

POWDER

SPECIAL ISSUE
PM²TEC2005
JUNE 19-23, MONTREAL

NEWS



CLOSER COOPERATION can maximize profitable growth

Alrik Danielson, the new CEO of Höganäs AB, sees closer cooperation between powder producers and component makers as a key factor for future success.



Alrik Danielson, President and CEO of Höganäs AB

Since taking up his position as CEO in May this year, Alrik Danielson has been gaining an insight into the global operations and prospects of Höganäs AB.

The new CEO has a strong background in manufacturing with metals having spent most of his career with the bearing company, SKF. He held a variety of management positions in sales, marketing, manufacturing and finance, and worked extensively outside Sweden, including a spell as President of SKF do Brazil. Alrik, 43, is married, and has three children.

Powder News talked to Alrik about the company, customers and the way ahead:

What are your first impressions of Höganäs AB?

"I have managed to visit most Höganäs AB subsidiaries around the world and I have met many talented and motivated people. I see

a company that is really trying to satisfy customers. It is a company that supplies excellent products as well as ensuring that these products actually work, providing the expected end result for the customer."

How would you assess future prospects for the P/M industry?

"I have also had the opportunity to meet customers and I am encouraged by all the new developments going on. However, the unsatisfactory profitability of the players in the P/M value chain is a concern and it may slow down future growth."

What needs to be done to ensure maximum growth?

"I see a need for the powder producers and component manufacturers to work even closer together in the future. It is only by fully leveraging the combined competencies that the complete potential for profitable growth in the P/M industry can be harnessed. I am encouraged when I look at what Höganäs AB can offer in this respect. I invite everyone to take part."

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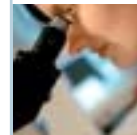


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Flying start

FOR STARMIX™ IN NORTH AMERICA

The new Starmix™ plant is helping customers in the pursuit of tighter tolerances.

Production at the new Starmix™ plant in Stony Creek, Pennsylvania, began in November 2004. The plant's capability to tailor the bonded mix, Starmix™, to meet tight tolerances is attracting enquiries and sample requests from customers not only in North America, but from around the world.

Ryu Goto, Market Manager for P/M Powders at North American Höganäs Inc. says: "The Stony Creek Starmix™ plant has the most advanced technology available, which enables a high degree of bonding, and consequently more consistent mixes during compacting. With more consistent mixes one can achieve higher productivity and better control of tolerances. It also enables our customers to produce parts with very complex shapes with less distortion. As a result of this, we are getting a lot of interest from manufacturers of high-performance parts."

"Before production start up, we performed extensive qualification testing of the product and the equipment at various major customers and the outcome was very positive," states Ryu. "The customers were very impressed with the results."

"What we now deliver direct from Stony Creek are engineered, customized products. We can identify and deliver the best combination of properties for a specific application," explains Ryu.

The new Starmix™ plant complements the wide product range of North American Höganäs, Inc., which has produced atomized iron and steel powders at the state-of-the-art Stony Creek facility since 2001. The new plant also improves service to US customers by providing direct delivery of locally produced, customized bonded mixes with shorter lead times.

"Customer feedback since we started production has been very good," says Ryu.

"One customer is in the process of eliminating a secondary operation in the component production by switching from a standard premix to a customized Starmix™ produced here. The customer is very pleased with the production cost reductions that will be achieved."

The world of Starmix™

Stony Creek is the third production plant for Starmix™. The product is also made by the Group at units in Sweden and Japan.

Starmix™ is a bonded mix, a metal powder concept pioneered and patented by Höganäs AB. The first organically bonded mix carrying the Starmix™ name was launched in the mid-1980s.

Today, bonded mixes are increasingly replacing premixes in gear production and other high-performance applications as they offer opportunities to improve efficiency and productivity as well as obtain tighter tolerances and complex shapes.

Good filling performance and minimal segregation are essential if P/M technology

is to meet the demands for close dimensional tolerances in high performance parts. Starmix™ products are designed to address these issues by bonding ingredients to reduce segregation and enhance filling performance.

