Höganäs

POWDER NEWS

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Soft approach

MAKES STELLITE P/M-FRIENDLY

New research opens up surprising niche role for stellite alloys in P/M applications.

The idea of compressible stellite has long been regarded as a contradiction in terms as far as P/M is concerned. However, a new paper by Ingrid Hauer and Owe Mårs of Höganäs entitled *Compressible Stellite* shows how a cobalt-based stellite metal powder can be simply produced and points to promising applications in the glass industry.

Stellite-type alloys with a cobalt, nickel or iron base have a clear appeal: they are known to be highly resistant to wear, particularly at high temperatures and in corrosive conditions. However, the hardness of stellites has previously deterred interest from the P/M industry as it makes compaction impossible in a press and sinter route.

The high cost of machining stellites in cast component production, especially for complex parts, prompted Höganäs R&D to take a fresh look at the potential of P/M to provide an alternative that could substantially cut production costs.

"It has always been considered that stellites were not suitable for P/M because of their hardness. With this study we have been able to show that a cobalt-based stellite material can be compacted and used in a high-temperature P/M application," says Owe Mårs.

The paper describes how a cobalt-based stellite powder can be compacted in a conventional P/M process and possess sufficient

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P/M gears roll on

TOWARDS DIN 7 QUALITY

Surface densification by radial gear rolling is a key process in the P/M industry's quest for DIN 7 automotive gear quality.

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green strength to be handled safely. The approach is based on eliminating the carbides to make the material softer and more compressible. If carbon is added to the stellite as graphite, compressibility is greatly improved and the component can be compacted. After sintering, a carbide network is created in the stellite particles and excellent hardness is achieved.

Stellites are a suitable material for neck ring and baffle insert applications in the glass industry. As glass is very abrasive, the material needed for these applications in the moulding process require good properties at high temperature and good machinability. The mould needs to have full density to enable a smooth glass surface.

The second part of the paper explores how full-density stellite components can be created by copper infiltration for neck rings and baffle inserts. Importantly, these components effectively determine the service life of the mould.

"Cobalt may be more expensive than nickel, but compared to today's nickel solution, a P/M cobalt-based stellite solution for neck rings can offer a lower total cost by offering a more durable solution to increase the mould's life span," states Owe.

A very positive finding was that the cobalt-based stellite powder component could be made using a standard P/M manufacturing route: "We used a standard pressing and sinter process and sintered at normal temperature settings," says Ingrid Hauer.

"It has been very interesting working on a very different type of material on this six-month project and it was satisfying to find we can extend the scope of P/M using a cobalt-based stellite powder."

As well as applications in the glass industry, cobalt-based stellite powders open up possibilities for P/M to replace cobalt in exclusive, niche areas of conventional component manufacturing.

"It gives manufacturers who use cobalt in certain high-temperature applications the opportunity to gain benefits from the low-cost P/M manufacturing route and net shape components," concludes Owe.

DIN 7 gear quality, one of the main requirements the automotive industry sets for transmission gears, has become something of a holy grail for P/M research.

Years of focused R&D at Höganäs have seen more and more boxes on the list of DIN 7 quality requirements ticked off. A new study to be presented at Euro PM2005: *Surface Densified P/M Gears Made of Chromium Alloy Powder Reach Automotive Quality* by Senad Dizdar, Linnéa Fordén and David Andersson continues this work and shows that there is only one DIN 7 quality requirement left to fulfil.

Senad Dizdar comments: "Our aim is to find a P/M manufacturing route that delivers low production costs for automotive gears. As this study shows, we are getting there. We have achieved three out of the four principal gear deviations – only profile deviation remains to be reached."

The specimen used in the study is a final-drive idle helical car transmission gear. The P/M gear samples, made from Astaloy CrL™, were cold compacted to 7.1 g/cm^3, sintered, surface-densified by radial gear rolling and finally, case hardened.

These gears achieved an overall DIN 7 quality after rolling for all single deviations deemed important in DIN 3961 for uniformity of rotation, load capacity and noise reduction of gears. However, after low-pressure case hardening, the gear quality for these deviations was DIN 7, except for the total profile deviation Fα, which was DIN 10 quality.

"We have to further improve gear rolling and optionally combine with one of the hard finishing methods to get close to DIN 7. We know the gear must be case hardened and that this will affect total profile deviations," explains Senad. "But, our intention is to carry on researching and improve this DIN10 to a 7. To achieve DIN 7 gear quality after case hardening, further work should include activities that aim to reduce the tooth width contraction along the tooth height."

"This paper shows the progress P/M is making and how far we have come with surface densification using gear rolling," states Senad. "Surface densification has played an important role in getting us to this point. It gives you the possiblity to withstand high stress gradients that can be formed at the surface. Surface densification involving a fully densified layer on the gear flank as deep as the case hardening depth is an essential part of achieving DIN 7."

As well as presenting new findings, Senad would also like to use the presentation at Euro PM2005 to open a discussion on the gear quality that is actually needed to reach automotive customer's performance goals.

