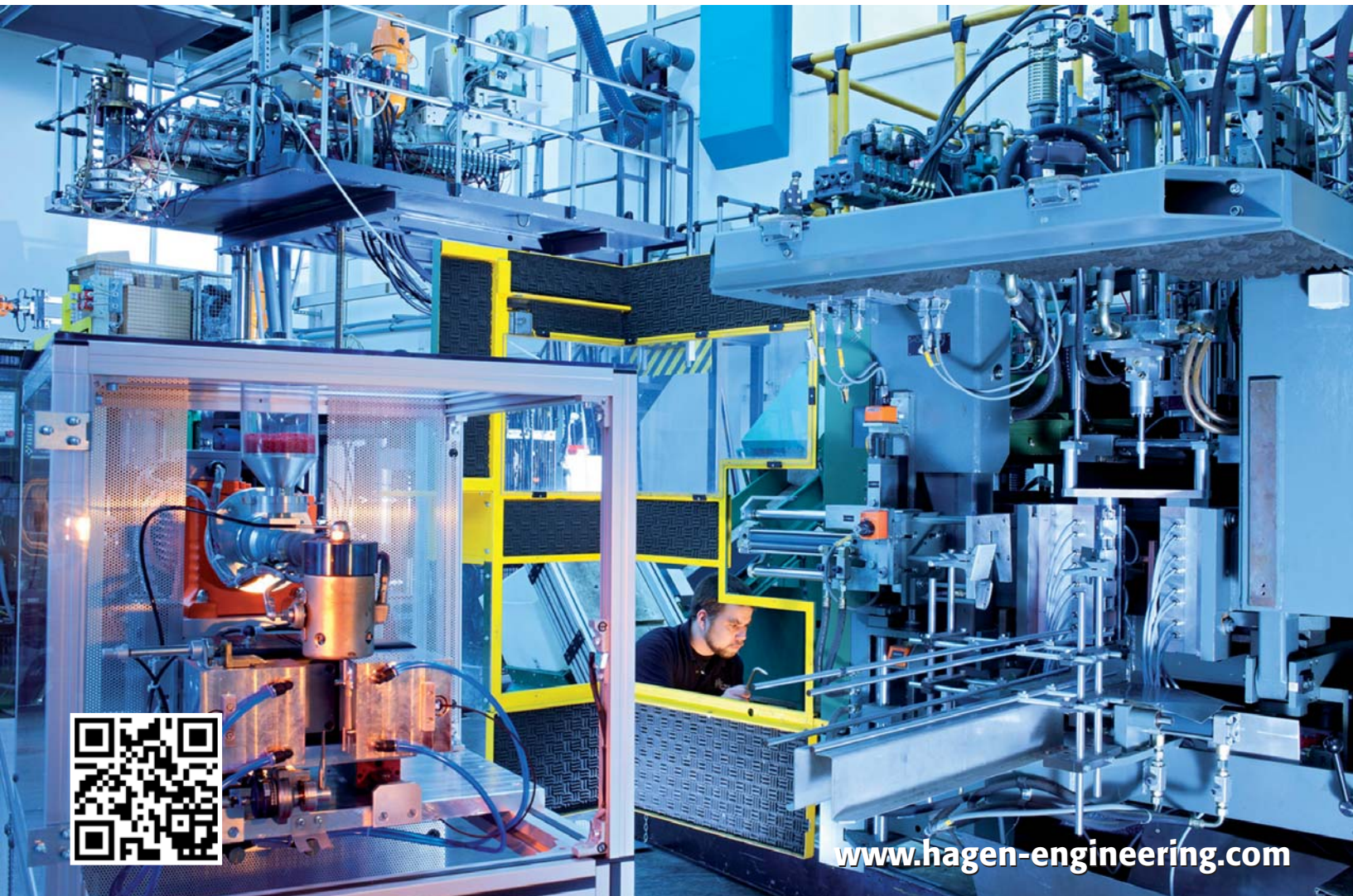


Development partners

- Product development
- Process and product simulation, feasibility studies
- Test and small-scale series moulds, special fixtures
- Proving
- Small-scale series