The advantages of Starmix™ over unbonded premixes have been documented and highlighted by R&D in numerous technical presentations, and include:

- Better filling performance
- Minimal segregation
- Less weight variation
- Less dusting
- Productivity increases during compaction
- The dimensional stability to deliver better final tolerances

The Starmix™ product and production process have been continuously enhanced, and in recent years advances have been made in key areas such as filling characteristics, dusting and lubrication.

The continuous development process focused on Starmix™ has created greater possibilities to engineer and customize mixes for specific applications.



Ryu Goto,
Market Manager
for P/M Powders
at North American
Höganäs Inc.

THE TECH CENTER

is geared up for new applications



By providing the right expertise and resources, the North American Höganäs Tech Center helps customers solve current technical problems and create future P/M applications.

The North American Höganäs Tech Center at the Stony Creek site in Pennsylvania has been supporting customers in North America since 2001.

Head of the Tech Center, Technical Director Ulf Engström, outlines the center's marketing support role: "One of our primary aims is to bring new products and technologies developed at Höganäs AB in Sweden to the North American market. At the same time, we provide R&D in Sweden with information on products and technologies emerging in North America and relay feedback from customers on new market needs."

Customer Technical Service Manager, David Milligan says: "We have good contacts with our customers and make them aware of the latest developments from Höganäs AB through a variety of technical presentation channels such as papers at conferences and MPIF seminars. We can also arrange on-site seminars on specific subjects for customers and end-users."

The Tech Center is also involved in raising customer awareness through training. It runs the P/M School three times a year, the Metallography School twice a year and

can also offer on-site training tailored to customer's needs.

Technical support

The ten-strong Tech Center team of engineers and technicians support the North American customer base with technical customer service. In practical terms, the team assists customers with challenges such as meeting end product specifications and conversions to P/M components. Finding solutions quickly is an essential part of the service: the Tech Center aims to supply both test mixes and Customer Support Investigation results within five days of the request.

"We have the broad competence to provide support on the P/M side and also have access to expertise in Sweden," states David. "A typical case would be to improve a certain material property for a component. If necessary, we can discuss the issue with colleagues at Höganäs AB in Sweden and find the best solution in terms of modifying the material or processing parameters."

"For customers, the Tech Center offers time and labor savings and other benefits," he continues, "What we provide is valuable outside assistance and a faster route to the right solution, whether it's investigating manufacturing problems or giving advice on optimizing materials."

Future applications

The Tech Center is becoming more involved in application development, especially for high-performance components. "Over the

past few years, we have built up a solid reputation as a resource that can help customers through technical support with their existing materials and processes," says Ulf. "Leading on from this, we are now increasingly working as a partner in application development projects with customers and end users. These applications tend to be at the high-performance end in areas such as automotive gears."

