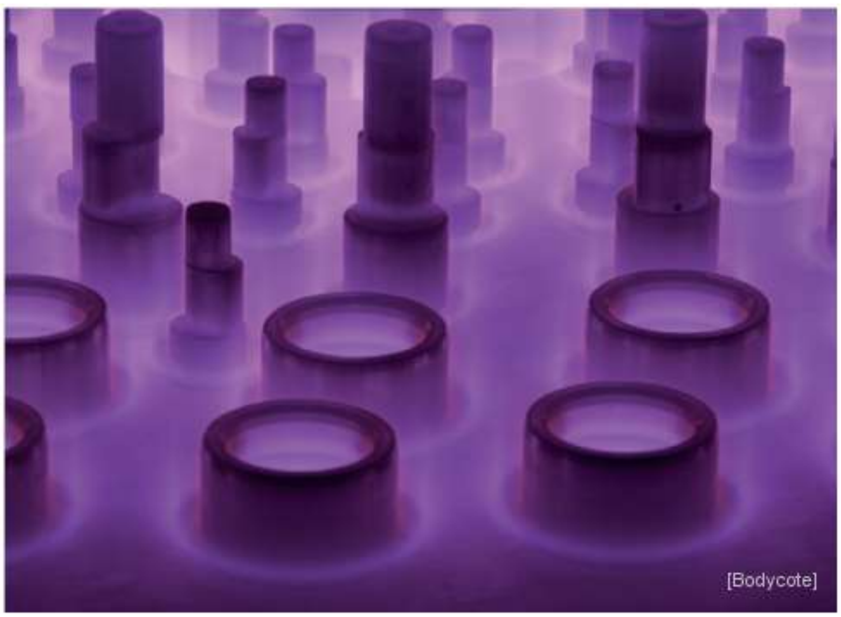
FFI

Less distortion and reduced fuel consumption by new developments and improvements in nitriding heat treatment processes (NitroVBC)



Project within FFI Sustainable Production Technology

Authors: Eva Troell, Swerea IVF; Sven Haglund and Jerome Senaneuch, Swerea KIMAB, Ninos Hawsho, Scania CV

Date: 2013-10-31

FFI

Content

FFI in short

FFI is a partnership between the Swedish government and automotive industry for joint funding of research, innovation and development concentrating on Climate & Environment and Safety. FFI has R&D activities worth approx. €100 million per year, of which half is governmental funding. The background to the investment is that development within road transportation and Swedish automotive industry has big impact for growth. FFI will contribute to the following main goals: Reducing the environmental impact of transport, reducing the number killed and injured in traffic and Strengthening international competitiveness. Currently there are five collaboration programs: **Vehicle Development, Transport Efficiency, Vehicle and Traffic Safety, Energy & Environment and Sustainable Production Technology.**

For more information: www.vinnova.se/ffi

1. Executive summary

The objective has been to manufacture components with low friction and high wear properties and reduce the need for post machining and straightening by utilizing the full potential of nitriding processes in combination with selection of steel grade. A major challenge for many components has been how to obtain required strength properties, e.g high-strength fatigue properties, as can be achieved by case carburizing.

Nitriding and nitrocarburizing are thermochemical heat treatment processes that enhance the surface properties of steel components, e.g. high resistance to adhesive and abrasive wear as well as low friction and high corrosion resistance. Another benefit is low distortion of the components due to the low process temperature.

Nitriding and nitrocarburizing of a wide range of steel grades have been applied in order to evaluate influences on compound layer, diffusion zone and residual stresses and consequently the overall impact on fatigue and tribological properties. Demonstrator components have been selected and measures to replace carburizing with nitriding processes. Demonstrator components have been; a piston (wear), a gear wheel (fatigue), an ejector part in a forging tool (thermal fatigue) and masking of threads (production aspects).

Fatigue tests performed on the gear wheel showed that the bending fatigue properties of nitrided wheels are highly dependent on the selection of steel grade. By selection of proper steel grade, nitrided parts superior to that of carburized may be produced. Compared to carburized steel a major increase in fatigue properties was obtained for the plasma nitrided wheels in pulsating bending fatigue test. The level of distortion is greater for the case hardened wheels (16MnCr5) compared to the nitrided wheels. Furthermore, there seems to be less scattering in distortion level between the nitrided wheels within a given steel grade, suggesting that the distortions would be easier to predict and compensate for compared to case hardened wheels.

