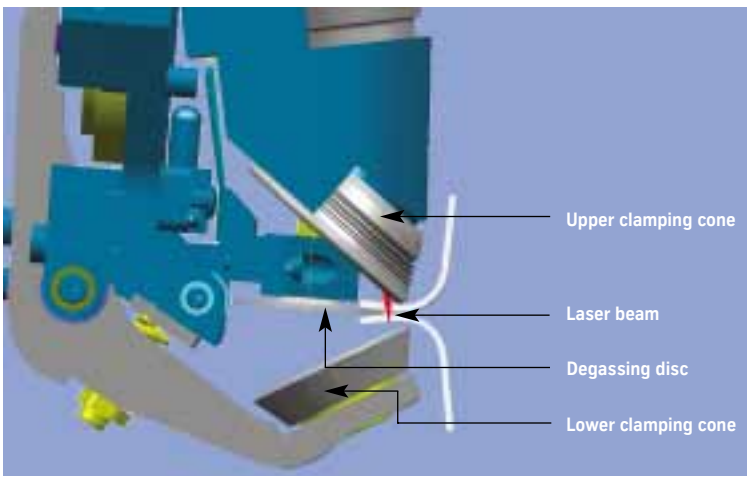
Thanks to the alignment of the roller pairs developed by ThyssenKrupp Drauz (upper and lower clamping cone) (Fig. 5) it is now possible to solve the zinc degassing problem in the laser welding head. This renders the burls superfluous. A degassing disc positioned between the sheets forms the flanges in such a way that a “degassing slant” is created. The fixed arrangement of clamping cone, degassing disc and laser beam guarantees a reproducible joint geometry and, therefore, the consistent quality of the weld seam. The modular structure of the system allows connection to various robot types and adaptation to suit various joint geometries. This means that flanges that are accessible from one side only, such as those that often occur in the floor area of vehicles, can be welded in exactly the same way as those that are accessible from two sides, which accounts for most other flanges in body production. The component structure in the holder, lens, protective equipment, active elements, compensating elements (Fig. 6) and the degassing tool make the application of the laser welding and clamping system in various laser welding tasks even clearer.

5 Process parameters

Various parameters influence the result of the laser welding process. The most important influencing variables include:

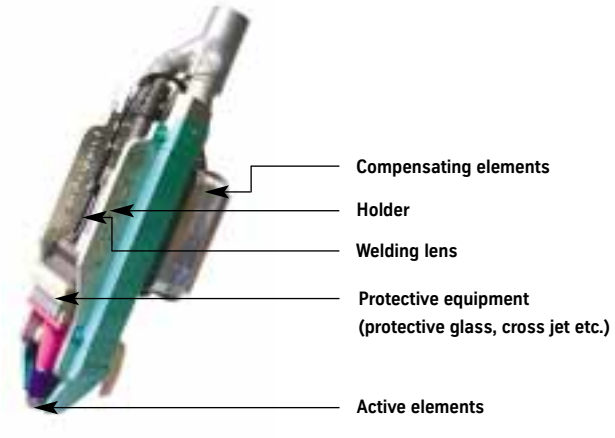
- the position of the focus
- the energy
- the process speed
- the beam incidence angle
- the working gases.

The taper rollers, which counter-rotate, permit high process speeds. This means that the fixed arrangement of the lens in relation to the upper clamping cone always



Detail view of the laser welding and clamping system (Fig. 5)

Components of the laser welding and clamping system (Fig. 6)

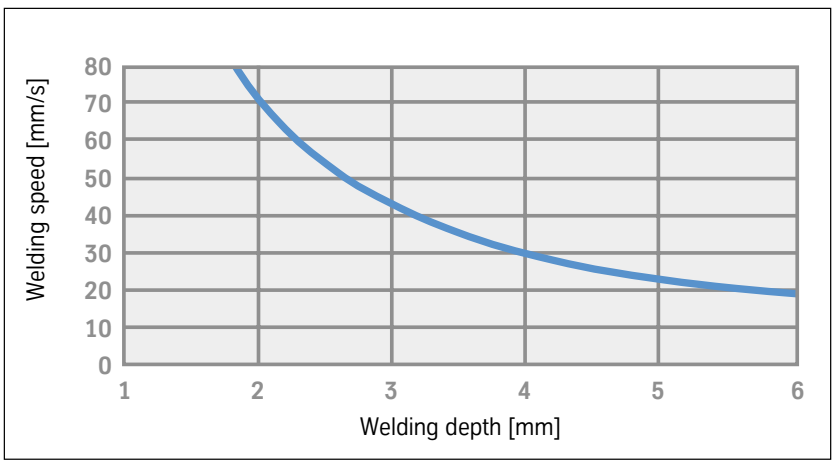


keeps the position of the focus constant. The cross jet is designed in such a way that interfering splashes or other soiling that occurs do not have a negative effect on the welding result. This enables welding speeds of up to 5 m/min (Fig. 7) and higher.

The system is subjected to a wide variety of loads when used in volume production. The proximity of the clamping cone to the weld seam generates high thermal loads. The sheets must sometimes be pressed together with great force, resulting in the creation of high friction and bearing loads. And there are also vapors and welding splashes, which are unavoidable when welding. The developments focus on the materials to be used and on advantageous designs for the various components with a view to maximizing both the service life of the wear parts and the ease of maintenance. By determining the loading cases of the degassing disc and the clamping cone, the design was altered in such a way that its service life was practically doubled. In this way, the maintenance concepts of volume production are also taken into account.

6 Summary and outlook

The laser welding and clamping system (LSK) developed by ThyssenKrupp Drauz combines welding and clamping functions in a single tool. The specially developed geometric alignment of the clamping elements and the degassing disc that is integrated into the tool enable zinc-coated sheets to be laser welded to a high quality without the creation of holes or pores. Welding speeds of up to 5 m/min can be implemented in production. The use of this system has proven particularly advantageous for the door tread plates of bodies-in-white and for window flanges. Flanges in the underbody area can also be laser-welded thanks to the modular structure of the LSK. This means that the system can be used for a broad range of applications in the body shop. Two-sheet joints have been reliably welded in volume production. In the future, the significance of 3-sheet joints is expected to increase. Further developments aim to weld these joints with integrated degassing and roller clamping technology.



Welding speeds for laser welding (Fig. 7)

Dipl.-Ing. Hans Korek
Anne Conrad-Schaller

Fully automatic forging line produces crankshafts with a 7.5-second cycle time

Main units of the new forging line (Fig. 1)

1 Introduction

Recent years have seen an enormous rise in the demand for diesel-powered vehicles, which are generally fitted with a forged crankshaft on account of the greater durability of this type of component. As a result, ThyssenKrupp Gerlach has found it necessary to expand capacity in this market segment. Following a two-and-half-year planning and construction phase, a new production line has now been completed at a cost of around €25 million. This new facility secures the company's position as the world's technology leader in the manufacture of forged crankshafts and, as such, meets a whole range of rigorous requirements. For example, the new production line is fully integrated and automated, from initial sawing of the steel bars right up to complete inspection of the ready-to-ship crankshafts. It has been optimally designed to economically produce four and six-cylinder crankshafts up to a rough part weight of 35 kilograms. Other crucial features include high availability levels, lower manufacturing costs, smooth and rapid program changes, high levels of safety and process reliability, consistent product quality, easy maintenance and inspection, and high environmental compatibility.

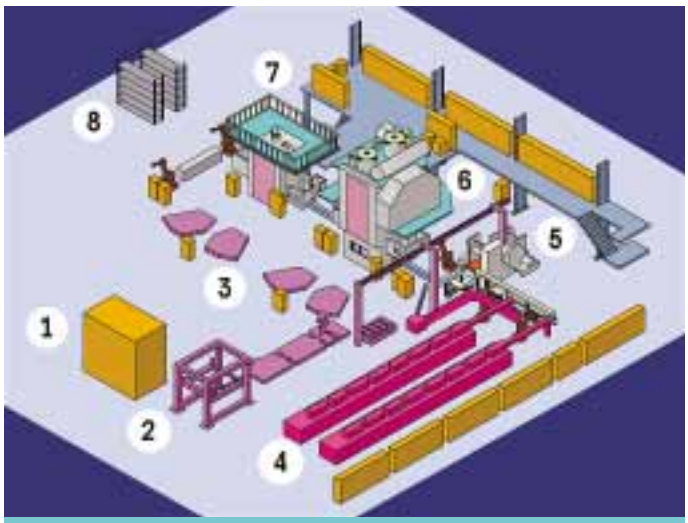
2 The new facility

The new facility is marked by a high level of innovation. Indeed, it is the world's most efficient production line for forged crankshafts and boasts a level of technology never before seen in this segment. This is true, for example, of the following features:

- heating with "stop-and-go" functionality
- rapid forging cycle
- new cooling system for the crankshafts
- fully automated final inspection.

With a cycle time of as little as 7.5 seconds and a throughput time of 4.5 hours from raw material to the customer's container, the new production line achieves a capacity of over two million crankshafts a year. That is more than twice the output of a comparable production line of conventional design. One of the major challenges facing the project staff from the Production

Schematic illustration (Fig. 2)



1 Central operation panel
2 Turning device die bolster
3 Die change system
4 Induction heater
5 Forging roll
6 Main press incl. automatic transfer feeder (preforming, blocker and finish forging, trimming)
7 Combination press incl. automatic transfer feeder (twisting, calibrating)
8 Cooling shelves

Easy-to-maintain induction heater (Fig. 3)

and Plant Engineering departments was to coordinate the individual systems and units from different suppliers – along with their interfaces – so that a unified cycle time could be maintained along the entire production line. The complete facility has CE certification. Equipped with its own decentralized system for compressed air and power supply, the line cannot be affected by any failures in the rest of the plant (Fig. 2).

3 Stations along the production line

Using two fully automated saws from the manufacturer Linsinger, steel bars of up to nine meters in length and 101 millimeters square are cut into blanks with a length of up to 700 millimeters. The saws, which are automatically fed with steel bars by a lifting system, receive the information on where to cut from a database. The advantage compared to shears is greater process reliability, i.e. high repeatability of the section length and quality of the cut surface, both of which are important pre-conditions for a fully automated forging process. Moreover, no preheating is necessary, and the saws operate at reduced noise levels.

Robots are used to transfer the blanks – also known as billets – via a conveyor belt to the two oven lanes of the induction unit

4-cylinder crankshaft in the main press (Fig. 5)

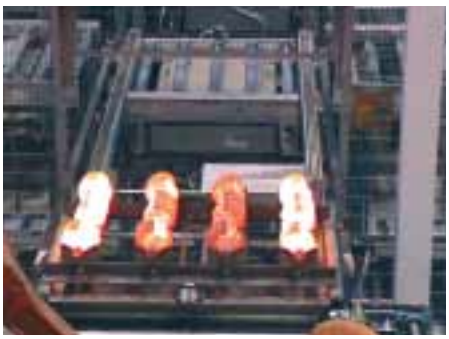
from Elotherm (Fig. 3). The major reasons behind the decision in favor of induction heating were high heat capacity and an even temperature profile – both of which have been shown to help reduce the press force required and to deliver consistently high product quality. Other key factors were the unit's compact dimensions and maintenance-friendly design. At a throughput of 18 t/h and a temperature of 1,280°C, the induction unit is at the top of the performance scale for systems used to feed a 6,500-ton press. The unit can also be operated in reversing mode, so that in the event of a malfunction the billets can be kept warm inside the coils. The last inductor in the unit is equipped with a sensor that checks the temperature of the glowing billets. This information is then communicated to a robot, which selects only those billets with the right temperature and transfers them to the next station, a forging roll. The forging roll from Sumitomo (Fig. 4) is used to achieve an optimal mass distribution within the billets, which is necessary for some types of crankshaft. This operation, which can consist of up to four steps, is required by the forging process and can generate material savings of up to ten percent.

Another robot then transfers the workpieces to the main press from Sumitomo. This has a press capacity of 6,500 tons and has four forming stages – buster, preforming, finishing, and trimming – two of which are always alternately in use (Fig. 5). Air and a forging die lubricant (water-graphite basis) are used to cool the forging dies, which are made in the plant's own die shop. The waste material from trimming is transported away from the production line to a container by way of a chute and conveyor belt.

A robot then transfers the red-hot crankshafts to a combination press from Sumitomo, which twists the workpieces, if required, and calibrates them. The unit has a press capacity of 400 tons; the cycle time is 8.5 seconds with twisting and 7.5 seconds without. Both the main press and the combination press operate with closed doors.

Following this process, a robot loads four crankshafts onto each of the trays of the adjoining cooling system (Fig. 6a). The

Forging roll (Fig. 4)



Tray with hot crankshafts on the way to the cooling shelves (Fig. 6a)

Cooling shelves (Fig. 6b)

Forged crankshaft in a measuring machine (Fig. 7)

cooling system serves as the link between the forging and finishing stages of the production process. This is the first time that this type of high-bay facility has been used in the manufacture of forged crankshafts, and it was also a new departure for the supplier Eisenmann. A total of 2,288 crankshafts distributed on 572 trays can be cooled in around four hours. Two computer-controlled floor conveyor units, each running in its own aisle, insert the trays complete with red-hot crankshafts into the individual bays and then remove them after the requisite cooling period (Fig. 6b). The entire process is fully automatic and controlled by a computer, which regulates the stacking of the bay, the precise cooling time, and the time of removal from the bay in line with a special sequential program. In the event of a fault, the cooling system acts as a buffer or intermediate store and, along with the finishing process, can also be operated completely independently of the forging process. There are two major advantages to such a system: less space is required for cooling standard crankshafts, and the concentrated waste heat of approximately 3,500 kWh can be used. The company is currently looking at how to best utilize this energy.

The trays bearing the cooled crankshafts are transported on a conveyor belt to the finishing area. Here, a total of six robots are in action at the following stations: shot blasting, inspection for clearance, inspection for bending, inspection of the crank envelope, inspection for spreading, crack detection testing (magnetic particle inspection), and packaging. The three universal measuring machines are fully automatic and employ a non-contact procedure featuring laser technology to measure all the dimensions relevant to the crankshaft's proper functioning (Fig. 7). The machines are set up automatically in accordance with parameters from a database.

A die change system equipped with two transfer cars is installed in front of both the main and the combination press. One of the transfer cars carries a die bolster equipped with the complete set of dies plus the upper and lower dies for the next stage in the production process. The second transfer car is used to receive the replaced die bolster. Both cars travel on rails right up to the two presses and equip them. With this system, the process of the changeover is fast and safe, and can be effortlessly accomplished by one employee in around 15 minutes (with a comparable unit of conventional design, the changeover takes 40 minutes and requires two operators). A separate die bolster rotating unit turns the upper die bolster, which weighs up to 20 tons, through 180° and presents it for pickup by the transfer car. A robot in a soundproof washing cabin is then used to clean the die bolster and dies with dry ice. Use of such an enclosed system makes a big contribution to improving health and safety in the workplace.

Robots in the finishing area (Fig. 8)

4 Robots

Such large-scale automation has also been accompanied by continuous developments on other levels. In the past, for example, the robot grippers had to be adjusted by hand for each different type of crankshaft. This involved loosening a screw and matching the gripper elements to the space between the main bearings. Today, the robots are able to automatically adjust the grippers for the new forged part on the basis of information received from a database. In other words, an operator no longer needs to reset the robots. Similarly, the fact that the grippers, the measurement equipment and other units are now adjusted fully automatically means that only one reference program is required for the robots (Fig. 8). Whereas in the past, programs had to be loaded individually for different types of crankshaft, a database now provides the robot control system with the specific parameters for each crankshaft type, which are

Peter Scheid, responsible for the finishing area control system and the coordinator of the forging line, Patrick Philippi (Fig. 9)

then used as the basis for adjusting the grippers. The figures behind this development are impressive: In 1993, there were a total of 15 variable parameters for a crankshaft per production line; on the new production line, that figure has grown to approximately 500.