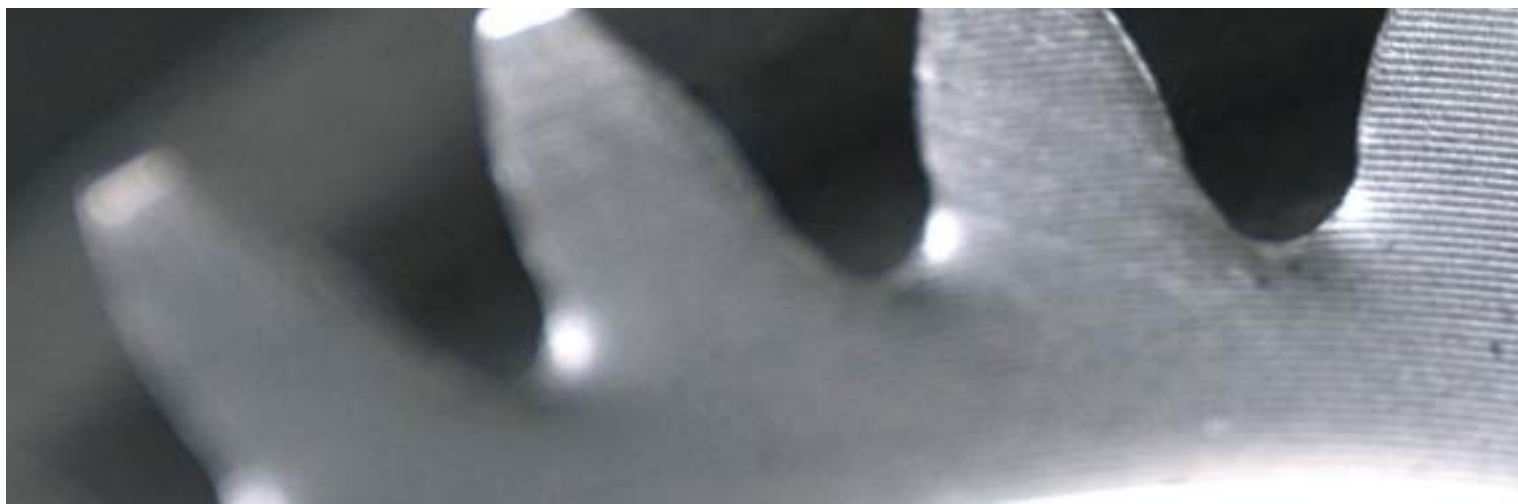
The application development means available at the Tech Center include a 100-ton press and warm compaction equipment, testing and high-precision measurement equipment, and access to performance-enhancing processing facilities for high velocity compaction and surface densification.

"We are fully geared up to work on and develop tomorrow's P/M components with customers and end users," emphasizes Ulf, "We want to expand our work in this area and create new powders and processing solutions that satisfy high-performance requirements for new applications."



*Ulf Engström,
Technical Director
at the Tech Center*

Towards high



At PM²TEC 2005 North American Höganäs, Inc. and Höganäs AB will present the latest studies on cost-effective routes to reach higher performance levels for powder components.

The pursuit of high-performance metal powder components through powder and process development is a prioritized R&D area for Höganäs AB. Providing high-performance solutions for parts in automotive applications can unlock a huge potential market for powder components. Several of the Group's technical presentations at Montreal will highlight how far R&D efforts have come in showing cost-effective manufacturing solutions for high-performance needs. The three PM²TEC 2005 presentations featured in this article focus on some of the most promising means – new cost-effective alloy systems, surface densification and high-temperature sintering – that can be used or combined to meet today's demanding performance requirements.

Chromium alloy systems

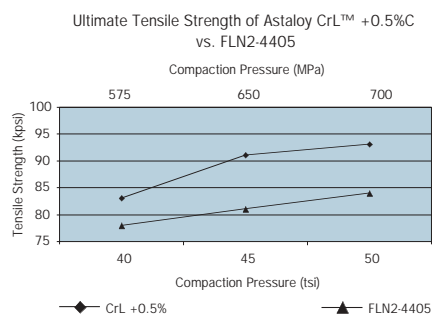
Chromium has become an increasingly attractive element in P/M manufacturing, not only for its effect on strength and hardenability, but also because it is a cost-effective alternative to traditional alloying elements. But, how does a chromium-based alloy system actually measure up in cost and performance terms against one of the most successful alloy systems used today?

The paper, *Cr-Mo P/M Steels as a Cost-Effective Alternative to Traditional Ni-Mo P/M Steels* by David Milligan, Ulf Engström, (North American Höganäs, Inc.), and Suresh Shah, Jerry Falleur, (Cloyes Gear and Products), provides the answers by comparing Astaloy CrL™ with the popular MPIF FLN2-4405 system.

The study was carried out in cooperation with Cloyes Gear and Products, a US manufacturer of components and systems for automotive and industrial applications. The company specializes in valve timing components and systems with production at three sites in Arkansas and Oklahoma and Germany.