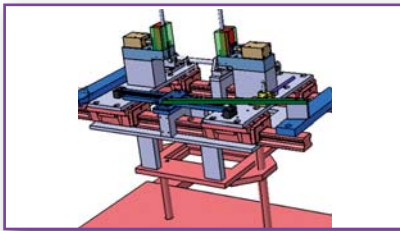


Innovations for success

From initial idea to finished product

As a development partner, Hagen Engineering GmbH offers its customers engineering know-how and competence in plastics. A broad service spectrum ranges from automotive engineering and both consumer and industrial goods to mechanical and mould engineering and training seminars. Hagen Engineering GmbH takes charge of all production stages during development of new products – from realisation of the idea in a process design to the production of prototypes, moulds and devices. The technical facilities available at the Dr. Reinold Hagen Foundation mean we can also offer materials proving and small-scale series for plastic products, particularly in the area of blow moulding technology.

Close cooperation exists with the Plastics Technology Centre research body of the Dr. Reinold Hagen Foundation, enabling us to address and solve particular issues that transcend a conventional service. We also work closely in this context with proven and reliable partners in higher education and industry.



Product development

Page 3

3D CAD design and construction - material and process-appropriate metal and plastic
Blow mouldings and injection moulded components
Special devices
Mechanical engineering



Feasibility studies / Product design

Page 4

Blow mould process simulation: Investigation of manufacturability
FE structural analysis: Prediction of product characteristics



Moulds and devices

Page 5

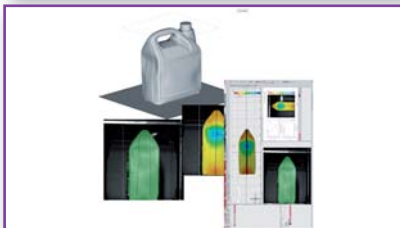
CNC milling of metal and plastic
Prototype and series moulds for blow moulding
Special devices / Test equipment



Proving / Small-scale series

Page 6

Mould sampling
Material sampling, process capability of blow moulding materials
Small-scale blow moulding series



Checking of results

Page 7

Material and component inspections
Development of test methods



Specialised training measures

Page 8

Blow moulding training seminars
Company-specific training measures

Whether metal or plastic is involved, each idea during development must be realised in a design appropriate to the material and process involved.

A close connection with the Plastics Technology Centre at the Dr. Reinold Hagen Foundation means that Hagen Engineering GmbH personnel have extensive practical experience with regard to the properties and use of different plastics. They provide support during material selection and assistance in deciding which processing method is best for a particular task.

Hagen Engineering uses powerful CAD systems such as CATIA V5 or Cimatron CAD/CAM for design implementation. Appropriate production drawings are compiled on the basis of the 3D CAD design. These in turn also serve as a basis for further tasks such as the creation of CNC programs for production or simulation of product features using the finite element method (FEM).

One speciality of Hagen Engineering is the special development of individual devices and systems that can be manufactured and fitted in the company's own tool and prototype production department.

Our equipment

- CATIA V5
- Cimatron CAD/CAM

Our services

- Design and concept
- Process and material-appropriate design
 - Blow mouldings and moulds
 - Injection moulded components
 - Special fixtures
 - Mechanical engineering
- Appropriate production drawings
- CNC programming