5 Human resources requirements

The introduction of new forging technology has also brought about a change in the job profile. Whereas in the past, a forging line would be operated predominantly by semi-skilled workers contributing a lot of heavy physical labor, the operation and maintenance of today's modern plant is accomplished solely by skilled workers with training in a metalworking or electrical/electronic field, some of whom also have additional qualifications as a master craftsman or technician. An in-house trainer is responsible for providing employees with the training required to operate the production facilities. The demands are particularly high in the area of electronics/control technology/programmable logic control systems (Fig. 9).

6 Environment

The induction unit and main press are connected to a joint recooling plant that recools the heated water from the inductors and the forging press and then feeds it back into the cooling system.

The main press, which generates a press capacity of 6,500 tons, is mounted on a frame resting on special spring-damper elements. This insulates the plant against the vibrations created by the unit. A trough approved in line with the Water Preservation Act (Wasserhaushaltsgesetz – WHG) and installed beneath the press catches the spray lubricant and oil. This mixture is then pumped into a collection tank, from where a suction vehicle transports it to the plant's own waste water treatment facility. Here, the oil is skimmed off, and the water cleaned by means of a flocculation/precipitation reaction: After flocculation, the heavy metals, graphite, precipitating agent (iron (III) chloride) and other solids are removed from the waste water by means of a chamber filter press. The resulting filter cake is disposed of as waste, and the processed water goes to the local sewage works.

During the planning stage, equipment from the suppliers was scrutinized for noise emissions. As such, it was possible to take appropriate action against any infringement of the statutory limits. For example, a substantial reduction in noise was achieved through modification to the design of the inductors in the induction unit. Similarly, in order to muffle the strong pulsing noise produced when trimming the workpieces, the complex for this process has been enclosed within a special hall. This scrap hall also houses the suction units for the press as well as the cleaning jets and the accompanying filter systems.

7 Health and safety

A comprehensive safety concept has been devised for the production line as a whole. The robots, for example, are located in safety cells, and safety doors seal off the working area of the presses when the units are in automatic operation mode. Workers are not required to directly handle the workpieces – hot or cold – or lift anything at any stage of production. Instead, their work essentially consists of monitoring the process. The high degree of automation in the changeover of dies reduces the danger to workers to a minimum. In the packaging area, laser scanners monitor the safety zones around the rotatable extraction tables and ensure that no workers enter these zones when the tables are in operation.

Dipl.-Ing. Gilles Ferrouillet
Dipl.-Ing. Serge Gaudu
Dipl.-Ing. Luis Moreno

A new concept for starter ring gears and flywheel systems (DEFONTAINE Flexwheel®)

DEFONTAINE Flexwheel® (Fig.1)

1 Introduction

Recent years have seen greatly increased interest in ways of reducing the fuel consumption and CO_2 emissions of automobile engines, all with a view to saving energy and helping preserve the environment.

A whole range of companies, most particularly the automobile manufacturers (OEM), have already done considerable work in this field. To date, they have come up with the following solutions:

- Stop-and-go programs
- Hybrid concepts
- Fuel cells etc.

Such developments were initially a cause of some concern for DEFONTAINE, the world's leading manufacturer of starter ring gears. The problem was that none of the starter ring gears in use around the world was able to match the durability required by the corresponding mechanical solutions.

A development team therefore set to work designing new starter ring gears and flywheel systems for so-called stop-and-go applications.

2 The problems

The problems the development team had to overcome were as follows:

- Component durability
- Noise emissions and vibrations
- Fuel economy
- Low CO_2 emissions.

First of all, the team tested the service life of the ring gears and the starter itself. This yielded a figure of 30,000 to 45,000 start cycles, which in turn corresponds to the standard service life of a vehicle engine.

For stop-and-go applications, the number of start cycles would need to be increased at least tenfold. Another important consideration is the comfort of the vehicle occupants. In this respect, it was important to find a solution that reduced the noise emitted by the starter.

The stop-and-go program offers a way of reducing fuel consumption and CO_2 emissions.

3 Research results

In order to find an appropriate answer to this problem, DEFONTAINE carried out 36 months of experimental work involving the following parameters:

a) Materials
b) Design modifications regarding:

- Transmission ratios
- Number of teeth on the starter ring gear
- Pinion gear design
- Heat treatment.

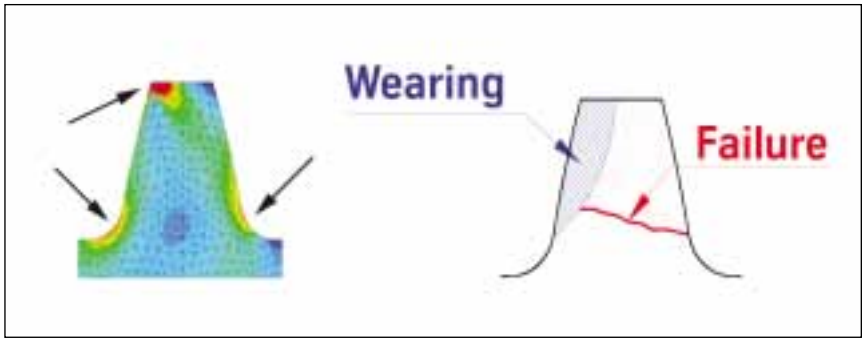
All these parameters were tested. It was discovered that there was no need for a fundamental design change with respect to the platform, engine or the transmission mountings on the vehicle.

During life time of starter ring gear, we can experiment wearing and later, at the very end, a failure of teeth (Fig. 2). Working on stress distribution increases life time of the gear (Fig. 3).

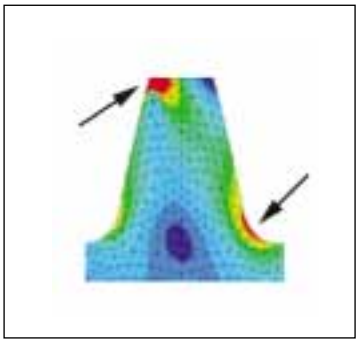
A system was tested that provides extra flexibility when the pinion gear engages with the starter ring gear. Following a total of 20,000,000 start cycles, the specifications had been established with which to patent the system. Today, it is better known as the flexible flywheel or Flexwheel®.

The consequence of this improvement is that the teeth now work with more compression stress (opposing the forces acting on them) and less tensile stress at the teeth bottom (Radius of root).

This use of completely new parameters has resulted in a substantial prolongation

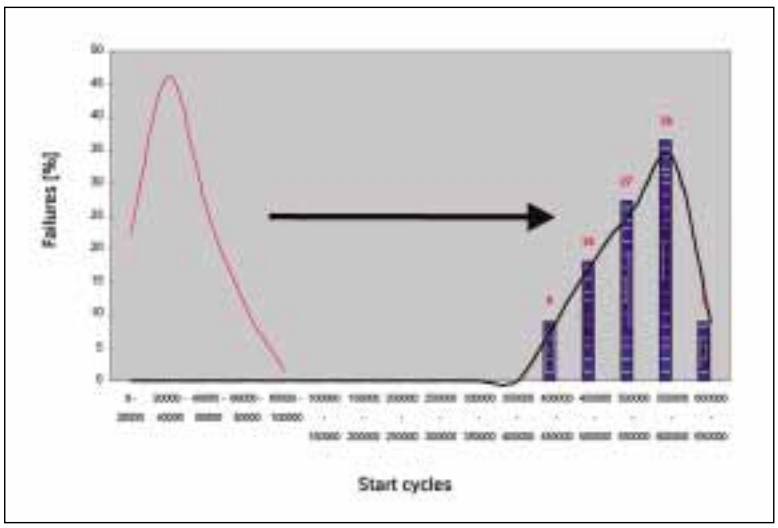


Stress in the tooth of a standard ring gear (Fig. 2)



Stress in the tooth of a Flexwheel® (Fig. 3)

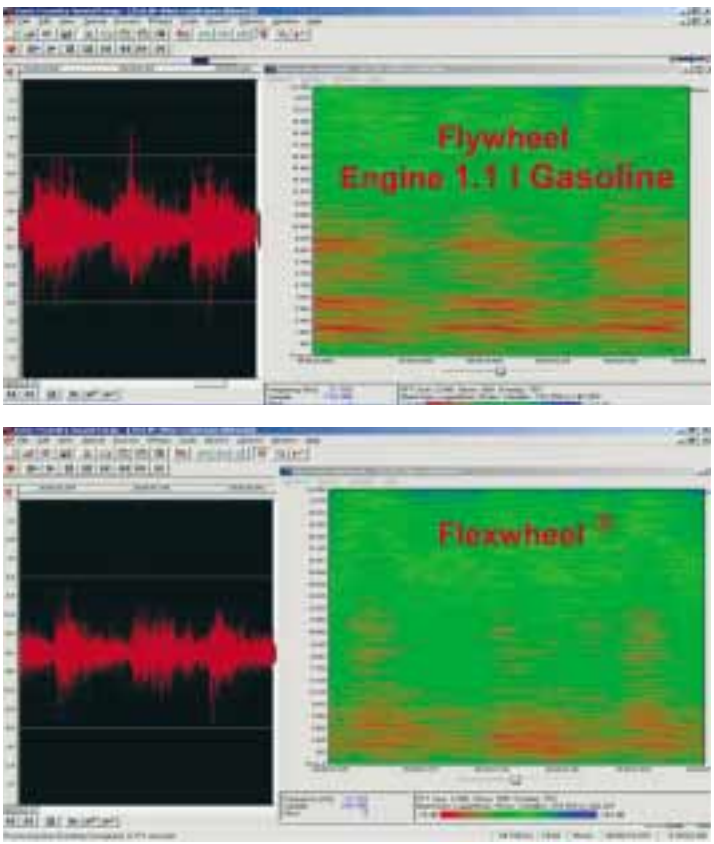
Significant prolongation of service life through Flexwheel® (Fig. 4)



This new development can be used for both gasoline and diesel engines of any size without the need for any modifications to the platform, transmission or engine itself. The associated savings in fuel consumption correspond to those achieved with other, already familiar stop-and-go solutions (between 3 and 10 percent).

of service life (Fig. 4). This is essentially due to the flexibility of the Flexwheel® teeth. It has proved possible to reduce wear to both the starter ring gear and the starter pinion. Using the same material and heat treatment parameters as for the original starter ring gear, a service life of between 300,000 and 600,000 start cycles can be achieved. This is fully adequate for use with stop-and-go solutions.

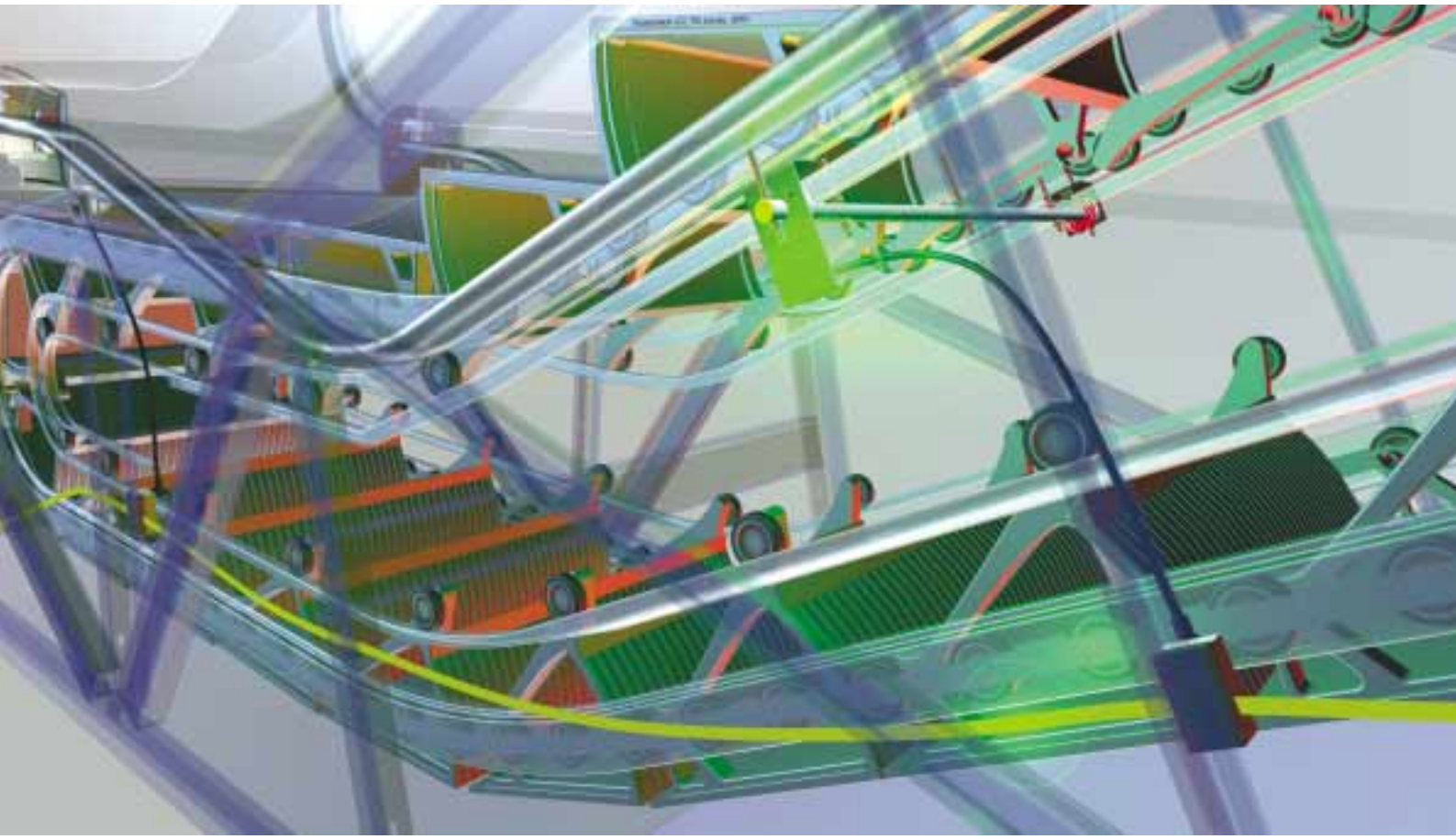
Our development team used a new 1.1-liter gasoline engine to carry out the second phase of the research program. The aim here was to discover ways of reducing noise emissions when the engine is starting. Noise is generated by both vibrations and the engagement of the starter pinion gear. An application for a new patent has been filed, involving the introduction of visco-elastic elements into the Flexwheel®. As shown in Fig. 5, the reduction in noise leads to a substantial increase in comfort. There has been a drastic cut in frequencies above 2,000 Hertz, with decreases of between six and nine decibels measured.



Acoustic study of starting cycle during compression and expansion phases (Fig. 5)

Dr.-Ing. Wolfgang Stein
Dipl.-Ing. Hans-Georg Walter
Dipl.-Ing. Hartmuth Willnauer

FT 900 e-escalator series



Digital monotoring by the sensors via the certified bus system (Fig. 1)

1 Introduction

Visitors to the 'Barkhof-Passage' shopping mall in Hamburg might not be aware of it, but they are actually entering new territory. As soon as they set foot on the escalator, they have one foot in the World Wide Web. For here in downtown Hamburg is the first escalator in the world to be hooked up to the internet: the e-escalator created by Thyssen Fahrtreppen (Fig. 2, Fig. 3). The new 900 series features a specially developed and patented technology that makes it possible to monitor the escalators online. This substantially improves the operation, service and safety of the escalators and thus significantly increases their availability.

2 Central Monitoring System

Two technological innovations are responsible for getting the escalator online: the Central Monitoring System (CMS) software and a new bus system. The Central Monitoring System uses an internet access device to monitor the e-escalator and presents all the operating parameters needed by the customer on a PC monitor (Fig. 4) – for example, the number of the operation hours the percentage of availability and a precise list of the upward and downward movements. The data are gathered by numerous sensors that monitor the e-escalator's operation at all key points. All sensors deliver their information to a central unit via a single bus cable (Fig. 5). The data are then transferred from the local diagnostic display to the internet access device, which manages the transfer of the data via the interface. This unit can serve up to eight systems via the interface. The e-servicing of the e-escalator thus offers the world's first internet-based escalator diagnostic system.