“We wanted to see if Astaloy CrL™ can be used as a general replacement for a very common and widely used material that has become much more expensive because of the dramatic rise in molybdenum prices,” says David Milligan of North American Höganäs, Inc.

Test bars and gears were processed in a number of ways – as sintered, heat-treated and induction-hardened – and resulting properties were compared.



“We found that Astaloy CrL™ can provide equivalent or better performance, but at a lower cost than MPIF FLN2-4405,” says Ulf Engström. “Astaloy CrL™ is a versatile material with a broad appeal that can be used to cover a wide spectrum of requirements in new or existing applications.”

The Group has been studying the potential of chromium as a low-cost alloying element since 1993. Astaloy CrL™ (1.5% Cr and 0.2% Mo) was launched at PM²TEC 2002 and along with Astaloy CrM® it has become a well established alternative for mass production applications.

Surface densification

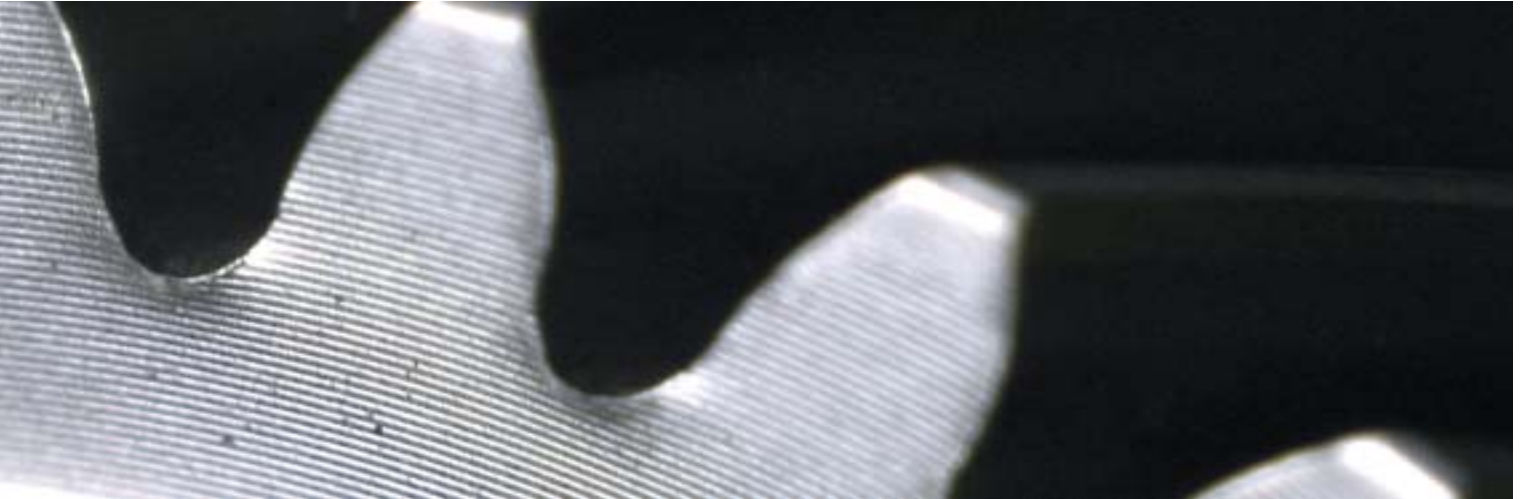
High performance features prominently in all three of the special-interest programs at Montreal involving Höganäs AB. One of the programs – P/M solutions for the next frontier – features a presentation called *Surface densification of helical and spur gears* by Sven Bengtsson, Linnéa Fordén (Höganäs AB), Magnus Bergström (Scania) and Claes Kuylentierna (Volvo AB).

The paper provides an insight into current knowledge on surface densification and its potential benefits in high-performance components such as transmission gears. The presentation draws on studies carried out over the years by Höganäs AB with heavy truck producer Scania and automotive manufacturer Volvo AB.