Blow mould plant for small parts & preproduction runs

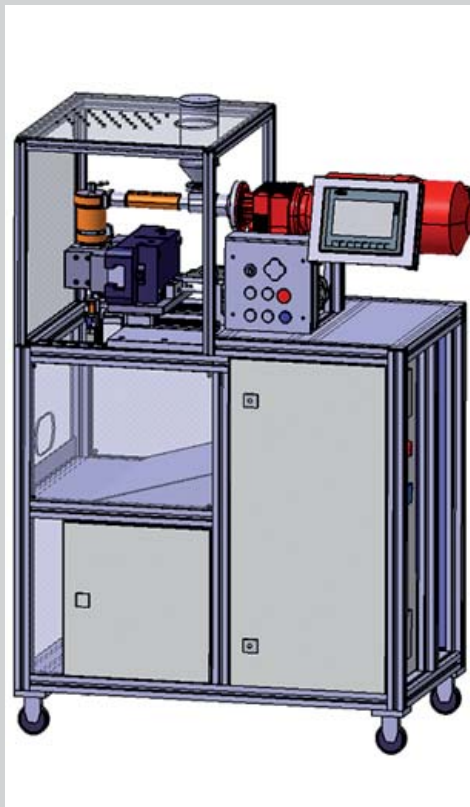
A blow mould plant was developed in the Dr. Reinold Hagen Foundation for the production of small items and material proving which, in terms of its extremely compact design, is unique on the market.

As a complete range of specialist skills in electrical engineering, design and production is available under the umbrella of the Foundation Group (including Hagen Engineering GmbH), a small blow mould plant was successfully realised and unveiled for the first time in 2010 at the K, the trade fair for plastics and rubber in Düsseldorf. All work was realised in-house, commencing with its design, then construction of the mechanism and electric wiring and, subsequently, PLC programming of the control system.

In addition to use in customer projects, this initial machine was regularly used as a practical demonstration plant at trade fairs and events such as the International Green Week in Berlin.



Initial small blow mould plant (constructed 2010) at the IGW Berlin in 2015

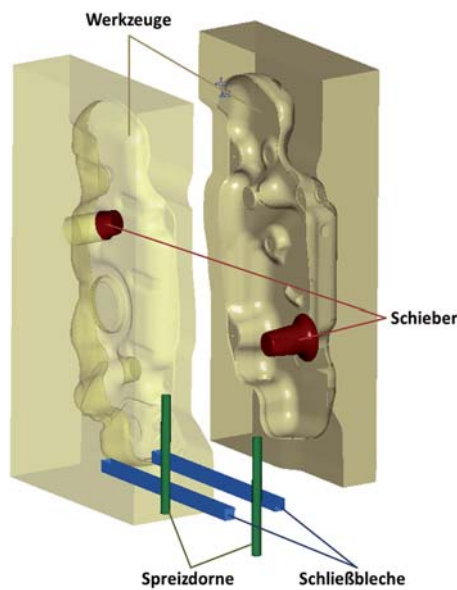


New construction of small blow mould plant, 2019 CAD RHS image

In response to the extremely varied application options encountered in the following years, it was decided to construct a second more advanced machine. As was the case with the first blow mould machine in 2010, the next-generation machine was also a complete in-house development and construction.

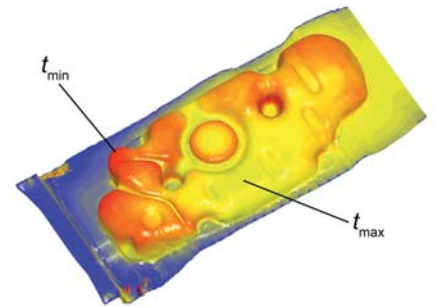
Experience gained with the initial plant has led to its successor being enhanced with a variety of new functions. The new plant has a considerably more efficient mould cooling system and can be operated comfortably using a touch panel and expanded as required through the addition of new functions. Further process-related developments such as a parison head with wall thickness control are currently undergoing testing.

Numerous decisions which decisively influence technical feasibility and process reliability can already be encountered during the early phases of the development process. Simulation tools such as PreBlow and B-SIM enable the reliable answering of precisely these questions in terms of product development appropriate to the process involved. Computer-aided assessment of the influencing factors and effect of both design modifications to the component and blow mould and changes to process parameters is also possible. Potential errors are identified at an early stage and expensive mould corrections avoided. Thanks to the practical know-how it has gained in blow moulding, Hagen Engineering GmbH can guarantee a reliable interpretation of simulation results. Unresolved issues relating to the practical implementation of findings are addressed in comprehensive consultation.