3 Breakdown procedure

If one of the escalators malfunctions, this is immediately registered and analyzed via CMS. The computer display shows which system has a problem: The Central Monitoring System presents a simplified floor plan of the building in question with 3D images of all the escalators. If the color of the escalator symbol changes from green to red (Fig. 6), the operator immediately knows that something is wrong. A double-click on the button above the flashing red escalator provides the service operator with a detailed picture of the situation. A cutaway diagram of the escalator shows its anatomy in detail, and an information window opens up next to the defective part to reveal the cause of the breakdown. This could be a problem with the bottom handrail inlet guide, a blockage in the area of the top comb segments or simply an emergency stop. The latter problem occurs rather frequently on escalators in public areas such as subway stations, where it is relatively easy

'Barkhof-Passage' project, Hamburg (Fig. 2)

'Barkhof-Passage' project, Hamburg/front view (Fig. 3)

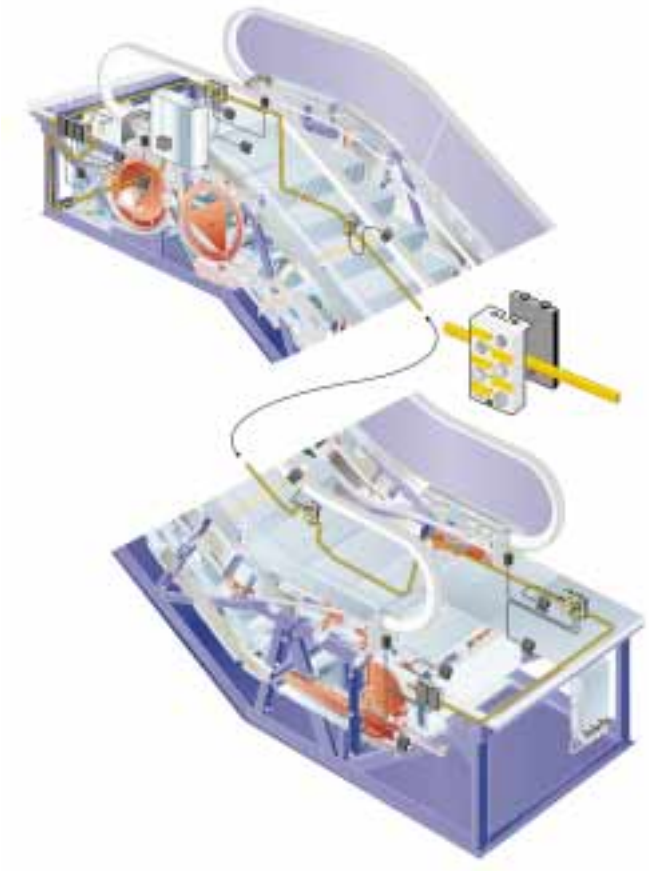
Visualization of the operating parameters on the PC monitor (Fig. 4)

for pranksters to disable a unit. The Hochbahn transport company in Hamburg, a long-standing customer of Thyssen Fahrtreppen, experiences about 50,000 such "false alarms" per year. These reduce the availability of the escalators and result in increased service costs and annoyance to passengers.

The new technology in the e-escalator can help here. Because the malfunction is analyzed online within a few minutes, a service team can be summoned via an e-mail or text message providing optimum information and then take any necessary replacement parts to the unit in question. In the event of an emergency stop, a telephone call to the building janitor or on-site security service is all that is needed. A quick look at the escalator, and it can be restarted without the need for any servicing. This type of "maintenance on demand" makes escalator operations highly cost efficient by avoiding time-consuming and unnecessary call-outs.

Another aspect of the new 900 series that increases escalator availability is a new fault prevention system. The CMS continually monitors and documents all essential operating parameters in its diagnostic memory. Brake wear, braking functions, cover plate contact, gear oil temperature, oil levels or power supply – the sensors connected to the bus cable deliver all the necessary information, and the CMS compiles statistics for optimal maintenance planning. Any deviation from the norm is registered immediately, and this innovative early warning system helps avoid expensive repairs later on.

There is yet another feature making the e-escalator the most advanced in the world today: an innovative acoustic monitoring system for the comb segments. A patented detector immediately sounds an online alarm if a fault occurs in these heavily used escalator components. Any break in a comb tooth will generate an altered acoustic signal that is recognized by the appropriate sensor, which then sends a message via the internet to the operating center. The entire communication route in the e–service process, from the escalator via the World Wide Web to the system operator (including all IP addresses, commands and escalator data), is encrypted. This makes the system inaccessible to unauthorized persons and prevents any data manipulation.



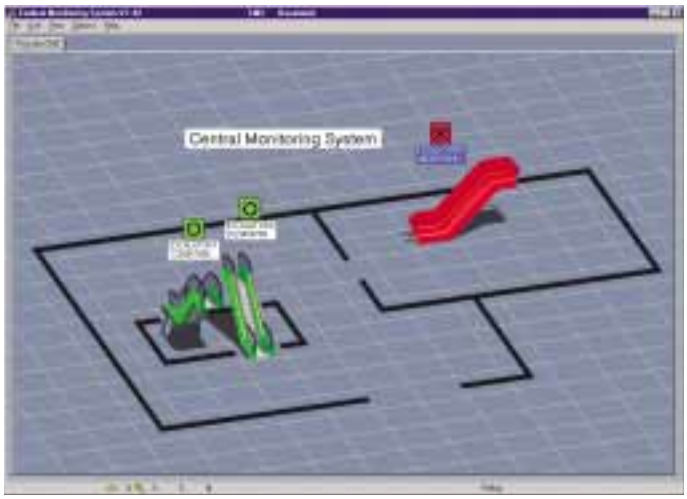
Escalator control via bus system (Fig. 5)

4 Outlook

The e-escalator developed by Thyssen Fahrtreppen is the most innovative means of transportation of its kind. The technology of the e-escalator can also be constantly updated as the technical potential of the internet develops further. Additional sensors can be connected to the bus cable as required without any difficulty.

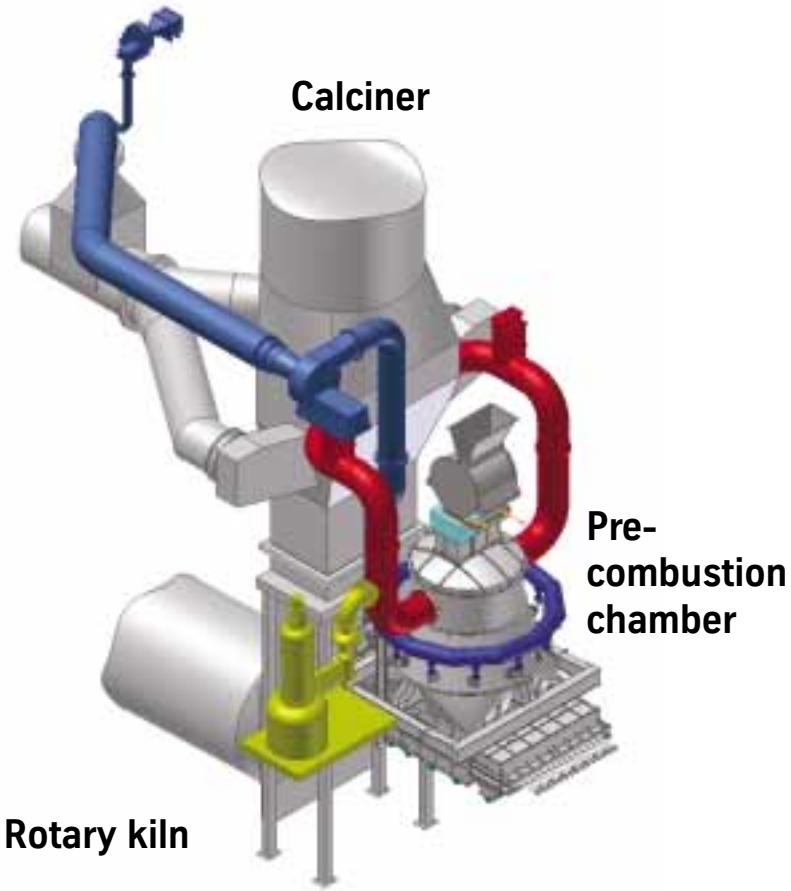
The Hamburg specialists are now working on an innovative system of e-monitoring to round off the range of services. This system will make it possible to monitor and control the escalator of the future entirely via the internet. Webcams will deliver real-time images to a Thyssen e-server – a process that will, for example, make it possible to restart the escalator via remote mouse click if an emergency stop is seen to be a “false alarm”. The operator will simply use a dynamic, regularly up-dated password to contact the escalators via a Thyssen Fahrtreppen web portal. The server will trigger the systems chosen by the operator, which will then send back their data. The data and web images of the escalator in question will then be available within seconds.

Failure information via CMS (Fig. 6)



Dr.-Ing. Ludger Brentrup
Dr.-Ing. Ralf Osburg

New pre-combustion chamber for lumpy secondary fuels



Integration of a pre-combustion chamber into a cement kiln (Fig. 1)

1 Overview

In the last 10 to 15 years or so, there has been a considerable increase in the use of secondary fuels in the cement clinker burning process. In comparison to other conventional fossil fuels, these fuels currently have a market share of 30 percent in Germany. There are therefore plants in which up to 70 percent of the heat required for the clinker burning process is provided by materials such as

- waste oil
- solvent waste
- old tires
- sewage sludge etc.

These materials are generally a lot more difficult to deal with and cause more process-related operating problems than heavy oil or coal dust, for example. However, they are considerably more popular with cement plant operators because of their significantly lower cost. "Negative fuel costs" are even possible for certain materials such as old tires, due to the credits that can be obtained on the secondary fuel market. In addition to the economic arguments, it is also worth mentioning the environmental aspects. Since the secondary fuels conserve natural resources they are defined as being "CO_2 neutral" and their use in cement plants greatly helps dispose of problematic residual materials. This is currently a very important argument in view of the self-regulation activities of various industries concerning emission reduction and the threatened imposition of taxes on CO_2 emissions.

The following article describes a technology that was developed to industrial maturity at Polysius five years ago. Thanks to this technology, lumpy, secondary fuels, such as old car tires, can be used – without limitations in terms of process technology or quality – to produce cement in cement burning plants with precalcination.

2 Background

In modern cement burning plants, approximately half of the fuel is fed into the calciner and the other half into the sintering zone. The cement clinker goes through the final burning process at material temperatures of around 1,450°C in the sintering zone. In other words, the preheated raw meal that is calcined at approximately 850°C in the calciner reacts to form the clinker minerals in a sintering process. Cement is finally produced following the joint grinding of the cement clinker with a setting regulation agent (gypsum). Large cement plants have a production capacity of several thousands of tons of cement clinker per day, while several hundreds of tons of fuel are required during the same period of time.

Owing to the high temperatures and the need for consistency, only high-quality fuels that can be accurately metered are used in the sintering zone. Lumpy materials such as car tires and many other secondary fuels are not suitable here for reasons of product quality and process stability. The combustion processes and the calcination of the raw meal run parallel to one another at much lower temperatures in the calciner. However, the calciners in the cement kilns are suspension pre-combustion chamber reactors, i.e. the raw meal that was finely dispersed in the flue gas stream of the rotary kiln is calcined in the entrained flow and receives the necessary energy from a similarly finely dispersed fuel – from coal for example, that is being simultaneously combusted there. It should therefore be clear that approximately 50 percent of the overall heat required for the cement burning process has to be supplied in the calciner. However, lumpy fuels that are therefore not dispersible either cannot be used here at all or can only be used with compromises and in extremely limited amounts. The fuel comminution technology that has to date been used to solve this problem in cement plants is energy and cost-intensive and thus has a negative impact on results. Polysius has therefore developed the pre-combustion chamber technology as a replacement solution.

On account of the aforementioned considerations, an R&D program was set up approximately five years ago with the aim of developing a reactor that can be integrated into the cement burning process. This reactor essentially meets the following requirements:

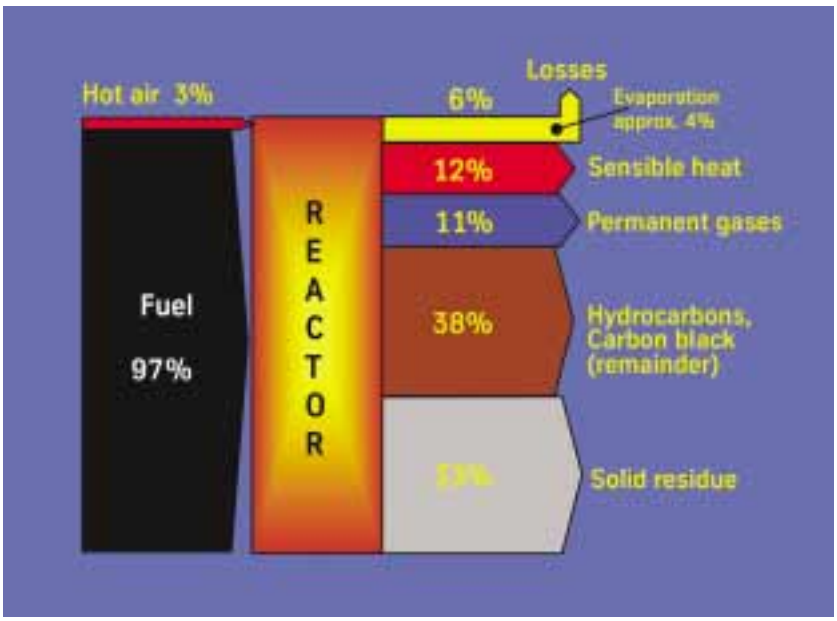
- The use of lumpy, secondary fuels, e.g. old timber or old tires (including those from trucks)
- The constant and controlled implementation of secondary fuels without producing a negative effect on the cement burning process and the quality of the cement
- The integration of occurring residual materials into the cement clinker
- A reduction of the process-determined emissions such as nitrogen oxide
- Operation at ambient pressure.

Although the pre-combustion chamber is fundamentally not dependent on one particular secondary fuel, the first development concentrated on the use of old tires for the following reasons:

- Old tires are an established and environmentally accepted fuel in the cement industry (Fig. 2), but they can only be used in relatively small quantities.
- The comminution process of old tires is both energy and cost-intensive.
- Attempts to develop a material preparation process for old tires have so far been unsuccessful.
- Old tires present a problem in terms of disposal in many countries and are in sufficient supply (approx. 2.5 million tons per year in the EU, for example).
- Sufficient credits are also paid for uncomminuted old tires on the secondary fuel market. Together with the fuel savings, they enable the amortization of the necessary investments within the space of a few years.

Storage of old tires in a cement plant (Fig. 2)

Energy balance of old tire gasification (Fig. 3)



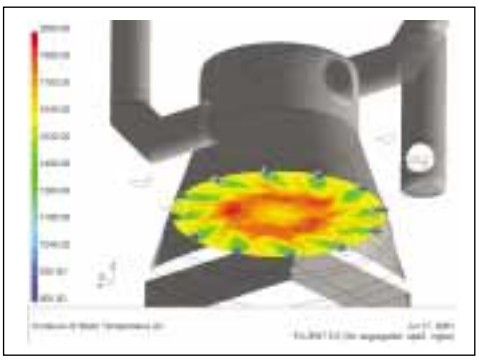
3 The development of the pre-combustion chamber

The pre-combustion chamber was developed by an interdisciplinary team from the Research and Development department at Polysius AG. After the initial considerations and the first tests carried out in the laboratory and technical test center, the following sequence was established: The old tires are converted sub-stoichiometrically in a shaft reactor using the exhaust air from the cement clinker cooler. A gaseous phase is produced from the volatile components of the tire rubber. Without undergoing any further treatment, this gaseous phase is fed directly into the calciner, where it is burnt. A solid phase consisting of a coke-type residual material and the wire contained in the tires remains in the reactor. Approximately two thirds of the original gross calorific value of an old tire goes into the gaseous phase and the remaining third goes into the solid phase. An energy balance of the process is represented in Fig. 3. It would be costly and pointless to further convert the tire coke into the gaseous phase. This coke thus contains a considerable proportion of energy and represents a high-quality fuel. Fig. 4 illustrates the "steel wire" and "coke" components resulting from a separation process integrated in the overall process and performed by the residue discharge and separation floor. Fig. 5 shows a 3D section with a view into the reactor.