Höganäs AB became involved in surface densification in the early 1980s and the technique has been extensively developed in R&D projects since the mid-1990s.

“We have worked on different parts with Volvo for many years to find ways to meet

performance



performance requirements and we have also enjoyed a long-term relationship in developing technology with Scania," says Sven Bengtsson of Högånäs AB

The new study investigates the effects of selective densification on the gear teeth of helical and spur gears. A process route consisting of compaction, sintering, surface densification by rolling and finally heat treatment was used to assess the feasibility of producing transmission gears by powder metallurgy. Tests on the gears focused on densification, gear quality and tooth root fatigue.

"What was different with these tests is that it is the first time we have looked at Astaloy CrL™ in surface densification tests with Volvo and Scania," explains Sven Bengtsson. "The results were good. Using this material we have managed to achieve the required gear quality with sufficient densification. Astaloy CrL™ was found to be highly suitable for surface densification."

"We are making good progress with surface densification and it is becoming more established in commercial applications," continues Sven. "Cooperation with end users such as Volvo and Scania has given us an opportunity to really understand their processes and improve our material development. The more we understand the processes, the more we will be able to develop solutions for surface densified parts that are cost-competitive and meet stringent end user requirements."

High-temperature sintering

Högånäs AB regards high-temperature sintering as a potentially effective processing

technique to capture future applications that demand higher performance from material systems. However, cost is commonly regarded as an issue when customers consider high-temperature sintering. But, what is the true cost of this performance-enhancing treatment?

High-Temperature Sintering, A Cost-Effective Way to Future High-Performance P/M Materials is a paper by David Milligan, Ulf Engström, North American Högånäs, Inc. and Steven K. Smith, Gasbarre Products Sinterite/C.I. Hayes Furnace Division that fully examines the question of costs and commercial benefits.

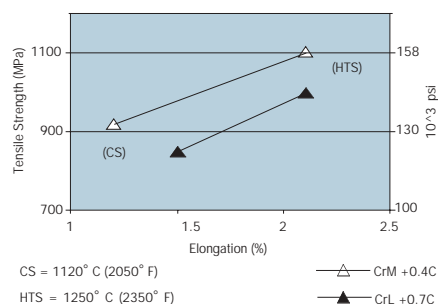
The paper brings together the high temperature sintering expertise of North American Högånäs, Inc. and extensive cost analysis studies carried out by Steve K. Smith, President of the Sinterite/C.I. Hayes Furnace division of Gasbarre Products Inc. based in St Marys Pennsylvania, USA. The Sinterite/CI Hayes Furnace division produce conventional belt sintering furnaces and high temperature industrial furnaces.

"Generally high-temperature sintering is more expensive than conventional belt furnace sintering, but what we have found after a comparison is that high-temperature sintering can actually be cost-effective when viewed from a cost to benefit ratio," says David Milligan at North American Högånäs, Inc.

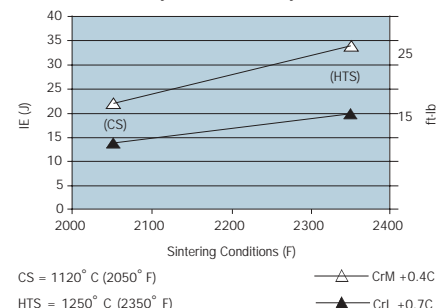
The study compares a number of aspects of P/M gears sintered at high and normal temperature, including sintering costs, static and dynamic properties and dimensional tolerances.

"High-temperature sintering is a way to get higher performance at a lower cost rather than opting for more complicated processing such as double compaction/double sintering," adds Ulf Engström. "Going to the higher temperature can give you up to 20% tensile strength gains and open up new areas for components in higher performance applications. We try to promote high temperature sintering, as we feel it delivers an attractive performance to cost ratio."