Suitable steel and nitriding process for the piston was evaluated by wear testing. In lubricated conditions the tribological properties were quite similar for all tested samples. The result in dry conditions resulted in a lower friction at lower loads for some of the steels nitrided and/or nitrocarburized compared to case hardened 16MnCr5. In addition the work on the piston clearly showed the need for future work regarding the surface characteristics and how the properties are influenced by steel grade and heat treatment.

The need for, or not to, mask internal threads when nitriding was evaluated by fatigue testing. The tests conducted confirm that there is a difference between masked and unmasked thread from a fatigue point of view. One can thus not completely exclude that there could be a need to mask threads prior to nitriding to avoid the formation of cracks by fatigue. However, the tests were performed with high quality bolts, so it is possible that in a normal situation the small negative influence of nitrocarburising on fatigue performance of the threads is actually negligible.

A cost comparison was made for steels and heat treatments used in the gear wheel study. For some of the steels the costs were comparable to case hardening followed by shot peening. The use of more expensive steels resulted in higher costs. However, it should be taken into account that no optimization of the costs have been possible to perform or to include the benefits of less distortions.

A simplified LCA was performed to evaluate the environmental impact for the different processes used for the gear wheel. The energy consumption is lower for the nitriding sequences compared to case hardening sequence and also the emissions according to carbon dioxide equivalents. The greatest impact has the steel that is used.

2. Background

In a heat treatment context nitriding is a low-temperature process providing components with less distortions and excellent low friction and abrasive resistance performance. By minimised distortions subsequent processes such as grinding and straightening can be eliminated or reduced to a considerable extent. In order to meet requirements for lower fuel consumption low friction powertrain-components are needed. Such surfaces can be achieved by nitriding. The major challenge is how to obtain required strength properties, e.g high-strength properties for many powertrain components. This can be provided by a proper selection of steel grade and nitriding process.

There are several different nitriding treatments available. The process can be performed in e.g. gas, vacuum or with plasma. Different processes and process parameters allow control of layer composition and possibilities to design the layer properties, e.g ε/γ′-ratio, porosity and thickness of the compound and diffusion layer. Compared to nitriding the benefits of nitrocarburising are shorter process times and possibilities for further improved corrosion resistance.

The performance of a nitrided component is influenced by material strength, diffusion zone (fatigue properties) and the compound layer (tribological and corrosion properties). At conventional nitrocarburising nitrogen and carbon are transferred to the steel surface, normally at a temperature of approx 570 °C. At the surface a wear resistant layer, the compound layer, with a thickness of 0.005-0.03 mm, is formed. It may also be porous. The compound layer consists of iron- and carbon-nitrides (γ'-Fe_4N and ε-$Fe_{2,3}(N,C)$). In particular nitrogen is further diffused into the steel matrix and forms the diffusion zone, which is characterized by the formation of nitrides within the original steel matrix. For alloyed steels also the alloying elements form nitrides. Depending on the steel an increased hardness to a depth of 0.5 mm may be obtained.

3. Objective

The overall objective of the project “NitroVBC” has been to manufacture surfaces with low friction and high wear properties in order to reduce fuel consumption and to reduce the need for post machining and straightening of steel components. By proper selection of nitriding process and steel grade the aim has been to customize component performance by achieving surfaces and strength profiles with optimal performance for existing application. Influence on cost, environment and production aspects should be stated.

4. Project realization

4.1 Screening tests

Two screening tests have been performed; one focusing wear properties and one fatigue properties. In the case of wear, compound layer properties e.g. hardness, porosity and phase composition are crucial. The hardness of the diffusion zone is of importance as load support and if the compound layer is worn through. Regarding fatigue properties depth and hardness of the diffusion zone are essential. Only a thin compound layer is desired in order to avoid surface cracks to initiate in the compound layer during fatigue.

Steels studied are shown in *table 1*. Samples for the screening test focusing wear properties were nitrocarburized at 580 °C for 120 min. For the screening test focusing fatigue properties the samples were plasmanitrided at 540 °C for 16 h.

The test probes have been evaluated regarding hardness, compound layer thickness and composition as well as residual stresses for the fatigue properties.

Table 1 Chemical composition for steels included in the screening tests.