The old tires enter the reactor at the reactor head via a specially developed rotary air lock. The hot gasification air from the clinker cooler is added via a circular pipeline and several nozzles (Fig. 6). In order to achieve high conversion rates and consequently a reactor that is not too bulky, it is necessary to produce temperatures that are as high as possible in the reaction zone. For this purpose, the gasification air is added at a certain angle and as a rotational flow to the tire bed that is

Solid phase components of old tire gasification (Fig. 4)

Simulated temperature distribution within the pre-combustion chamber (Fig. 7)



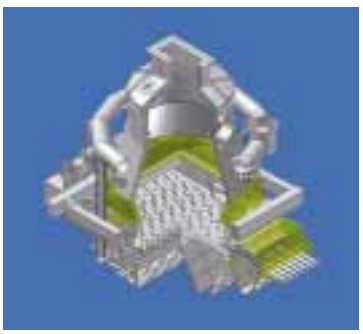
forming. However, it is also necessary to protect the brick-lined outer wall of the pre-combustion chamber from excessively high temperatures. The CFD simulations (CFD: computational fluid dynamics) of the flow and reaction processes in the reactor played a significant role in optimizing the design of the reactor so that it meets these requirements. Fig. 7 illustrates the calculated temperature distribution. A very hot ring-shaped zone is located toward the center of the pre-combustion chamber and not in the direct proximity of the wall.

The residual coke and wire materials reach the lower part of the pre-combustion chamber after the degasification process, i.e. the expulsion of the volatile components from the tire rubber, which is largely completed within the space of a few minutes under these reaction conditions, even when dealing with large and heavy truck tires. After the thermal decomposition process, the tire coke is still loosely connected to the wire. The discharge system consists of several hydraulically operated bars arranged side by side and equipped with specially shaped conveyor elements. The wire and coke phases are largely separated by the process of transporting the residual material to the rotary kiln inlet. The wire is completely integrated into the cement clinker, thereby replacing a part of the iron component that would otherwise be added to the raw material. The coke falls through the bars, is collected by a flat bottom conveyor and then metered into the calciner.

An aforementioned requirement for combustion in the calciner is thus fulfilled. Both the gaseous and coke phases have properties or particle sizes that make them suitable for the “calciner” entrained-bed reactor. They thus enable the desired temporal and spatial proximity between the energy-supplying combustion and the energy-consuming heating and calcination of the raw cement meal.

4 The state of the art

Once the theoretical studies and practical investigations in the laboratory and technical test center were completed, a small pilot plant was put into operation in a Swiss cement plant over several months. The customer was so impressed by the results achieved and the overall procedure that an order for the first industrial plant for the conversion of three tons of old tires per hour was placed in 1998. After joint commissioning and a few improvements, this plant was handed over to the customer in the fall of 2000. The knowledge gained here was instrumental in the design of a second plant which went into operation in a German cement plant in May 2002. This plant is able to convert 5 tons of old tires per hour and save approximately the same quantity of coal. Fig. 8 shows a view toward the top of the brick-lined reactor where the tires are fed in via the rotary air lock. One of the product’s gas ducts through which the hot gaseous phase is led directly to the calciner can also be seen.



Sectional view of the pre-combustion chamber (Fig. 5)

Supplying gasification air to the pre-combustion chamber (Fig. 6)

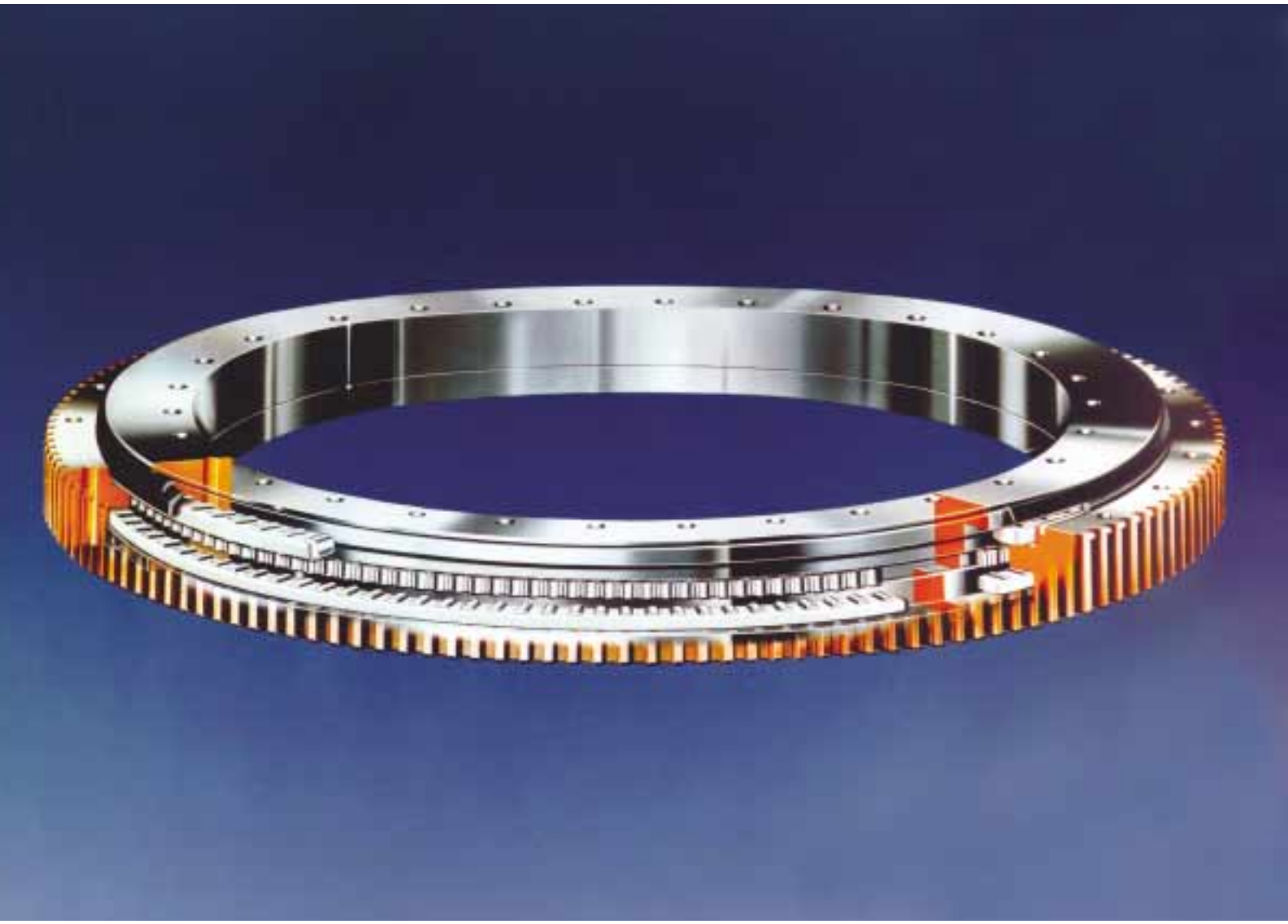
5 Summary

By developing the pre-combustion chamber, Polysius AG successfully entered the market for secondary fuel handling and disposal for the first time ever with this strategic product. The combination of the economic benefits and environmental advantages satisfies two key criteria regarding a successful market launch. The selected technical concept opens up a whole new range of uses for the Polysius pre-combustion chamber, while keeping investment costs low. As a result, the high flexibility and short amortization times have attracted the interest of many customers.

View into a refractory-lined pre-combustion chamber from bottom to top (Fig. 8)

Dr.-Ing. Thomas Handreck

Analysis of large-diameter antifriction bearings in conjunction with customer-specified companion structures



Three-row roller bearing from slewing ring from Rothe Erde (Fig. 1)

1 Introduction

Large-diameter antifriction bearings are used to create a rotatable connection between two machine parts which allows forces and moments to be transmitted in any direction. They are used in many areas of engineering, particularly in materials-handling technology, tunnel boring equipment, and wind turbines. There are different types of large-diameter antifriction bearings, including roller and ball bearings as well as single-row and multi-row versions (Fig. 2). As a rule, a large-diameter antifriction bearing is connected to the companion structures by means of high-strength prestressed bolts. For the bearing to function properly, the companion structures must display sufficient stiffness distributed as evenly as possible around the circumference of the bearing.

2 The problem

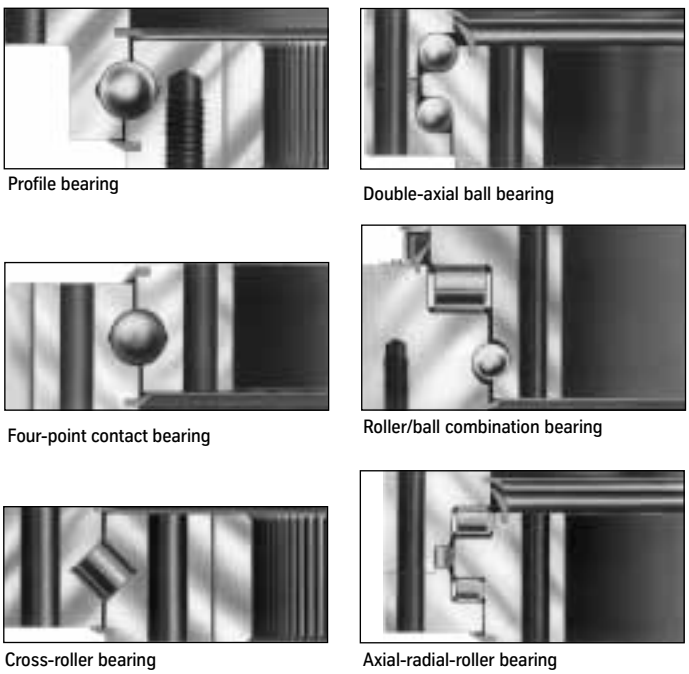
There are numerous difficulties involved in analyzing the bearing's raceway system and fastening bolts. For example, the force-deformation behavior of the rolling elements at their areas of contact with the raceway is nonlinear. Similarly, the contact angle of the balls in a ball bearing changes when the bearing is subject to a load. In roller bearings under load the bearing ring can tilt, thereby leading to uneven distribution of surface pressure along the length of the rollers. Depending on their use, large-diameter antifriction bearings are either manufactured with clearance or prestressed. This aspect must also be taken into account during the analysis.

When subject to minor loads, the bolted connection between the bearing rings and the companion structures initially acts in a linear-elastic manner. Larger loads, however, especially large tilting moments and lifting axial forces, cause a partial opening of the contact surfaces between the bearing rings and the connecting flanges (Fig. 3). In such circumstances, the elastic behavior of the stressed components changes. In addition, there is a major redistribution of the forces acting on the rolling elements within the raceways.

The bearing rings used for large-diameter antifriction bearings have a relatively large diameter in relation to their cross-sectional area. Consequently, their inherent stiffness is limited. For this reason, the supporting stiffness provided by the companion structures has a major influence on the load-bearing characteristics of such a bearing.

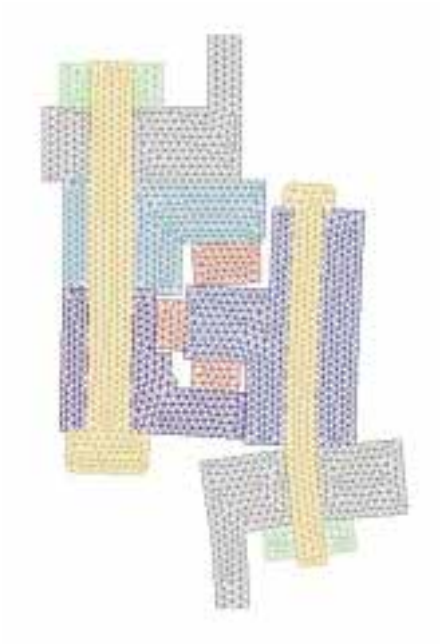
Conventional analysis methods can be divided into two groups. The first group comprises highly simplified approaches, which as a rule proceed upon the assumption that the bearing rings are rigid. As such, they focus merely on the contact stiffness of the rolling elements and the raceways. The stiffness of the companion structures and the elastic behavior of the bolted connections are ignored. Such methods will rapidly generate an approximate solution. In a specific case, however, the results they produce can differ quite substantially from the values actually measured.

The second group comprises complex numerical approximation methods generally based on finite element analysis. In a process involving much manual effort, models are drawn up that take account of all parameters of importance for the analysis. Such a model must include the raceway system, the bolted connections and the two companion structures. If the analysis is carried out by the manufacturer of the large-diameter antifriction bearing, then the company will first have to obtain detailed



Examples of various designs of large-diameter antifriction bearings (Fig. 2)

Exaggerated illustration of cross-sectional deformation in the case of high lifting stresses (Fig. 3)



information regarding the companion structures. Experience has shown that study of the design documentation and the subsequent modeling process are extremely time-consuming. On the other hand, customers conducting the finite element analysis must first obtain all the requisite data from the manufacturer so as to gain the specialized knowledge required to model the bearing.

And even when all this has been accomplished, it is still not absolutely certain that the results achieved will provide a sufficiently accurate representation of what actually happens in reality. Even on a modern PC it is not possible without additional optimization of the solution algorithms to draw up a model that contains all the required details. An enormous amount of memory and computing power is required to be able to simultaneously solve the contact problems in the bearing itself and in the contact surfaces between the bearing rings and the flanges. For these reasons, such calculations are often carried out in two steps, using somewhat simplified models. In the first step, the load distribution in the raceway system is calculated, taking into account the stiffness of the bearing rings and companion structures as well as the contact stiffness of the rolling elements-raceway pairs. At this stage, the specific characteristics of the bolted connections and any opening of the contact surfaces are not taken into consideration. The second step of the calculation employs a part model comprising ring segments bolted together. This generates very precise data on the stiffness of the stressed parts and the bolts themselves as well as the contact properties in the contact surfaces. The load selected here is generally based on the maximum forces acting on the rolling elements as determined in the previous calculation of load distribution. Sometimes, the internal forces and moments acting on the edges of the cutaway ring segments are also incorporated into the second part model. Although this method of conducting a finite element analysis for large-diameter antifriction bearings is widely used, it nevertheless has substantial drawbacks. Neglecting the opening of the contact surfaces between the bearing rings when calculating the load distribution leads to insufficiently accurate determination of the maximum forces acting on the rolling elements under high loads. Moreover, if these inaccurate values for the rolling element forces are then used as loads in the second part model, the non-linearity present results in the calculated additional stresses on the bolts being subject to an even larger relative error. These large deviations are due to the fact that in practice, the opening of the contact surfaces under high loads leads to a significant redistribution of the forces acting on the rolling elements, which likewise substantially modifies the load placed on the bolts.

3 The task

In the light of the analysis of the methods conventionally used to conduct calculations for large-diameter antifriction bearings, we specified the following requirements as essential for any new computation procedure:

- In order to achieve a high degree of agreement between computed and empirical results, the following three major factors must be simultaneously accounted for in one and the same comprehensive model:
  - the contact properties of the rolling elements and the raceways
  - the elastic behavior of the bolted connections, including any partial opening or slipping of contact surfaces and
  - the supporting stiffness of the two companion structures.
- Manual processing requirements should be substantially reduced in comparison to the effort conventionally required to draw up finite element models.
- It should be possible to use a modern, averagely equipped PC to conduct a complete analysis for a bearing in a processing time of less than one hour.
- Customers should no longer have to come to terms with the design details of the large-diameter antifriction bearing. Similarly, the bearing manufacturer should no longer have to deal with the specifications of the companion structures.

4 The solution

In the development of new machines, the finite element method is increasingly used to optimize prototypes. Unlike in the past, the practice of verifying individual components in isolation is less and less accepted today. Today, optimizing a piece of plant or machinery in which a large-diameter antifriction bearing is to be used is a joint task involving the machine manufacturer and the bearing manufacturer.

First of all, the model as a whole is divided into three part models (Fig. 4). This spreads responsibilities between the customer and the bearing manufacturer and thereby establishes the basis for an economical analysis. Fully centralized development of an overall model is no longer necessary. This avoids the problems involved with having to interpret unfamiliar design documentation. The three part models are as follows:

- the upper companion structure from the customer
- the large-diameter antifriction bearing including fastening bolts
- the lower companion structure from the customer.