Tensile properties for conventional and high temperature sintered Astaloy CrM™ and Astaloy CrL®



Impact Energy for conventional and high temperature sintered Astaloy CrM™ and Astaloy CrL®



PHOSPHOROUS

- improving a proven alloy system



Recent research in cooperation with DaimlerChrysler has shown that even a well-proven alloy system can be improved after analysing component microstructure.

Phosphorous-alloyed sintered steels offer a unique combination of strength and ductility and they are also suitable for components requiring good soft magnetic properties.

However, certain conditions can occasionally cause intergranular cracking in parts that contain phosphorous. Until now the microstructural mechanisms behind this material behaviour have been difficult to identify, but a new joint study between Höganäs AB, DaimlerChrysler and the Oak Ridge National Laboratory in the USA has enhanced understanding of the phenomenon and pointed to a solution.

"Our study has established that a relatively simple additive solution exists to prevent intergranular cracking. This solution can be used as a basis for developing robust processes that ensure ductile components," says Ulf Engström of North American Höganäs, Inc.

The path to the solution is set out in a presentation for PM²TEC 2005 called *Ductile Components of Phosphorous-*

Alloyed P/M Steel by Jean Lynn, Paulo Rosa, (DaimlerChrysler Corporation), Harry Meyer III, (H.T. Materials Lab, Oak Ridge National Lab) Ulf Engström, (North American Höganäs, Inc.) and Sigurd Berg, Jan Tengzelius, Ola Bergman, Robert Frykholm, (Höganäs AB).

The key to understanding intergranular fractures has been to show what happens during processing of phosphorous-alloyed (with Fe₃P) sintered steels at a microstructural level. This has been achieved using a combination of conventional metallographic evaluation and the surface analysis technique, Auger Electron Spectroscopy (AES), which can examine the composition of atomic layers adjacent to the interfracture surfaces. The AES analyses were carried out at the High Temperature Materials Laboratory of the Oak Ridge National Laboratory.

The study investigated a theory about the cause – that phosphorus segregation and oxide formation weaken the grain boundaries of the sintered component – and the cure – that graphite additions may prevent brittleness in Fe-P sintered steels.

To determine the effect of graphite addition on the embrittlement mechanism, AES analysis focused on Fe-P materials with and without graphite additions. This was supplemented by an examination of mechanical properties and microstructures.

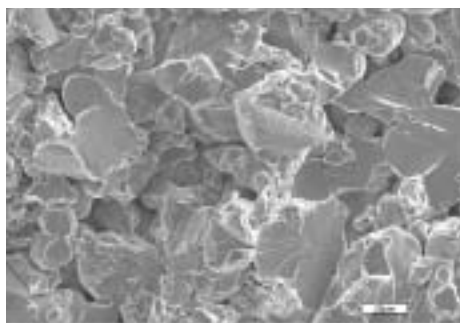
Confirming the cause

Both the "cause" and the "cure" theories were confirmed. "Grain boundary phosphorus segregation and oxide precipitation were shown to cause brittleness in Fe-P sintered steels," says Ulf Engström.

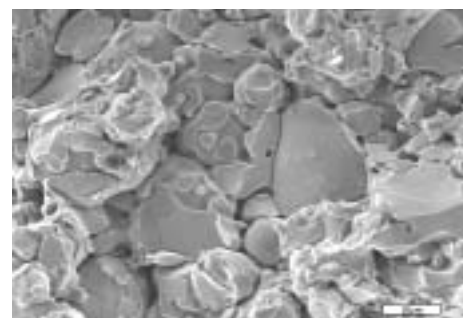
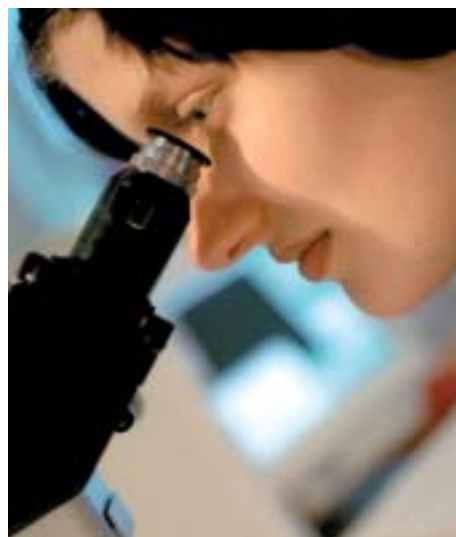
"Consequently, it is important to identify preventive measures for these mechanisms."