"It is often said that the higher the gear quality, the higher the performance, but when looking at gear load capacity, there are gear macro-geometry issues involved too, and these may be more important than single gear deviations," he concludes.

Deviation according to DIN 3960, 3961 and 3962	Symbol	After rolling	After case hardening	General importance	Rotational uniformity	Load capacity
Profile form deviation	$f_{f\alpha}$	7	8			
Profile angular deviation	$f_{H\alpha}$	7	11			
Profile total deviation	F_α	7	10	Yes		Yes
Helix form deviation	$f_{f\beta}$	6	6			
Helix profile deviation	$f_{H\beta}$	7	7	Yes		Yes
Helix total deviation	F_β	7	9			
Single normal pitch deviation	f_u	6	6			
Difference between adjacent pitches	f_p	6	6			Yes
Total cumulative pitch deviation	F_p	5	6		Yes	Yes
Cumulative circular pitch error over z/8 pitches	$F_{pz/8}$	5	6			
Tooth thickness variation	R_s	2	5			
Runout tolerance	F_r^*	-	-		Yes	

** The gear measuring centre evaluated the run-out deviation Fr, according to teeth geometry neglecting the real bore eccentricity, which need to be adjusted by using bore grinding or similar machining.*

NOTCHING UP NEW DATA FOR POWDER COMPONENT DESIGN

New information on notch sensitivity provides vital data for designing components with P/M steels.

"The theme of presentations from the Höganäs Fatigue Group this year has been how P/M can be used to replace many components currently made with wrought steel," says Anders Bergmark. "Our presentation at Euro PM2005 in Prague will continue our strategy of providing design data that can be used not only by customers, but also end users, so they can test P/M as an alternative for the design process."

The presentation is entitled *Fatigue Performance of Chromium Pre-alloyed P/M Steels' Notch Effect* by Anders Bergmark, Jessica Andersson and Sven Bengtsson. It focuses on Astaloy CrL™ and Astaloy CrM®, two chromium-molybdenum pre-alloyed P/M steels developed as the basis for low-cost alternatives to high-fatigue performance P/M steels containing nickel. The paper describes a systematic investigation of these materials' bending fatigue performance and notch sensitivity, and benchmarks the results against other P/M alloying systems.

As modern design tools include FEM calculation of stresses, it is important for the design process that the material database includes information on the notch sensitivity of P/M steels as well as the performance of un-notched material.

"What is new with this research is that we have tested notched specimens, not at radius 3 mm as before, but at .9 mm and .25 mm, because you find many components with small notch shapes, such as synchroniser hubs," says Anders. "Providing good information on notch sensitivity and fatigue behaviour gives design engineers confidence in the materials available for the design of P/M components."

The highest performance of the notched materials was by case hardened Astaloy CrL™, with a nominal bending stress of 395 MPa.

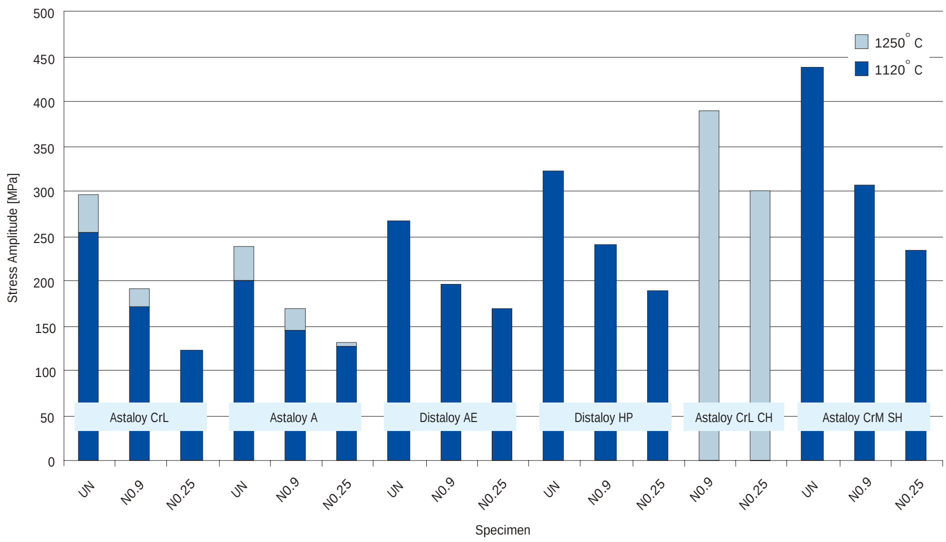
"Perhaps the most important conclusion is that Astaloy CrM® provides good fatigue performance using regular 1120º C degree sintering for both notched and un-notched bars," emphasises Anders. "On the process side, our findings on notched bars would lead us to recommend sinter hardening in a methane atmosphere for best results. Importantly, you can keep 1120º C sintering. So no investment needs to be made in the equipment, just an investment in the knowledge to process it well."