According to the new analysis method, the customer draws up separate finite element models for both the upper and the lower companion structures. Contrary to the conventional procedure, however, these models initially serve only to analyze the stiffness of the companion structures. The customer then receives instructions from Rothe Erde – the large-diameter antifriction bearing manufacturer – on how the models of the companion structures should be adjusted in the area of the bearing flange so as to guarantee their problem-free combination with the finite element model of the large-diameter antifriction bearing. For the finite element models of the companion structures, there is no particular limit to the number of degrees of freedom or details incorporated. In a subsequent step, the overall stiffness matrices thus generated, which may be of any order of magnitude, are reduced by a process of static condensation to the degrees of freedom of the connecting nodes in the area of the bearing connection. This generates files of a few megabytes in size, which the customer can easily send to Rothe Erde via e-mail.

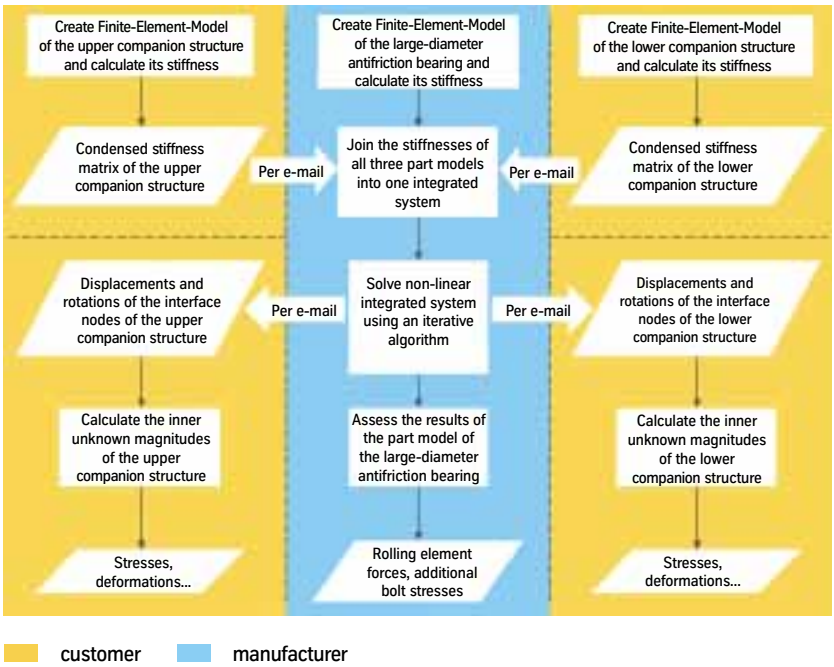
Finite element model of the upper companion structure

Finite element model of the large-diameter antifriction bearing

Finite element model of the lower companion structure

Mobile harbor crane; divided into three part models (Fig. 4)

Schematic of the calculation method designed by Rothe Erde (Fig. 5)



At Rothe Erde, special software has been developed that enables the part model of the large-diameter antifriction bearing to be generated efficiently. This procedure also employs a finite element model, which covers the bearing rings, the rolling elements and the fastening bolts. The cross-sections of the individual bearing rings are described by means of input data similar to that used in CAD. The amount of data on the rolling elements and the fastening bolts is only minimally greater than that required for the procedure used to date and can be extracted from the company standard. The customer files with data on the reduced stiffnesses of the companion structures can be directly imported by the special software without any manual processing and then added to the model of the bearing (Fig. 5). This generates a complete model in which all the key factors are taken into account simultaneously.

For ball races, the results are based on a distribution of the individual ball forces in terms of magnitude and direction; for rollers, on the distribution of the individual roller forces and their eccentricities. In addition, the calculation also covers the contact surfaces for the raceway system, the pressures in the contact surfaces, the maximum forces acting on the rolling elements and the resulting theoretical life of the bearing. Similarly, any clearance or prestressing in the bearing can also be taken into account in the calculation.

In special cases such as design deviations or where the mounting flange of the bearing is known to deviate from the plane, or incorporates bends or eccentricities, these factors can also be incorporated in the calculation. The large-diameter antifriction bearing can be subject to a load of any complexity. It is also possible to simulate different turning positions of the rotatable part of the bearing with respect to the stationary part. This is done by altering the parameter that reflects the angle of rotation. Similarly, any opening of the contact surfaces between the bearing rings and flanges can be simulated very accurately. Here, the simulation takes into account the possibility that the contact surfaces could open to both the inside and the outside. The contact behavior in the contact surfaces depends upon the specified coefficient of friction. As soon as this coefficient is exceeded, the model automatically moves from a state of static friction (stiction) to the simulation of slipping friction in the individual bolted ring segments.

In the model, the fastening bolts are prestressed comparable to what occurs in a cooling process. The analysis model simulates the full range of spatial loads on the bolt, i.e. bending around two axes, torsion, tension and compression, and transversal forces in two axes. The results are generated in terms of either the additional stress relative to the original prestressed state or as an absolute stress. Similarly, the stresses in the bearing rings can also be calculated.

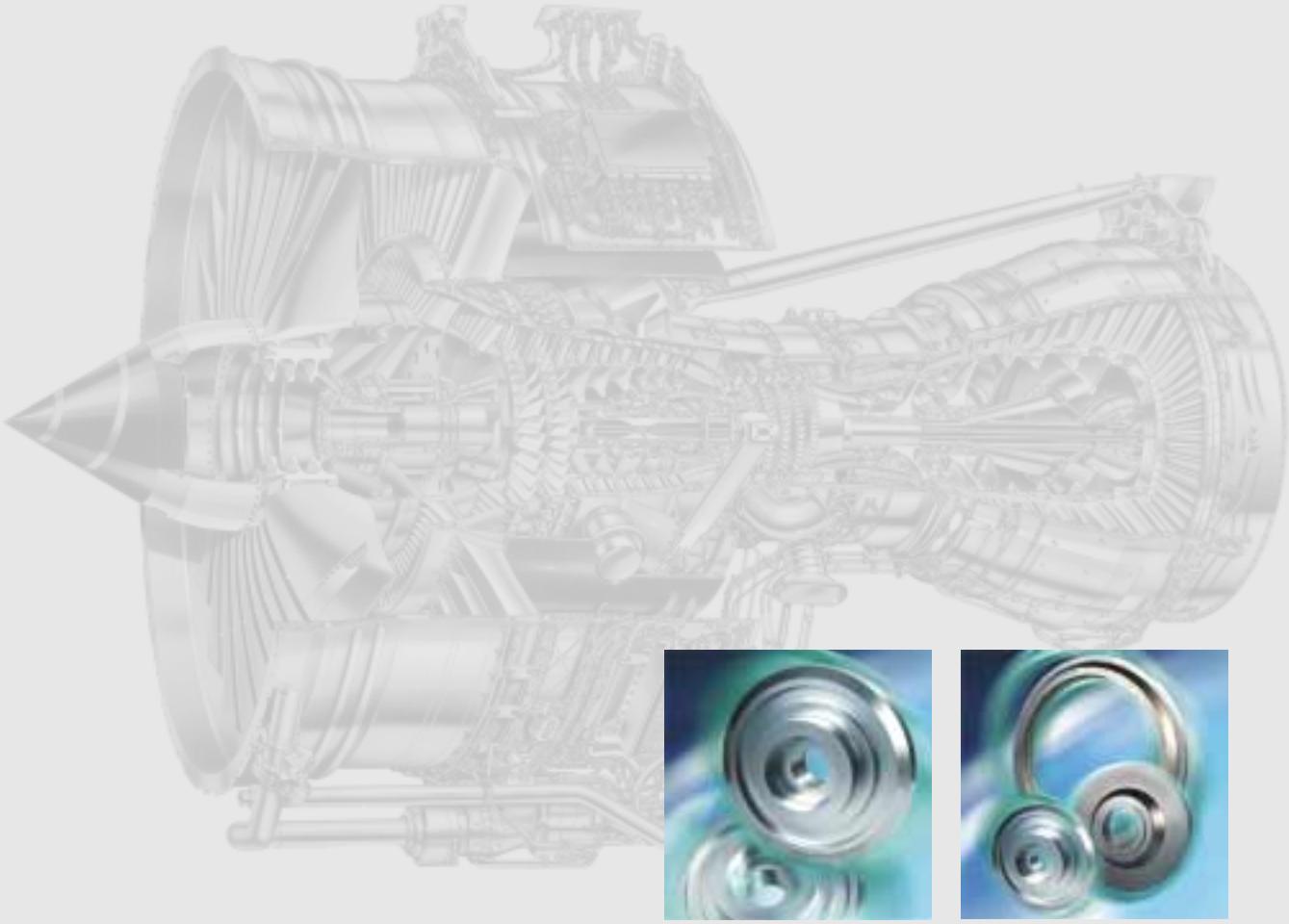
Once the bearing calculation has been completed, the customer receives an e-mail with files containing data on the displacements and rotations of the connecting nodes on the flanges of the companion structures. The data can be directly imported into the customer's finite element program and used to calculate the corresponding internal deformations and stresses to which the companion structures are subject (Fig. 5). This offers an economical means of optimizing prototypes in which design weaknesses can be rapidly identified. After modification of the part model concerned, the simulation can be repeated with minor effort.

5 Conclusion

Provision of this new calculation method devised by Rothe Erde offers the customer an opportunity to participate in a long-term development partnership. The analysis thus generated of the large-diameter antifriction bearing together with its companion structures is both highly economical and very thorough from a mechanical point of view. For the first time ever, it is now possible to use a PC to calculate the mutual influence of the raceway system and bolted connections at varying loads. The results generated agree very closely with those determined empirically. With the use of simulation, it is no longer necessary to investigate components experimentally. This in turn greatly reduces the time the customer needs to invest in prototype development. Similarly, the processing costs at Rothe Erde fall by up to 90 percent compared to former approaches based on the finite element method.

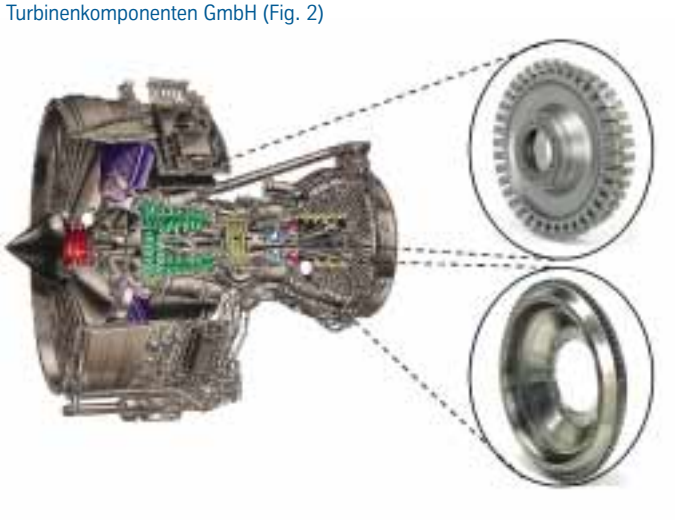
Dr.-Ing. Peter Klaus Kirner
Dr.-Ing. Daniel Holstein

Fully automated heat treatment line for compressor and turbine disks



Aero engine disks from ThyssenKrupp Turbinenkomponenten GmbH (Fig. 1)

Products in an aero engine manufactured by ThyssenKrupp Turbinenkomponenten GmbH (Fig. 2)



1 Overview

ThyssenKrupp Turbinenkomponenten GmbH, based in Remscheid, manufactures forged components for the aerospace and the power generation industry. As an expert and experienced supplier of aero engine parts, the company offers a product range featuring not only compressor blades but also a wide range of compressor and turbine disks and other disk-like products with diameters of up to 1,100 millimeters (Fig. 2). Once the disks have been forged and then machined, they are subsequently fitted with the appropriate blades by the turbine manufacturer. Disks from ThyssenKrupp Turbinenkomponenten GmbH are found in just about every civil and military aero engine on the market and are used in both compressors and in turbines, where the thermal loads are high.

Quality demands are extremely stringent in every area of aero engine manufacture. Consequently, compressor and turbine disks need to meet precisely defined specifications. In normal flight operation, i.e. subject to a combination of high temperatures and centrifugal forces, sufficient safety margins must be maintained. Moreover, the component properties have a major influence on the service life of the disks. A consistently high level of component quality lengthens the intervals between routine inspections and thereby lowers the engine's operating costs.

2 Background and project objectives

The two most important characteristics of a compressor or turbine disk are its internal stress level and its microstructure. In the commonly used high-temperature titanium and nickel superalloys, a homogeneous microstructure tailored to the local stress conditions provides the superior mechanical properties which largely characterize the turbine disk's permissible operating load. These properties are set in the heat treatment process following forging. This comprises solution annealing followed by quenching in a special oil or water bath and subsequent ageing. The objective of quenching is to achieve homogeneous and precisely defined cooling. Cooling rates must be as uniform as possible across the entire surface of the disk so as to ensure maximum uniformity of its properties.

Conventional heat treatment lines neither regulate the temperature of the quenching bath nor homogenize the temperature at various levels within the bath. As a result, disk cooling may well be uneven and inadequately defined. With a view to remedying this situation, a collaborative project between MTU Aero Engines, Rolls-Royce Deutschland GmbH, Brandenburg Technical University in Cottbus and ThyssenKrupp Turbinenkomponenten GmbH was launched to develop a new process technology for the production of the nickel superalloy Udimet 720. The aim of this project, which received support from the Federal Department of Education and Research (File No.: 03N3067), was to implement an innovative quenching process as part of a new, highly automated heat treatment facility. From the customer's point of view, the aim was to develop a process which would optimize component properties and in so doing significantly lengthen the intervals between routine maintenance inspections of the turbine disks.

3 Automated heat treatment facility

The central feature of the new heat treatment facility at ThyssenKrupp Turbinenkomponenten GmbH is a pioneering quenching technology featuring an environmentally compatible fume-extraction system. Constant cooling rates are ensured across the entire surface of the disk by circulating the oil in both horizontal and vertical planes for the first time while oscillating the charge (Fig. 3). The quenching oil outlet nozzles can be accurately positioned. In addition

Fully automated heat treatment line (Fig. 4)

Batch furnace (Fig. 5)

the circulation rate of the oil as well as the amplitude and frequency of the vertical charge motion are subject to variable control. Therefore, a predefined temperature throughout the quenching bath is obtained. This process makes it possible to achieve the preconditions for component-specific quenching characteristics.

In addition to this innovative quenching technology, the heat treatment facility is also equipped with modern charging and process control systems (Fig. 4). Both the central chamber furnace (Fig. 5) and the various quenching baths with oil of differing qualities are charged automatically. The high degree of automation makes it possible to achieve predefined, precisely reproducible transfer times between furnace and quenching bath. Comprehensive process control technology records these times as well as all the other process data. The system documents not only the programmable setpoint values but also the actual values, e.g. the bath temperature and the temperature curve in the furnace. This process data monitoring is augmented by computer-aided visualization of the process sequence, providing an overview of the entire heat treatment process chain.

The heat treatment line has a charge weight capacity of up to 2,000 kilograms and can be used for nickel alloys, steels, and titanium alloys. In mid-2001, this fully-automated facility received customer approval for the heat treatment of aero engine components.

4 Benefits

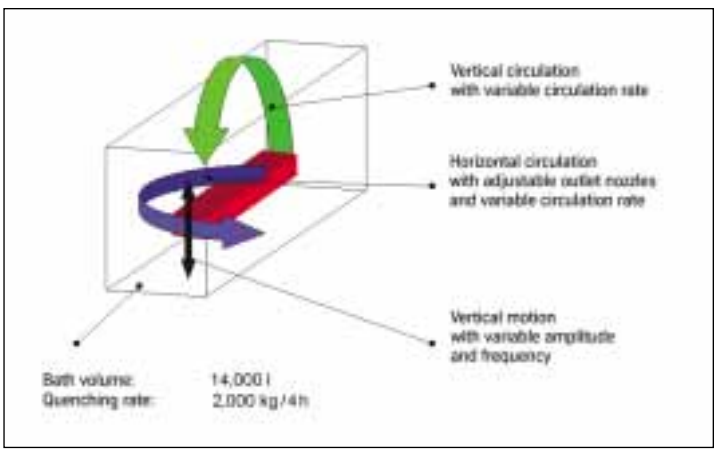
4.1 Company benefits

Use of this fully automated heat treatment line generates a number of benefits in terms of process reproducibility, reliability and stability (Fig. 6). The extensive control and monitoring functions provide for significantly enhanced component quality. The mechanical properties of the turbine disks are matched exactly to stress requirements and display high uniformity (Fig. 7). In the final analysis, this results in reduced quality inspection costs for inspections during manufacture.