Several factors, such as Fe₃P particle size, heating rate and cooling rate, were shown to affect the embrittlement mechanisms. Low cooling rates should be avoided since they allow more time for phosphorus segregation and formation of embrittling oxide precipitates at the grain boundaries. It was concluded that cooling rates $\geq 0.5^\circ \text{C/s}$ should be applied after sintering in the processing of Fe-P sintered steels.

As for the cure: "It was found that an effective way to avoid embrittlement of Fe-P sintered materials is to add a small amount of carbon, either by using Fe₃P containing carbon or by adding graphite to the powder mix. This beneficial effect was confirmed by AES analysis," states Ulf Engström.



Ductile fracture – graphite addition.



Brittle fracture – without graphite addition



Hard evidence

Vacuum-carburizing can give Astaloy CrL™-based solutions the exterior hardness needed to compete in the gear market.

Many high-performance components such as gears require a hard surface and a tough core. These properties are commonly achieved by casehardening operations, which aim to improve the fatigue strength and wear resistance of P/M components. In the case of a Cr-alloyed material such as Astaloy CrL™, vacuum-carburizing is an interesting means to improve properties with low risk for oxidation of the material during processing.

This area is explored in the PM²TEC paper: *Efficient Low-Alloy Steels for High-Performance P/M Applications* by Ulf Engström, David Milligan, Alexander Klevkovkin (North American Höganäs, Inc) Sigurd Berg (Höganäs AB) and Leonid Frayman, Gerd Hinzman, Bill Edwards (Hawk Precision Components Group).

Hawk Precision Components Group is a US company supplying engineered precision components to industry. Hawk has six production sites in the USA and one in China. The test bars used in the study were sintered at the Hawk facility in Falls Creek and Clearfield, Pennsylvania, and vacuum-carburized at C.I. Hayes Heat Treating Corp.

The paper shows the properties achievable with Astaloy CrL™ at different density levels after conventional and high-temperature sintering and vacuum-carburization.

“One of the many reasons for the growing interest in chromium as an alloying element is the excellent mechanical properties attainable both in the as sintered condition and after secondary heat treatment, such as through hardening or case hardening,” says Ulf Engström of North American Höganäs, Inc.

Enhancing properties

The study shows that high-temperature sintering is able to increase material performance by triggering beneficial changes in the microstructure.

Vacuum-carburization of materials based on Astaloy CrL™ significantly increased tensile strength, transverse rupture strength and hardness compared to the as sintered material. These properties are further enhanced at higher densities.

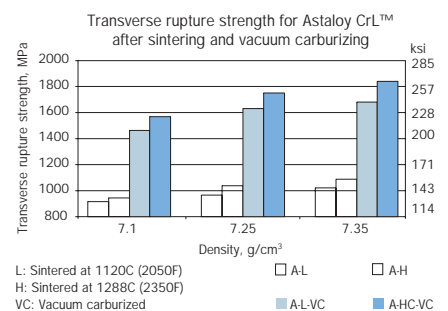
Some impressive gains were recorded. Tensile strength after vacuum-carburizing increased about 40 per cent for the material sintered at 2050F (1120C) and 30 per cent for the material sintered at the higher temperature 2350F (1288C). Transverse rupture strength following vacuum-carburizing was between 40 to 50 per cent higher for the material sintered at 2050F. Vacuum-

carburization dramatically increased apparent hardness at all densities, and hardnesses of 35 to 40 HRC were obtained after quenching and tempering for both materials irrespective of the sintering temperature used.