Mould for plastic fuel tank with slides, strike plates and expanding mandrels in B-SIM

Blow mould simulation offers additional advantages, as the wall thickness distribution calculation is used as an input variable for a subsequent structural analysis (see next page) to determine product and performance characteristics.



Blown plastic fuel tank – specific wall thickness (t_{min} , t_{max}) is achieved

Unterstützung in vielen Fragen

Die Blasformsimulation bietet Ihnen Unterstützung in den folgenden Bereichen des Entwicklungsprozesses:

- Feasibility studies / Applicability of blow moulding process
- Optimising of wall thickness distribution through use of wall thickness control systems (AWDS, PWDS and SFDR)
- Prediction of item weight
- Prediction of possible production problems (wrinkles/thin areas) and their remedying
- Design and use of slides
- Simulation of 3D blow moulding
- Automatic transfer of wall thickness distribution in a subsequent structural analysis

Our mode of working

Well-founded statements regarding the feasibility of their blow mould products can be made following completion of two significant working steps. Moulds, slides and other elements required are transferred to the simulation environment and process parameters and material data are defined in an initial step.

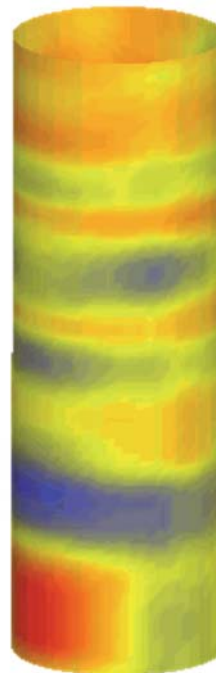
A first simulation run with consistent wall thickness distribution in the preform provides early indications of critical points in the blow moulding. Potential thick/thin areas or wrinkles can be identified.

The second step exploits the automatic wall thickness adaptation integrated in PreBlow and B-Sim for generating the required wall thickness in the item. The result achieved is the point of departure for all further optimisations.

If error sources and areas requiring optimising are detected in the product, an initial attempt is made to achieve improvements without changing the geometry or mould parting line of the component. Possible process variables include blowing pressure, preform diameter or practical adaptation of the wall thickness distribution.

The geometry of the component is only changed where this is unavoidable and only following consultation with the customer.

Optimised preform (wall thickness depicted in colour)



A practical example

The advantage of blow mould simulation in the development process is clearly illustrated in a project:

In the case of packaging products, the process means that the neck/handle area is a particularly sensitive zone. The packaging manufacturer's development project has been delayed due to wrinkling occurring in this area.



Wrinkle in neck area

Several expensive attempts to rework the production mould to avoid the occurrence of wrinkling through a change in geometry failed. Only through blow mould simulation did it prove possible to both confirm the fault through simulation and achieve speedy and cost-effective optimising of the geometry. It subsequently proved possible to eliminate the wrinkle completely from the product.

This example indicates that use of blow mould simulation as early as possible means a considerable time and cost saving during the development process!

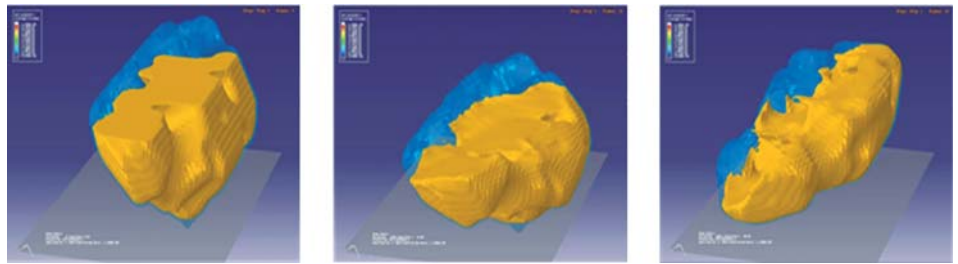


Solution developed

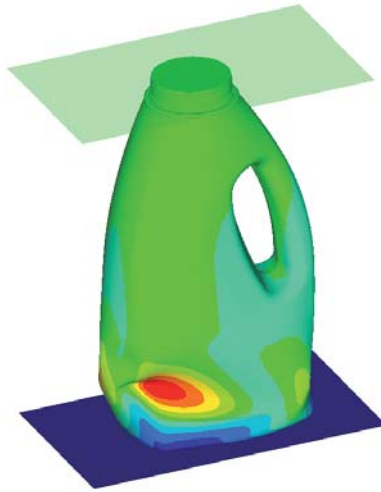
The finite element method (FEM) also offers the possibility of assessing the characteristics of a product, even where no prototype exists.