The high degree of automation means shorter heat treatment cycle times. This allows a higher throughput, which is of particular value with such time-consuming processes as solution annealing and ageing. The benefits of this new facility have enabled ThyssenKrupp Turbinenkomponenten GmbH to strengthen its technological leadership in the manufacture of aero engine disks.

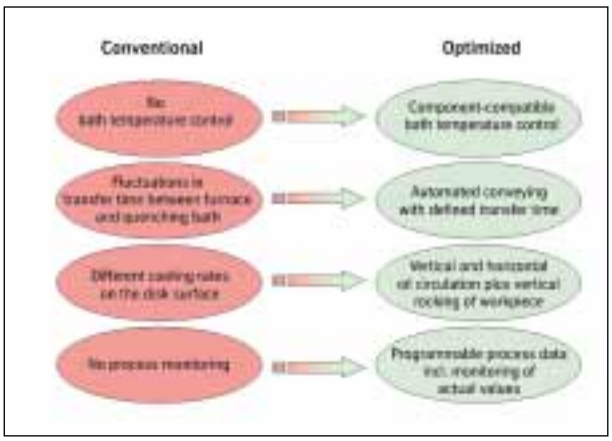
4.2 Customer benefits

Optimized properties also generate significant potential for the customer. In the past, further machining in the customer's plant repeatedly led to distortion from residual stresses which exceeded tolerance limits. Thanks to enhanced quenching technology, however, the associated scrap rates have now been reduced to a minimum. Similarly, the safety margin of the turbine disks, i.e. their reliability, has also increased as a result of highly uniform mechanical properties tailored



Circulation and vertical motion (Fig. 3)

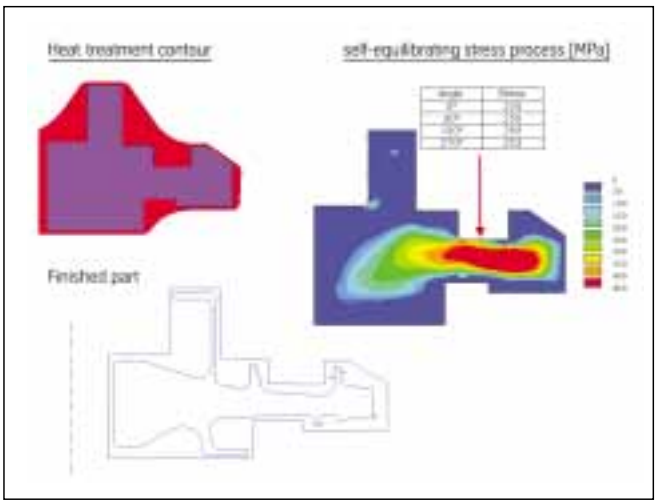
Comparison of characteristics of a conventional and the new heat treatment line (Fig. 6)



to specific load situations. This establishes the basis for extending the service life of the disks and increasing the intervals between inspections, thereby ultimately lowering the operating costs for the aero engine.

5 Conclusion

The development of this fully automated heat treatment line for turbine disks provides an example of successful collaboration between customers, a university and a supplier. Customer requirements for high-quality components were implemented by the supplier using modified processes. This project has not only led to the development of a pioneering process and equipment technology but also cemented the partnership between the customer and supplier. The resulting synergies have enabled ThyssenKrupp Turbinenkomponenten GmbH to secure a technological edge over its market competitors.



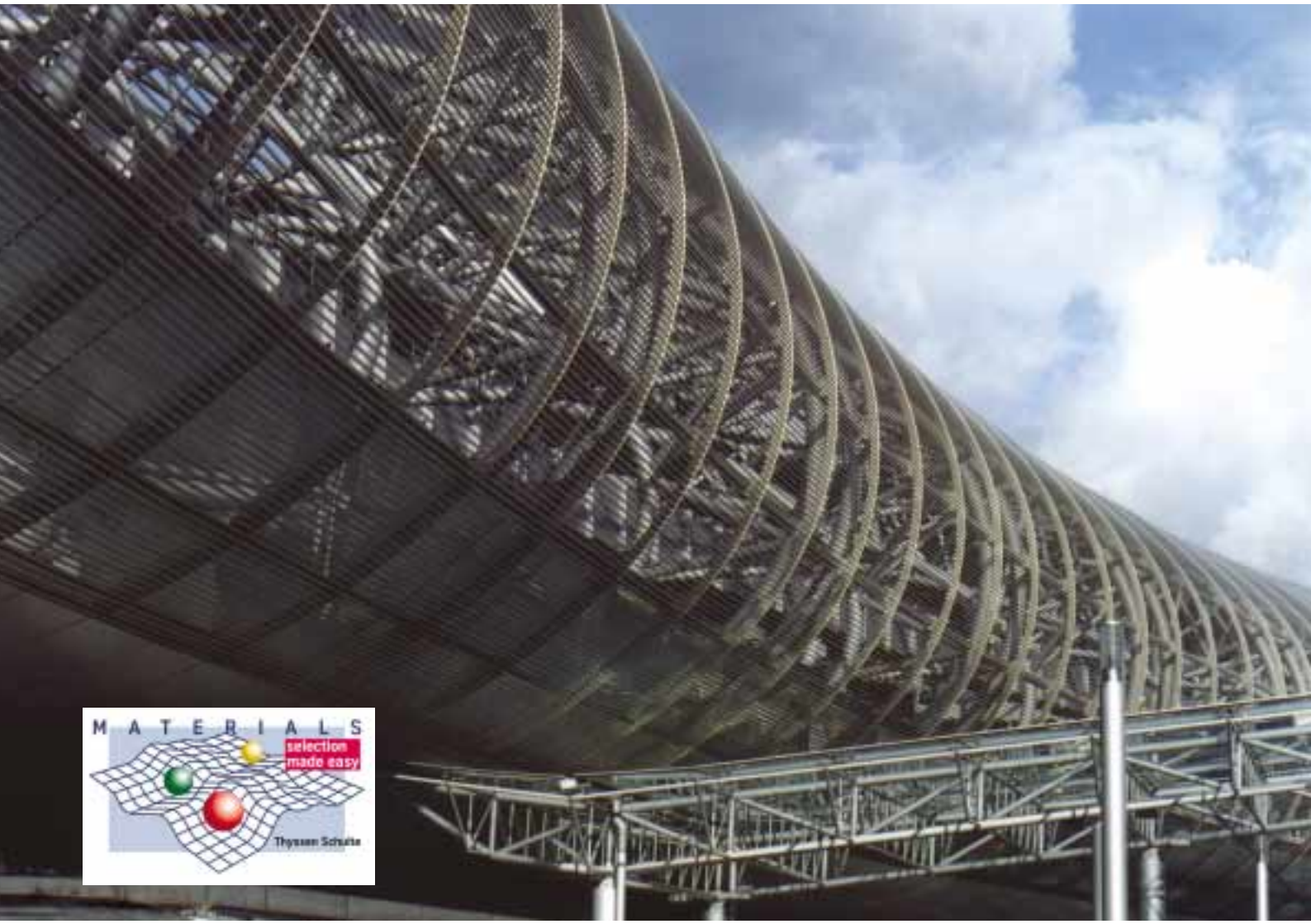
Disk geometry and residual stress state (Fig. 7)

6 Acknowledgement

ThyssenKrupp Turbinenkomponenten GmbH would like to thank the Federal Department of Education and Research (BMBF) for its support of the collaborative project “An Investigation into the Potential of the Material Udimet 720 Li at Temperatures above 650 °C”.

Dipl.-Ing. Jochen Adams
Dr. rer. pol. Claus Algenstaedt

Database for customers to optimize the selection of steel grades



Stainless steel facade on the new terminal at Düsseldorf airport; Thyssen Schulte was involved in devising the materials concept and supplied stainless steel tubes and sheet, including processing services (Fig. 1)

1 The concept

Technical marketing and material-oriented customer consulting services play an important role in the business strategy of Thyssen Schulte, one of the leading materials suppliers and service providers in Germany. As it advises customers – above all medium-sized processing firms from a broad range of industries – the company is increasingly addressing and providing assistance in areas relating to material use, testing (Fig. 2) and optional selection under specific conditions of use. This is a key area of responsibility at the Technical Sales department in Essen.

The main office supports the sales departments of the branch offices and subsidiary companies. Since the mid-1990s, electronic media have been used and updated systematically for the storage of materials data.

Meanwhile, a comprehensive electronic program has been developed for selecting the optimal grade of steel for a given use. The program brings together more than 400 DIN-EN carbon and stainless steel grades, with an emphasis on flat products. In particular, these include unalloyed and alloyed steels (rust-, acid- and heat-resistant); special construction steels; steels for ship-building, including offshore applications; steels for welded pipelines and steels resistant to compressed hydrogen.

Unlike other approaches that only consider theoretical values or thresholds of the given standards, the electronic database system at Thyssen Schulte is based on statistically validated frequency distributions. These data have been generated from decades of practical experience and evaluation. The raw data come from results obtained by the quality center of August-Thyssen-Hütte/ThyssenKrupp Stahl as well as the results of many years of customer consulting practice at the Technical Sales department.

The database is parameter-driven and uses combinations of properties as selection criteria for the optimal steel grade in view of the planned processing or use. Taking into account the restrictions specified by the user, the program supplies a material data sheet for the optimal steel grades in any given case. The basic blueprint for this information was likewise developed by Thyssen Schulte. For each steel grade, it includes the following data:

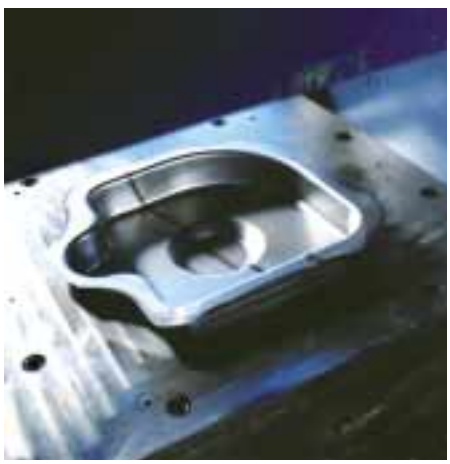
- Scope
- Application and typical fields of use
- Chemical composition
- Mechanical properties
- Physical properties
- Hot forming
- Processing/welding
- Further reading.

2 General objectives: Customer retention through expertise

The demand for qualified technical advice in commercial transactions with steel and other materials is growing. More and more often, there are concerns regarding special problems relating to processing (Fig. 3), lifetimes and corrosive influences, as well as hardening and tempering, forming and welding.

In addition to its utility for designing and steel-consulting institutions, designers, engineers and universities, the steel selection program is intended primarily to facilitate and support the stock and service business (including the increasing first-stage processing capabilities (Fig. 4)) of Thyssen Schulte for the typical customer groups from industry and other processing fields. The selection program is of particular importance for steel-processing companies that have orders of varying types and/or fixed delivery deadlines.

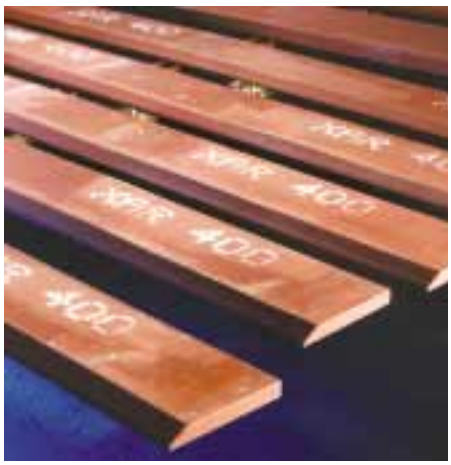
Bending test to determine extreme load capacities during cold forming (Fig. 2)



Sheet metal processed by deep-drawing and laser welding (Fig. 3)

New laser line used to process stainless steel and aluminum to customer orders in the Dortmund central warehouse (Fig. 4)

Cutting blades for excavator shovel construction made from high-strength special structural steel XAR 400, manufactured on the flame cutting line in the Essen central warehouse (Fig. 5)



Blanks made from sections and plate, blasted and/or primed – Heilbronn central warehouse (Fig. 6)

A special encoding of all steel grades according to the status of their stock availability or their procurement in direct sales automatically provides another criterion for optimized selection. Often, the best (fastest) availability of a steel grade is an important factor in a customer's procurement process.

Particularly fast access to the steel grade is possible if the local sales department of Thyssen Schulte can use its own warehouse – in other words, the stock in immediate proximity to the customer. Delivery at short notice via central warehouses is another good alternative, which, following substantial investments, allows Thyssen Schulte to offer a very extensive assortment from permanent stock. Thyssen Schulte maintains central warehouses of this kind for all product lines. In the case of steel, these central warehouses are located in Essen/Mülheim (Fig. 5) and Heilbronn (Fig. 6). For stainless steels, many transactions are conducted through the central warehouse Dortmund (Fig. 7), the most advanced of its kind in Europe.

The database is based on linked properties and features (Fig. 8) derived from practical experience and applied to 400 grades of steel. Up to 40 characteristic features per steel grade are deposited, including mechanical properties such as yield point (Fig. 9), tensile strength, elongation at fracture, notch impact work etc. In addition, the program offers the opportunity to ascertain which grades of steel are typically used in individual sectors. In this way, essential specification profiles can be compared in concrete instances.

3 Updates and improvements

The database system is being improved and extended systematically. It now contains a number of criteria and items of information that extend far beyond the classical approach of a demand profile.

• SN curves

The complex subject of the fatigue strength of steels is of vital importance for designers and customers in the field of mechanical engineering. Since the stresses experienced by machine parts frequently change in magnitude and direction, fatigue fractures must be prevented in advance through the optimal use of appropriate structural steels.

The program provides dynamic strengths as stress-number curves for a variety of stress ratios (ratio of minimum stress to maximum stress) and for samples with various surface finishes. These curves are different for each steel grade (Fig. 10). They show empirically determined values for lifespan as a function of the stress amplitudes involved (type of stress).

• Corrosion resistance

The steel selection criteria in this part of the program include important chemical and physical parameters for the corrosion resistance of alloyed and high-alloyed steels under exposure to waste water and exhaust gases. The PC program (Fig. 11) offers 4,000 types of stress in the waste

Thyssen Schulte's central warehouse in Dortmund is the largest and most advanced warehouse complex of its kind in Europe – the photo shows one of the halls (Fig. 7)

Mechanical, physical and other material properties stored in the steel selection program as selection criteria (Fig. 8)

water category and 56,000 varieties in the case of exhaust gases.

This part of the program is intended primarily for industries such as hydraulic engineering, the chemicals sector, and plant and mechanical engineering, where steels must be used in environments with specific stresses. The combination of individual requirements (parameters) results in the optimal grades of steel for the given stress environment. A material data sheet with detailed information can then be requested from the program and printed out.

• TTT diagrams

In the meantime time-temperature-transformation diagrams have been integrated as well. In the past, customers have had to make a separate request for the TTT diagrams from Technical Sales in Essen. TTT diagrams, which provide information about the time-dependent hardening processes and the course of the austenite transformation (γ/α transformation) during the cooling of a steel grade following heat treatment, often serve as indispensable aids. This is especially true when it comes to achieving the optimal settings for the heat treatment of a steel grade in a processing company.