Processing and testing procedures were duplicated on a spur gear. The data obtained corresponded very well and therefore data from test bars can be used in the design of gears that will be vacuum-carburized.

Vacuum-carburization was thus shown to be an effective process to case harden spur gears made of Astaloy CrL™ with a carbon content in the range of 0.2 to 0.30 per cent.

Ulf Engström concludes: “This paper adds to the growing body of evidence that Astaloy CrL™ is a cost-effective material that can, with the right processing solutions, deliver properties such as high fatigue strength that are required in automotive gears and other high-performance applications.”



TECHNICAL PRESENTATIONS

AT THE PM²TEC2005 CONFERENCE, MONTREAL, JUNE 19-23

Monday June 20	Tuesday June 21	Wednesday June 22	Thursday June 23
<p>Microstructural Reinforcement Obtained by Diffusion Bonding Höganäs AB <i>Luiği Alzati, Anders Bergmark Jessica Andersson</i></p> <hr/> <p>High-Temperature Sintering, A Cost-Effective Way to Future High-Performance P/M Materials North American Höganäs, Inc. <i>Ulf Engström, David Milligan</i> Sinterite/C.I. Hayes Furnace Division <i>Steven K. Smith</i></p>	<p>Means to Improve Machinability of Sintered Stainless Steel North American Höganäs, Inc. <i>Prasan K. Samal</i> Höganäs AB <i>Owe Mårs, Ingrid Hauer</i></p> <p>SPECIAL INTEREST PROGRAMS</p> <p>Surface Densification of Helical and Spur Gears Höganäs AB <i>Sven Bengtsson, Linnéa Fordén</i> Scania CV AB <i>Magnus Bergström</i> Volvo AB <i>Claes Kuylenstierna</i></p>	<p>Improved Property and Dimensional Consistency Achieved Using Bonded Premixes North American Höganäs, Inc. <i>Peter J. Thorne, Ulf Engström David Milligan</i> Höganäs AB <i>Daniel Edman</i></p> <hr/> <p>P/M Steel for High-Loaded Applications Höganäs AB <i>Anders Bergmark, Sven Bengtsson</i> Volvo AB <i>Claes Kuylenstierna</i></p> <hr/> <p>Chromium Prealloyed P/M Steels for High-Performance Applications Höganäs AB <i>Robert Frykholm, Ola Bergman</i></p> <hr/> <p>Ductile Components of Phosphorus-Alloyed P/M Steel Daimler Chrysler <i>Jean C. Lynn</i> Oak Ridge National Laboratory <i>Harry M Meyer III</i> North American Höganäs, Inc. <i>Ulf Engström</i> Höganäs AB <i>Sigurd Berg, Jan Tengzelius Ola Bergman, Robert Frykholm</i></p> <hr/> <p>Cr-Mo P/M Steels as a Cost-Effective Alternative to Traditional Ni-Mo P/M Steels North American Höganäs, Inc. <i>David Milligan, Ulf Engström</i> Cloyes Gear and Products <i>Suresh Shah, Jerry Falleur</i></p> <hr/> <p>Efficient Low-Alloy Steels for High-Performance P/M Applications North American Höganäs, Inc. <i>Ulf Engström, David Milligan Alexander Klevkovkin</i> Höganäs AB <i>Sigurd Berg</i> Hawk Precision Components <i>Leonid Frayman, Gerd Hinzman Bill Edwards</i></p>	<p>Machining of Chromium-Alloyed PM Steels Höganäs AB <i>Olof Andersson, Sigurd Berg</i></p> <p>SPECIAL INTEREST PROGRAMS</p> <p>Growth of PM through Material and Processes Development for High-Performance Components Höganäs AB <i>Sigurd Berg</i></p> <hr/> <p>Processing Means to Achieve High-Performance P/M Materials North American Höganäs Inc. <i>Ulf Engström, David Milligan</i></p>
<p>For daily update of presentations visit www.nah.com</p>			

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