This enables the early detection of possible product weak points in the development process. Expensive corrective measures are avoided during the prototype phase and series production. Furthermore, use of simulation methods enables the comparison of different solution variants and concepts with each other at an acceptable cost.

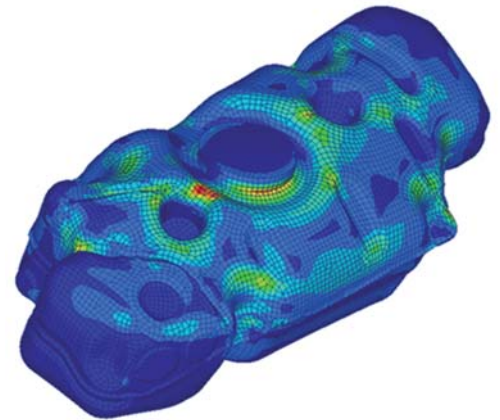
Hagen Engineering GmbH is your contact and partner when it comes to addressing a multitude of issues encountered in daily engineering practice. We are at your service, both with regard to our core plastics expertise and for all general problems.



FEM simulation of drop testing of a canister filled with liquid



Topload optimising for a packaging product



Simulated short-term internal pressure testing on the plastic fuel tank depicted above

Our equipment

- **Statistical analyses**
 - Deformation behaviour
 - Stress analyses
 - Contact problems
 - Stability problems (bending, buckling)
- **Dynamic analyses**
 - Crash behaviour
 - Drop simulation of filled blow mould product
 - Material laws for crash simulation
 - Vibration analyses
- **Thermal analyses**
 - Heat conduction
 - Cooling behaviour of blow mouldings
- **Damage analyses**
 - Metal / Plastic
- **Optimisation**
 - Shape / Geometry
 - Material substitution
- **Process analyses**
 - Simulation of extrusion blow moulding
- **Coupled analyses**
 - Fluid-structure interaction (FSI)
 - Interfaces to process analysis

Product optimisation / Design of machine components

In addition to focusing on adherence to specifications, weight and cost reductions are increasingly important during the design of machinery and machine components. Component behaviour under a specified load can be predicted as early as the development process through an FE structural analysis. Findings include the component deformation behaviour and local stress and strain factors.

A complete assembly including all couplings can be modelled, depending on the task involved. However, separate examination of individual critical areas is also adequate in individual cases. The installation state needs to be replicated through appropriate modelling of the load application and mounting conditions. The advantage of this approach is the reduced modelling effort which, in turn, significantly reduces the costs and calculation times involved.

Following creation of the simulation model, a variety of component variants can be compared with each other with very little effort. A consider-

able reduction in component weight can frequently be achieved through an optimised design, while simultaneously retaining the same durability. Mathematical optimisation methods, such as design or topological optimisation, can also be employed here.



Varied machine component design an weight optimising tasks

Components developed in the design department can be manufactured in the in-house production centre. In addition to moulds for the blow moulding industry, typical products include prototypes and small-scale series in metal and plastic for medical technology and laboratory needs.

Aside from conventional machine tools, the equipment available includes a 5-sided milling centre.

Test and small-scale series moulds

During development of new blow mould products and materials, manufacture of the first real prototypes or production of small-scale and pre-series in series production material is necessary as of a certain stage of the project.

For this reason, Hagen Engineering GmbH relies on the latest milling technology in this area, as this assists us in milling prototypes and small-scale series moulds directly from aluminium in the shortest possible time.

When designing prototype moulds, the shape is initially reduced to the least complex, but most practical development stage required for the production of pre-series products. Production of the first blow mouldings can be realised in our Technical Centre or at your own premises.