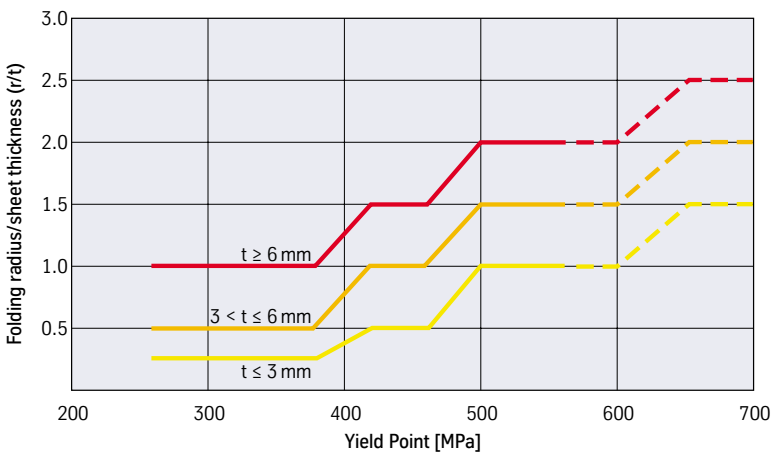
• Tempering diagrams

The properties of steel grades can be influenced significantly through hardening with subsequent tempering. The heating of a workpiece below the first arrest point ($t < A_{C_1}$) following the hardening process is important in this respect. The remaining stresses and the strength, toughness, yield point and dynamic load-bearing capacity change as a function of the tempering temperature. Each steel grade has a separate hardening and tempering diagram that provides design engineers with useful information. Plans have been made to integrate these diagrams in the program.

4 Technically-oriented sales support

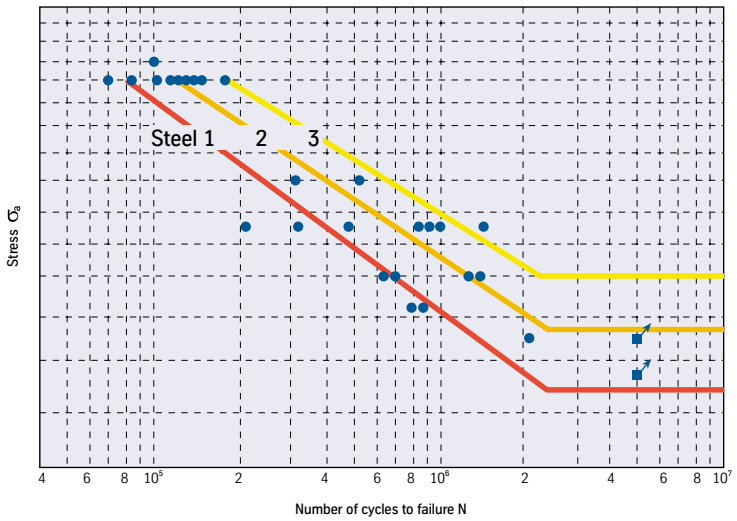
The deployment of its own electronic information-retrieval system for processing companies underscores the materials expertise of Thyssen Schulte. There is no comparable product on the market offering such a universal, practice-oriented compilation of properties and data/fact combinations for steel (unique selling point).

The information on availability levels (procurement) for each steel grade, which forms part of the system, furnishes additional parameters that customers can use in their own order processing, and it also provides new selling points for



Recommended folding radii in proportion to sheet thickness as a function of yield strength (Fig. 9)

As with all other data, the SN curves describing the behavior of steel under oscillating loads are based on statistically validated empirical findings (Fig. 10)



Thyssen Schulte: The modern storage system offers many advantages over the competition in terms of stockholding and the ability to deliver rapidly ex stock/central warehouse.

Sales of high-quality steel grades are rising at higher-than-average rates at Thyssen Schulte. The innovative development of steel grades – more than half of the roughly 2,000 steel grades on the Stahl-Eisen-Liste have been further developed or added in the last six years – has led to an expansion of stock and business activity. This growth is expected to continue.

The steel selection program means that users do not have to undertake their own time-consuming studies or pay for consulting services in order to validate the use of a material in a given instance. This is a considerable advantage for medium-sized processing firms in particular, as they often operate without extensive human resources for research and materials testing.

5 Conclusion

Each year, Thyssen Schulte sells roughly 3.0 million metric tons of carbon and stainless steels, with a total sales volume of more than €1.7 billion. During the last decade, it has been possible to achieve a significant increase in the proportion of high-quality steel grades offered – such as high-strength, wear-resistant and corrosion-resistant steels – and to integrate processing companies that use them into the customer base.

The electronic steel selection program serves as an important tool for supporting the further strategic expansion of customer market share at the upper end of the product range. It offers users and processing companies the following benefits:

- Selection and optimization of steel grades on the basis of individual user specifications
- Optimal problem-solving through access to three starting variables that serve as essential control values for the individual selection process
- Availability code for each steel grade ex stock/central warehouse or as a direct sale
- Decision-making support through practice-oriented, statistically validated key figures
- Easy operation – whether provided as PC software or internet-based in conjunction with online systems.

The steel selection program gives Thyssen Schulte an important competitive advantage in the core area of the stock business: There are no comparable user-friendly, universal programs or databases – neither at institutions engaged in metallurgical research or consulting, nor at competing companies in the domestic and foreign materials markets.

In view of the diversity among customers and the wide range of inventory programs, the database program presented here provides Thyssen Schulte with attractive opportunities for ongoing business support. Use of the program at subsidiary companies and in other segments of the Group is conceivable, and there are plans for its further development and expansion.

The extended version of the selection program was presented at the tube and sheet exhibitions held in 2002 in Düsseldorf and Hanover; the photo shows the booth at the TUBE trade show (Fig. 11)

Ulrike Grönefeld
Dipl.-Ing. Jürgen Schlenker

Reusable panel: Plastic composite panel with replacement film

A revolution in the formwork market (Fig. 1)

1 Current situation

When it comes to pouring the concrete used to build walls and ceilings, the construction industry generally uses formwork made of plywood panels framed with steel or aluminum elements that simply interlock with one another. Today, more and more formwork manufacturers rent out such equipment as a service in what is an increasingly discriminating market. The plywood in a soffit formwork panel can be used approximately 40 – 60 times, in a wall formwork panel approximately 60 – 80 times. In between different building sites, however, the panels need to be cleaned and then repaired by hand.

At present, this labor is the biggest generator of costs. Thus, the aim is to reduce cleaning and repair requirements to a minimum and increase the lifespan of the formwork, while continuing to provide the customer with a top-quality product. In the hunt for a suitable material that combines all these properties with the stability and rigidity of the conventional plywood, in early 2001 the construction industry began to look at plastics. Polypropylene has proved to be most suitable replacement from both a technical and an economic point of view. Yet before this material can yield the desired results, it requires further processing. Hünnebeck has therefore developed a heat treatment technique that substantially improves the quality of the surface of polypropylene panels.

2 Plastics versus plywood

Compared to traditional plywood panels, the plastic variety has four major advantages.

Firstly, it doesn't absorb any moisture and is therefore weatherproof and holds its shape, whereas wood swells.

Secondly, plastic formwork panels are easier to clean, as the material repels dirt. Similarly, repair requirements are lower.

Finally, damage to the surface of a plastic formwork panel is less common. By contrast, the face veneer on plywood panels often starts to peel.

Moreover, the plastic panel is also superior to plywood from an environmental point of view. For a start, valuable wood resources are conserved. Secondly, the plastic can be recycled, whereas plywood formwork treated with phenolic resin has to be disposed of as hazardous waste.

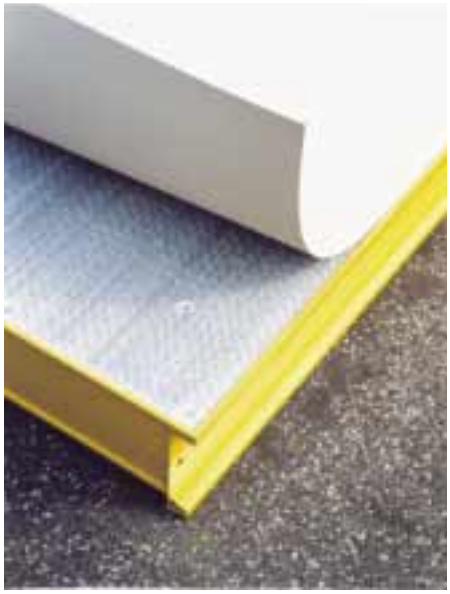
3 A technological revolution

The drawback of the plastic formwork panels already on the market is that they have to be repaired by hand. This necessarily involves a lot of manual labor and therefore high costs. Hünnebeck has therefore gone a step further and is now working on a reusable panel that can be repaired by machine.

4 The principle

The base plate of the panel and the surface are separate elements (Fig. 2). The base plate is made of low-weight, foamed polypropylene reinforced with a layer of fiberglass cloth up to two millimeters thick (Fig. 3, Fig. 4). The surface coating consists of a polypropylene film approximately one millimeter thick. The two elements are bonded together in a mechanical process (Fig. 5). Should the surface of the polypropylene film become damaged – with nail holes, for example – it can be easily removed from the base plate by means of a mechanical process. In such cases, the base plate is simply coated with a new film and is therefore as good as new. This greatly increases the durability of the base plate, which can now be used over 200 times. During all the processes, the base plate remains within the formwork frame.

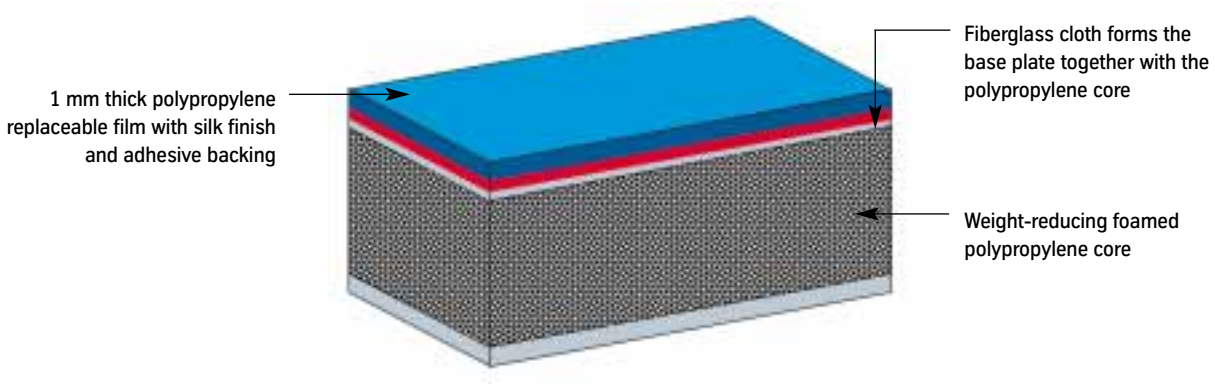
Reusable panel: the polypropylene film is bonded onto the fiberglass cloth of the base plate (Fig. 2)



5 The benefits

The reusable panel fulfills all the important demands made of a modern formwork system. Customers are able to obtain a formwork panel with a new surface coating at any time. This ensures excellent results, producing a smooth concrete surface at favorable conditions previously unknown in the industry. The extreme durability of the base plate and the use of a mechanical process to repair any damage make both bought and rented formwork much more economical. Between 35 and 40 percent of the current cleaning and repair costs

Section through the base plate (Fig. 3)



can now be saved. Similarly, the environmental aspect has also been considered. With the new system, the used material can be recycled and made into new base plates.

6 Outlook

Hünnebeck is planning to use this new development in its Topec, Rasto and Manto systems. As it may also be possible to apply the patent to non-Hünnebeck systems, however, this method could add competitors on the formwork market to Hünnebeck's customer portfolio and thus significantly improve the company's market position.

Checking the polypropylene base plate (Fig. 4)

Finished base plate exiting a hot pressing line (Fig. 5)

Dr.-Ing. Volkhard Nobis

Safety in underground transport systems thanks to smoke extraction systems from ThyssenKrupp HiServ

People and buildings are protected by removing smoke and heat directly from the source of the fire (Fig. 1)

1 Background

The fire disasters of the past have made it horrifyingly clear that particularly in tunnels and underground stations people are unable to get to safety quickly enough. Engulfed in smoke they lose their orientation and fall victim to toxic combustion gases. A few breaths of carbon monoxide are all it takes to lose consciousness, while prolonged inhalation is fatal.

2 Dangers of a tunnel fire

Particularly at the start of a tunnel fire a great deal of smoke is generated, which spreads initially under the tunnel roof. The further it propagates, the more the smoke cools, to be transported back to the fire with the combustion air flowing in near the floor. In underground stations the hot smoke rises through stairways. People are trapped. Rapidly decreasing visibility and the paralyzing effect of carbon monoxide prevent escape. All this happens very quickly.

As well as the rapid development and spread of smoke which makes self-rescue and evacuation in an underground fire difficult, heat also plays a role. Owing to the confined space and the sometimes considerable fire loads, the heat of combustion, like the smoke, cannot escape properly. The high temperatures ignite further vehicles, so tunnel fires can go on for days. If the fire service cannot get to the source of the fire quickly enough, attempts to extinguish it are doomed to failure.

The consequences of tunnel fires are well known. The immediate consequences are loss of life and damage to property in the form of burned-out vehicles and structural damage. After-effects such as tunnel closures for repairs cause additional traffic problems and increased congestion on alternate routes. Also not to be underestimated is people's fear of further accidents.

The often considerable damage done to structures is illustrated by data from some tunnel fires (Fig. 3).

Almost all the tunnels in which fires broke out were already fitted with smoke extraction systems. However, the effects of past disasters illustrate the limited performance capabilities of these systems.

Despite all preventive measures, fires in underground transportation facilities can never be completely ruled out. For example, long-term statistics for the high-traffic Elbe Tunnel show an average of one fire every month. Continually rising traffic volumes and the increasing proportion of heavy goods traffic, above all in tunnels, have led to demands for increased safety and, associated with that, more effective smoke extraction systems.

Example tunnel fires / Source: Tunnel 2/2002 (Fig. 3)

Year	Tunnel	Fire load	Damage to the tunnel structure
1969	Moorfleet Tunnel, Hamburg	Truck carrying 14 t polyethylene granulate	Walls and roof damaged over 25 m area
1984	Summit Tunnel, England	Freight train carrying 600 t gasoline	Damaged area 60 m
1996	Eurotunnel	15 trucks with cargo	Damaged area 500 m
1999	Montblanc Tunnel France-Italy	Truck carrying 12 t flour and 8 t margarine, following 30 vehicles burned out	Damaged area 1.5 km
1999	Tauern Tunnel Austria	Truck carrying paints, following 40 vehicles burned out	Damaged area 400 m

3 Task definition

The central requirement a smoke extraction system must meet is to keep escape routes clear beyond the period of self-rescue. For this, smoke extraction systems must be designed to channel smoke directly out of human traffic areas and to handle the volumes of smoke this involves. They should also be able to limit the spread of heat and damage. New ducting systems and collection equipment to remove fire smoke should also display high thermal stability over longer fire durations, unlike existing concreted systems.

Fire disaster in the Gotthard Tunnel, 2001 (Fig. 2)

The main requirements in summary:

- direct channeling of fumes out of human traffic areas
- escape routes must be kept clear
- limit smoke and heat spread to reduce damage
- thermal stability
- assure access for fire fighting.

Since the exhaust capacities of currently installed systems cannot be significantly increased without major difficulty owing to the restricted tunnel cross sections, future smoke extraction systems must display substantially higher efficiency. This means that with the same exhaust capacity the proportion of removed fumes must be significantly higher than at present. Only a system capable of handling large fume volumes can be expected to safely manage large fire loads, for example a laden heavy goods vehicle.

4 ThyssenKrupp HiServ smoke extraction systems for tunnels

To develop systems that meet the above requirements, the first step is to analyze smoke propagation and the increase in smoke volume. ThyssenKrupp HiServ has been working for many years on industrial extraction equipment and smoke removal from buildings, and specializes in the thermodynamic design of air and flue gas ducts.