In the benchmarking, un-notched Astaloy CrL™ sintered at 1120º C and 1250º C matched the performance of the diffusion-alloyed material Distaloy AE. "This comparison also made us to take a fresh look at performance of Distaloy AE and Distaloy HP in the notch bar context and it was shown that these two well established products deliver very good performance" remarks Anders.

Sharp stress gradients occur around notches and the paper also examines how mechanical performance can be improved by introducing some kind of case hardening and/or shot peening to create an optimum microstructure.

"Our data confirmed that case hardening or shot peening are effective methods to increase fatigue performance in notched bars," states Sven Bengtsson.

Sven says of the presentation as a whole: "What we supply here is coherent data on these P/M materials based not on one test, but an entire series of tests, and that makes it a valuable a source of reliable information."



Plane bending fatigue performance at load ratio R=-1 for (from left) as sintered Cr/Mo pre-alloyed Astaloy CrL™+0.8%C, Ni/Mo pre-alloyed Astaloy A+0.7%C, Distaloy AE+0.8%C, Distaloy HP+0.8%C, case hardened Astaloy CrL™ and sinter hardened Astaloy CrM®.

Test are performed on un-notched test bars (right) and on notched test bars with notch radius 0.9 and 0.25 mm respectively. All three types have chamfered edges in the minimum cross-section.

Achieving optimum machining with Astaloy CrM®

With the right guidelines, even the hardest P/M materials such as martensitic Astaloy CrM® can be cost-effectively machined.

Even though P/M is a net shape or near net shape process, machining is necessary in some applications to reach the final required tolerances. P/M materials are sometimes considered difficult to machine, but high productivity and low cost levels can be achieved for a specific material by choosing the right combination of tool material, insert geometry, optimised cutting data and additives.

Höganäs, the world's largest metal powder producer, and Sandvik Coromant, the global leader in manufacturing and supplying tools and techniques for machining, work together to provide guidelines for machinability of components based on Höganäs P/M materials. The partnership began in the mid-1990s with tests to identify machining parameters for a number of Höganäs base powders. Over the years, the companies have tested around 25 base powders and variants.

The latest material to be examined by Höganäs and Sandvik Coromant is Astaloy CrM® in a paper called Machining of Martensitic Chromium Pre-alloyed P/M Steel by Sigurd Berg. This presentation for Euro PM2005 extends a previous study focusing primarily on bainitic Astaloy CrM® and allows an interesting comparison between bainitic and harder martensitic microstructures to reveal what it takes to get the best out of both in machining terms.

"Our aim is to spread information to those who are interested in the machinability of Astaloy CrM®," says Sigurd Berg. "The bainitic and martensitic structures require a different approach and should be considered as two different materials. It's important to be clear on the structure you are working on because it determines how you can best combine the elements of the machining process."

Sigurd continues: "The paper gives precise guidelines, so customers can make the right choices in machining – with or without cutting fluid, the right cutting speed, the optimum insert and so on. We present a summary of the process routes that can be successfully applied for these materials, above all for the cost-effective machining of a martensitic microstructure, which is generally regarded as one of the most difficult to machine."

Olof Andersson, a Development Engineer at Höganäs, adds that advances in machining technology have made it simpler to machine P/M materials. "Nowadays, it's easier than many people think. For Astaloy CrM® in a martensitic state, for instance, there are much better CBN inserts available now that make it a cheaper and more productive process. These advances, in combination with the important guidelines we obtain from the series of turning tests done by Sandvik Coromant give customers the opportunity to radically improve machining of martensitic Astaloy CrM® and other P/M materials."

There were some similarities in the optimum process for bainitic and martensitic structures, such as the considerable positive effect of an additive (MnS) on tool life (number of passes) and productivity (feed rate).

"There was one surprising finding which illustrates just how different these microstructures are," notes Olof. "The martensitic structure works best with dry machining, while the bainitic structure works better with cutting fluid, something which is unique for P/M materials."

TECHNICAL PRESENTATIONS

AT THE EURO PM2005 CONGRESS, PRAGUE, OCTOBER 3-5

Monday October 3

Fatigue Performance of Chromium Pre-alloyed P/M Steels' Notch Effect
Höganäs AB (Session 6)
Anders Bergmark, Jessica Andersson, Sven Bengtsson

Tuesday October 4

Tribological Properties of Lubricants Used in P/M Process
Höganäs AB (Session 18)
Naghi Solimanjad, Mats Larsson

Wednesday October 5

Surface Densified P/M Gears Made of Chromium Alloy Powder Reach Automotive Quality
Höganäs AB (Session 21)
Senad Dizdar, Linnéa Fordén, David Andersson

Machining of Martensitic Chromium Pre-alloyed P/M Steel
Höganäs AB (Session 22)
Sigurd Berg

Chromium Alloyed Surface Densified P/M Gears to Replace Conventional Machined Gears
Höganäs AB (Session 22)
Pernilla Johansson, Luigi Alzati, Senad Dizdar, Linnéa Fordén

Compressible Stellite
Höganäs AB (Session 24)
Ingrid Hauer, Owe Mårs

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