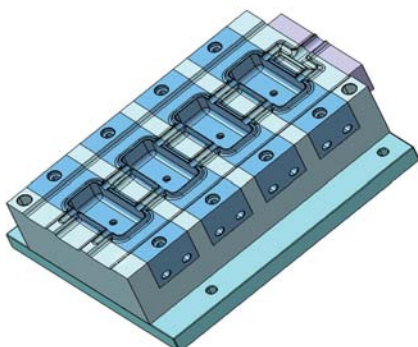


Image caption: Test mould for assessing weld seam strength in blow mould parts
Special moulds are frequently required to record the impact of process-specific peculiarities of blow moulding on the final product. These can be used to highlight particular effects specific to blow moulding. Simul-



taneously, the shape of the test mould can be adapted to facilitate sampling from the test mould/product for later laboratory testing.

The test mould design, design of the CAD model and production of the test mould are realised completely in-house. In addition, it is also possible to sample the moulds created in our Technical Centre. Samples of the items manufactured can be assessed subsequent to this in our test lab for the required characteristics.

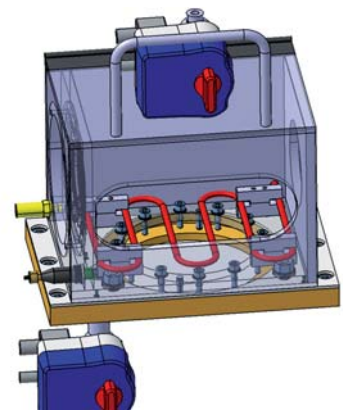
Special fixtures

In addition to the production of moulds and individual components from metal and plastic, the development and construction of special devices and machines is a further focus of Hagen Engineering GmbH.

A broad spectrum can be realised in-house, thanks to the availability of a wide range of technical know-how in electrical engineering, design and subsequent production.

This ranges from individual production of, for example, a complex prototype of a mounting fixture for cable ducts and test fixtures to

machines such as a complete blow mould plant for products up to 40ml.



Development of a bubble inflator for CA material data acquisition, RHS image

Ausstattung Werkzeugbau

- 5-sided DMU 70 machining centre
- CNC 3-axes Kunzmann
- CNC 3-axes Hermele
- Several conventional milling/turning machines
- Surface grinding machine

The following processes can be depicted

- Extrusion blow moulding
 - Conventional
 - Suction blow moulding
 - Continuous extrusion
 - Parison feeder
- Extrusion
- Deep drawing

Mould and material proving

Mould and material proving is realised on our modern blow mould machines.

External mould proving offers the customer the advantage of avoiding expensive and disruptive downtimes on their own main productive lines. Mould behaviour in series production can be assessed both rapidly and cost-effectively.

Material proving allows manufacturers to examine the behaviour of their material in the blow moulding process. The findings serve as a basis for any necessary material modifications. Material manufacturers can exploit this to expand the application areas of their products in the growing blow moulding technology market.

Small-scale series

Hagen Engineering is your partner for the production of prototypes and small-scale series involving quantities of up to 20,000 per annum. In addition to the production of small-scale series, Hagen Engineering also offers the manufacture of initial prototype series. Short routes through the in-house design department and internal toolmaking facility guarantee delivery on schedule and the technically correct design of the mould in this respect.

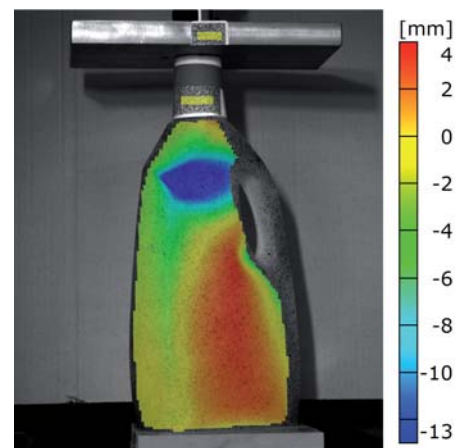
A continuously recurring task is the production of prototype series where different process parameters vary in the customer order. Prototypes of this kind generally undergo the required function testing at the customer's premises. The competencies of the customer are complemented by the know-how of Hagen Engineering in an iterative improvement process.