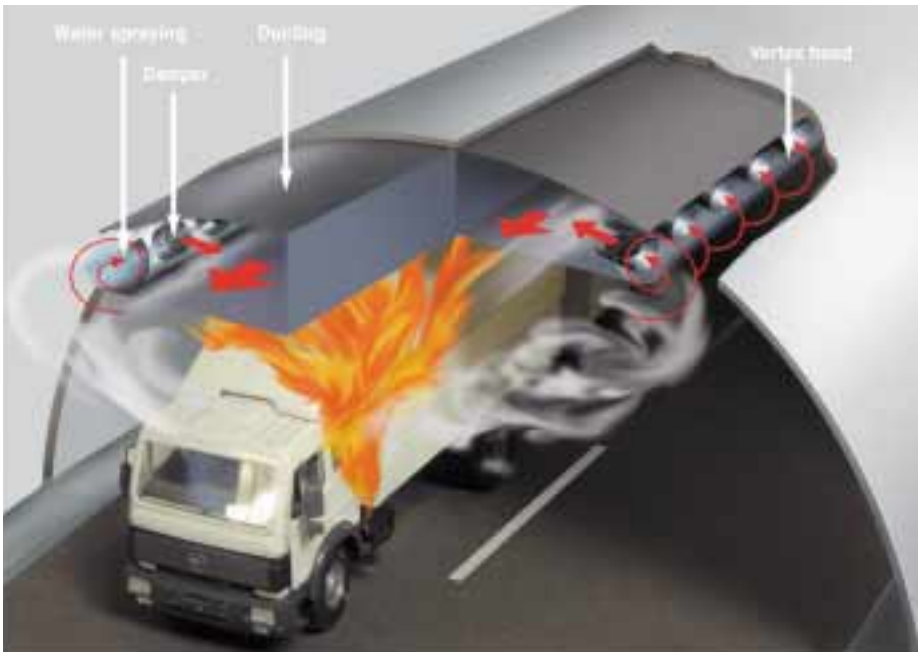
The core element of the ThyssenKrupp HiServ smoke extraction system is the vortex hood, fitted with dampers, to capture the smoke. Fig. 4 shows a cross section of a smoke extraction system for tunnels. On both sides along the tunnel roof there are vortex hoods, and arranged between them ducts to conduct the fumes to the exhaust fans. The vortex hood itself is cylindrical. This cylinder is open over an angle of roughly 90°. Exhaust ducts are arranged at regular intervals inside the cylinder. Air is drawn into the hood and set in rotation, which produces a negative pressure zone in its center along the cylinder axis. The new smoke extraction system makes it possible to produce a stable vortex and extend it as required along the length of tunnel.

The vortex hood combines several advantages:

- enormous suction power of the vortex
- extremely uniform suction along the vortex hood
- reliable extraction of fast flowing smoke through self-stabilization of the vortex flow.

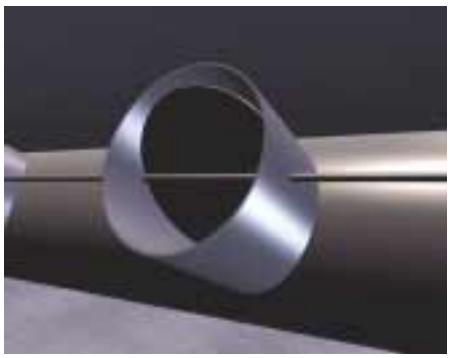
In an emergency the dampers (Fig. 5) are only opened over the fire source to focus the full exhaust power on the fire. Fig. 6 shows the incremental activation of the vortex hood segments. In addition, it is also possible to spray water into the vortex to cool the fumes. This further increases smoke extraction capability and protects the system against heat damage.

The segments are made of stainless steel (1.4571). The use of steel rather than concrete provides the necessary thermal stability. It also reduces wall thickness and therefore increases duct cross sections and thus the capacity of the system.



Vortex hood system for the removal of smoke (Fig. 4)

Dampers (Fig. 5)



5 Advantages at a glance

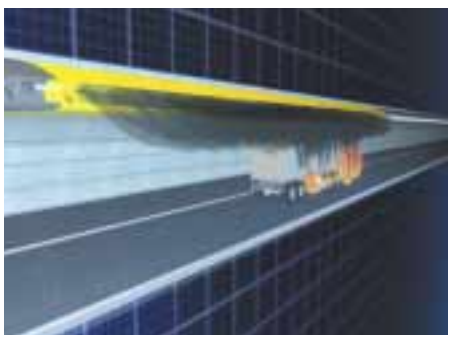
ThyssenKrupp HiServ smoke extraction systems meet central demands placed on modern safety equipment. The most important of these is to protect people in the event of a fire. The physical conditions in tunnels present a special challenge which vortex hoods installed in the tunnel roof can solve. Extensive modeling tests and computer-aided analyses have demonstrated this.

The strengths of the ThyssenKrupp HiServ vortex hood at a glance:

- optimized collection efficiency
- suitable for very high fire loads
- proven thermal stability even at high temperatures
- thermal protection of tunnel roof
- low susceptibility to longitudinal air flows through the tunnel
- simple equipment design
- simple installation
- tunnels can be re-opened quickly after a fire
- integrated high-quality ventilation
- integrated service shafts.

6 Outlook

Steadily increasing traffic volumes call for continuous expansion of transportation systems. In densely populated areas, additional transportation routes can frequently only be created by tunnels. Environmental factors can also be the spur for building tunnels, for example in conservation areas or mountainous regions. So the number of tunnels is set to increase continuously. Both existing and future tunnels offer an attractive market for vortex hood technology. Thanks to its modular, scalable design and the use of steel, vortex hood technology can be used to control even very large fire incidents. This makes the ThyssenKrupp HiServ smoke extraction system unique. In addition, ongoing patent applications and the development of a specially adapted detection system mean ThyssenKrupp HiServ is well positioned to develop this market segment.



Suction power targeted on the fire source (Fig. 6)

Dr. rer. nat. Wolfgang Zacharias

Triaton.Castrum Sequence – The control center for just-in-sequence module production in the automotive supply industry

Assembly of the rear axle drive module for the smart® in Hambach, France (Fig. 1)

1 Background

Triaton is the main source of revenues at ThyssenKrupp Information Services, which has more than 3,200 employees and achieved sales of €0.5 billion in fiscal year 2000/2001. The company is one of the leading international systems houses and the third largest vendor-independent systems house in Germany. Through its many locations abroad and its global business partners, Triaton is active in industrial conurbations throughout the world.

Triaton grew out of the IT units of the former Thyssen, Krupp, Hoesch and Hoechst companies and is now part of one of the largest industrial groups in the world. This IT service provider is backed by many years of specialized expertise in the industry. The challenges posed by the automotive, chemicals, pharmaceuticals, manufacturing and metal/paper/wood sectors are well-known. Triaton responds to these challenges with sector solutions based on specific needs – not with standardized, off-the-peg products.

As a "business processor" Triaton uses IT to optimize the business processes of industrial companies and adapt them to the requirements of the eConomy. The company's renowned customers are impressed by its process capabilities and its reliability. Based on a Plan/Build/Run approach, customers receive tailored solutions – from consulting through e-business solutions to the outsourcing of secondary processes. With more than 500 systems, Triaton is one of the leading providers of SAP services in Europe. Customers should be allowed to concentrate on what they do best – their core business activities. To enable this, Triaton offers them one-stop shopping with IT solutions covering the full spectrum of information technology. The advantage for the customers is that they can respond better to the demands of the market, offer interesting innovations and even become pioneers in the market. The customers themselves thus become "business processors".

Based on its lengthy tradition of IT services in the automotive supply industry, since 1995 Triaton has been providing functions to support the just-in-time production of system suppliers (first-tier suppliers) to auto manufacturers (OEMs). Today it is possible to provide automotive system suppliers with a modular concept to support the just-in-time production of their satellite production facilities located on the OEMs' sites.

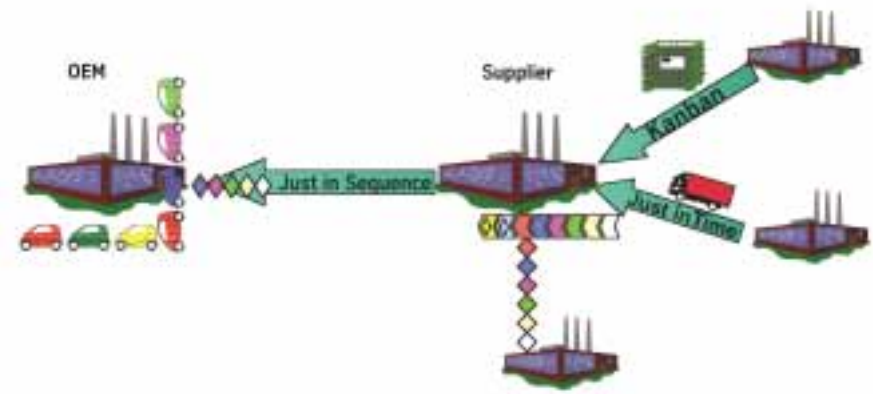
2 Triaton.Castrum Sequence

2.1 Functionality

Supply Chain Management (SCM) has a long tradition in the automotive supply industry. One of the most complex processes in production management is the supply of vehicle-specific system parts to OEM final assembly lines. This business process requires system suppliers to deliver their product not only just-in-time but also just-in-sequence and in the specific variant required for a particular vehicle.

To achieve this, the system supplier must take direct account of the material flows from its sub-suppliers to its own production operations. The large number of variants on today's automobile market means that to handle the large number of components, sub-suppliers must also deliver components to the system supplier on a vehicle-specific basis or at least in accordance with KANBAN (ordered from the supplier in containers on the basis of current use in the production line) and just-in-time (Fig. 2).

The modular application package "Triaton. Castrum Sequence" was created in order to monitor this special just-in-sequence production process. The following essential functions are supported by individual modules (Fig. 3):



Flow of material between the partners involved in the manufacturing process (Fig. 2)

- OEM call-offs synchronized with production
- compilation of vehicle-specific production data
- plausibility checks to maintain the vehicle sequence
- printout of necessary production documents (order documents/barcode labels/picking lists)
- integration of production subsystems
  - documentation of the torques of tensor screw systems (vehicle-specific quality testing)
  - control of materials-handling systems (PLC controls)
  - interfaces with test systems (electronics checks)
- registration of serial or batch numbers for parts that must be documented (e.g. airbag/steering system)
- checking or alternatively controlling the correct module sequence in deliveries to the customer (OEM)
- support for just-in-sequence packaging in special charge carriers.

2.2 Technology

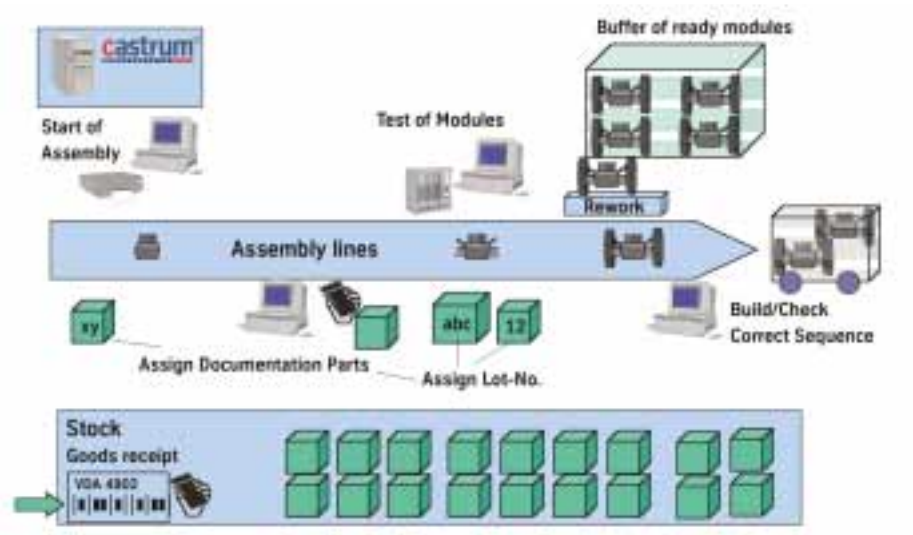
The Triaton.Castrum Sequence application package is a JAVA-based application. It uses Enterprise JavaBeans on an application server (BEA Weblogic Server). The use of a three-layer architecture ensures that the application data, the functions of the system and the user interface are strictly separated from one another. The application can be operated from any standard PC via an internet browser. Furthermore, this technology makes it possible to design the total application system to meet customer wishes regarding performance and failsafe properties (Fig. 4).

The use of the special system logic of the application server means that when the system is in operation, parallel servers can replace one another without any delay in the event of a breakdown, and that in normal operation the system burden can be distributed evenly among all the available application servers. The result is an application package that, in customers' high-availability scenarios, has the capacity to control module production for up to 1,200 vehicles/day (one module produced every 30 seconds). The system can also be used to simultaneously support several assembly lines operating in parallel. The business processes of the application system can be fully integrated in the customer's enterprise resource planning systems. In particular, the application package has a standard interface to SAP R/3, and it supports the special functions of the sector solution SAP DI 4.6C (Discrete Industry) in the area of just-in-time production logistics.

The application package can be used in two different installation variants:

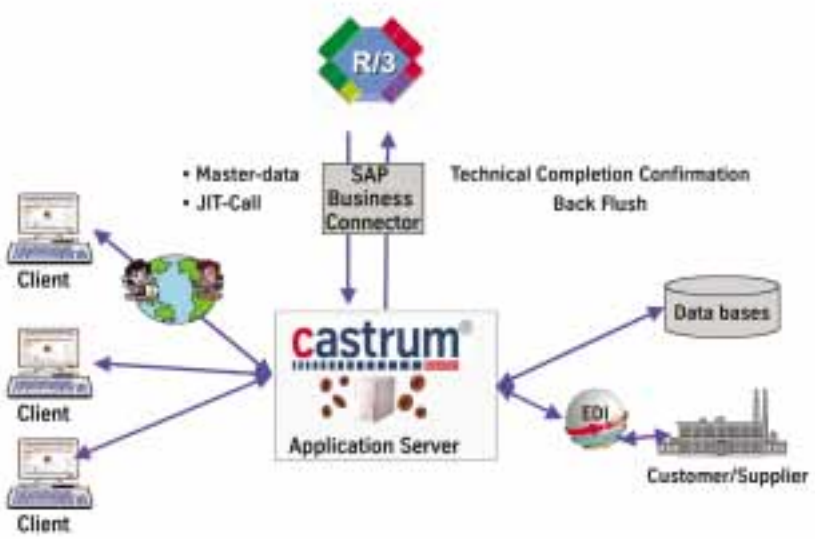
- **Castrum Sequence as a production control center**
  In this variant, CASTRUM serves as the lead system to control the entire production process of the assembly lines, prints out the production documents that are needed, and monitors the material inventories for the production lines.

- **Castrum Sequence as an emergency organization system**
  In this variant, sequential assembly is controlled by means of remote data transmission from the customer's central planning system (e.g. SAP R/3). Castrum Sequence synchronizes itself automatically with the current production situation and can directly take over the control center function in case of an emergency (e.g. if the remote connection should fail). Once the function of the lead ERP system has been restored, control is returned to the ERP system along with the complete production information for the downtime.



Schematic representation of just-in-sequence manufacturing with Triaton.Castrum Sequence (Fig. 3)

System architecture (Fig. 4)



2.3 Benefits

The Castrum Sequence modular application package is particularly suitable for supporting system suppliers and leading logistics service providers in the organization of sequential assembly processes. Its design in terms of lean logistics processes and fully automated production flows makes it possible to have production runs with only minimal stocks in batch size 1, allowing individual modules to be produced without the need for cost-intensive safety stocks.

The use of this modern software architecture expands existing planning systems by adding internet capability, and it reduces hardware investments to the purchase of standard personal computers for the production lines. Based on many years of experience with the system, the user interface has been specially adapted to meet the need for easy operation in the assembly area of production lines.

Thanks to the software architecture used, these advantages can be offered without sacrificing the scalability and high availability of the application.

3 Conclusion

The Triaton.Castrum Sequence application package provides a solution for automotive system suppliers and for leading logistics service providers which controls the just-in-time production lines of ThyssenKrupp both within the Group and externally (e.g. at the smart® production line in Hambach, France (Fig. 1, Fig. 5)). In addition, the system is already being used at six other locations outside the Group as a production control center. The customers are not only making use of the system's functionality but are also taking advantage of the 24-hour user support offered by Triaton.

smart® assembly line with oil filling and final inspection (Fig. 5)