In order to transfer know-how from the development process to the series, personnel from Hagen Engineering are also on hand following project completion to mediate for the customer when series production starts up, for targeted training of employees and to address optimisation issues.

Test lab

All aspects of our range of services are supported by our in-house test laboratory, the focus here being on product testing and tests conducted during production. Selected standard tests can also be conducted in our laboratory.

Practical experience indicates that, in general, no standard tests are intended or suitable for checking the actual performance characteristics of most products. We develop customer-specific test methods and equipment for their applications through bundling of our design, production and measurement technology skills.



Optical 3D deformation analysis with GOM Aramis on a gripping lug



Technical Centre of Dr. Reinold Hagen Stiftung

Our laboratory equipment

- Faro articulated measuring arm
- Tension, bending and compression tests
- 3D image correlation with Aramis (optical, non-contact deformation measurement)
- High-speed camera
- Short-term / long-term internal pressure testing up to approx. 6 litres
- Shore and ball indentation hardness tests (DIN 53505, DIN 53456)
- PC-supported microscopy / microtomy
- Melt flow index testing (MFI / MFR)
- Moisture analysis for plastics
- Charpy impact test
- Thermographic imaging
- Environmental chamber
- Drop tests up to 3.5 m
- We offer other test methods (DMA, DSC, etc.) in cooperation with our network partners.

Blow moulding / process engineering training seminars

We offer two seminars in the area of blow moulding technology within the Foundation Group for training of your employees. In the Basic Blow Moulding Seminar, participants learn the most important basic skills and knowledge relating to blow moulding technology. They can expand their knowledge and skills further in the Advanced Blow Moulding Seminar.

Naturally enough, our "from practical application for practical application" approach also applies here, meaning that theoretical education is always followed by the practical application of that which is learnt and live observation in our Technical Centre.

Basic Blow Moulding Seminar

Practical and process engineering fundamentals of blow moulding are taught. Independent commissioning and set-up of blow mould machines are learnt, along with the skills required to independently manufacture blow mouldings.

Course content:

- Introduction to plastics technology
- Structure of blow mould machines
- Fundamentals of process engineering
- Set-up and commissioning of blow mould machinery
- Production of blow mouldings

Advanced Blow Moulding Seminar

Participants are empowered to realise independent process optimisation. Knowledge gained in product proving is consolidated to develop a solid base.

Course content:

- Fundamentals of process engineering
- Influencing of product quality through variation of process parameters
- Quality testing
- Practical exercises using blow mould machines in the Technical Centre
- Blow moulding process simulation on the computer



Specialised company-specific training measures

In addition to blow moulding courses, the Foundation Group also offers to create company-specific courses together with companies to ready employees for future challenges.

A good example of this is the European Space Agency (ESA) course addressing the issue of "Maintenance and Repair".

The background here is fact that, after 20 years in orbit, the International Space Station (ISS) increasingly requires inspection, maintenance and repairs. Training in these tasks is normally conducted in advance on Earth. However, incidents occur time and again on the ISS that place increasing demands on the crew and require their intervention.

To meet these requirements, the European Space Agency (ESA) commissioned the Belgian company Space Application Services and the Dr. Reinold Hagen Foundation to develop a course in which relevant technical knowledge and appropriate skills are imparted to future astronauts. Astronauts attending the 8-day course at the Training Centre of the Foundation Group learn practical skills in the areas of mechanical and electrical engineering, electronics, hydraulics and pneumatics.

The main objective of this course is to offer astronauts a structured educational option based on realistic cases from space.

The course was initially tested in February 2017 by the experienced ESA astronaut Leopold Eyharts and subsequently certified by the ESA. The course was then held for the

first time in December 2017 with the astronauts Matthias Maurer and Samantha Cristoforetti.

LEGAL NOTICE



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