Steel	C	Si	Mn	P	S	Cr	Ni	Mo	V	Cu
Orvar Supreme (~H13)	0.39	1.00	0.4		<0.003	5.20		1.40	0.9	
Nimax	0.1	0.30	2.5			3.00	1.0	0.30		
SS2244 (42CrMo4)	0.42	0.33	0.80	0.011	0.023	1.00	0.15	0.19		0.22
Ovako 225A (18CrMo8)	0.18	0.30	0.85		0.015	1.85	0.30	0.55		
Ovako 277 (16CrMnNiMo9)	0.15	0.30	1.30		0.023	2.20	0.50	0.50		
SS2172 (S355JR)	0.20	0.55	1.60	0.045	0.045					
2520 (~17NiCrMoS6-4)	0.14-0.20	<0.40	0.60-0.90	<0.035	0.030-0.050	0.80-1.20	1.20-1.70	0.10-0.20		<0.35
100Cr6	0.93-1.05	0.15-0.35	0.25-0.45	<0.025	<0.015	1.35-1.60		0-0.10		

4.2 Demonstrator components

Demonstrator components have been used as cases; a piston (wear properties), a gear wheel (fatigue properties), an ejector part in a forging tool (thermal fatigue) and masking of threads (production aspects during heat treatment), *figure 1*.

The *gear wheel* was selected for the evaluation of fatigue properties. Gears have been manufactured in steel Orvar Supreme, Nimax, 42CrMo4 and Ovako 225A and plasma nitrided. As reference wheels in steel 16MnCr5, case hardened to CHD ~0.7-0.8 mm, was manufactured and tested. Evaluation was made regarding distortions and gear fatigue.

a) b) c)

Figure 1 Demonstrators a) gear wheel b) piston c) internal threads

The *piston* was selected for wear properties. Due to extremely tight manufacturing tolerances, it was not possible to produce a piston for full scale rig testing, according to the original plan. As an alternative a comprehensive wear screening test was performed covering steel grades, heat treatment and wear testing methods according to *table 2*. Wear testing methods used were a Tribological load scanner and a pin-on-disc machine.

Table 2 Screening tests for evaluation of wear.
CH-case hardened, NC-nitrocarburized, PN-plasmanitrided

Test	**Steel**	**Heat treatment**	**Tribological load scanner**		**Pin-on-disc, lubricated, 10 kg**	
			Lubricated, 10 000 cycles	**Dry, 1 000 cycles**	**Against 100Cr6**	**Against Orvar Supreme PN**
1	16MnCr5	Case hardened	CH ↔ CH	CH ↔ CH	X	X
2	42CrMo4	Nitrocarb	NC ↔NC	NC ↔NC	X	X
3	Ovako225	Nitrocarb	NC ↔ NC	NC ↔ NC	X	
4	Orvar Supreme	Nitrocarb	NC↔ NC	NC↔ NC	X	
5	Orvar Supreme	Plasmanitrided	PN ↔ PN	PN ↔ PN		
6	Nimax	Nitrocarb	NC↔ NC	NC↔ NC	X	
7	42CrMo4	Plasmanitrided	PN ↔ PN	PN ↔ PN		
8	16MnCr5	Case hardened and grinded	CH ↔ CH	CH ↔ CH		

The Tribological load scanner tests were made by Ångström Laboratory in Uppsala. In this test sliding contact is evaluated. One test bar is mounted in the lower holder and another bar is mounted in the upper holder. Parameters such as speed, load range, number of strokes and lubrication can be varied in a load scanner. The samples were 100 mm long with a diameter of 10 mm. Tests were made in lubricated and dry conditions.

In a pin-on-disk machine a spherical test probe is worn against a horizontal rotating disc. Sliding disc, load and lubrication can be varied. After a defined distance during testing the wear mark is measured in a microscope. The surface load will decrease during testing.

a) b)

Figure 2 Wear testing equipment used: a) Tribological load scanner b) Pin-on-disc

A third demonstrator was *threads*. Masking of internal threads for risk of cracks is one of the steps in the process chain prior to nitriding and nitrocarburising. It would save both time and costs if this could be avoided. The aim of the test was to assess the risk of leaving threads not masked during nitriding or nitrocarburizing. Threaded parts were manufactured in 42CrMo4 and nitrocarburized. Half of the batch was masked following a “standard” procedure, when the other half was not masked. The threads were tested in tension-tension fatigue in a 100 kN servo-hydraulic MTS machine at 20 Hz. The tested components were mounted on a Bulten B14 M10 bolt.

4.3 Influence on cost, environment and production aspects

An economical and environmental analysis was conducted based on the manufacturing sequence for the gear wheels, *figure 3*. This could in reality be changed; e.g shot peening is not included after case hardening, which is a common operation, and the need for post heat treatment such as isothermal annealing or normalizing after forging needs to be adjusted depending on component and dimensional tolerances. After nitriding grinding should be avoided to maintain the properties of the compound layer, however polishing could be relevant. If no compound layer is desired grinding can be applied. Input for the analysis was achieved from participating companies, external contacts and, for the LCA, also SimaPro data base.

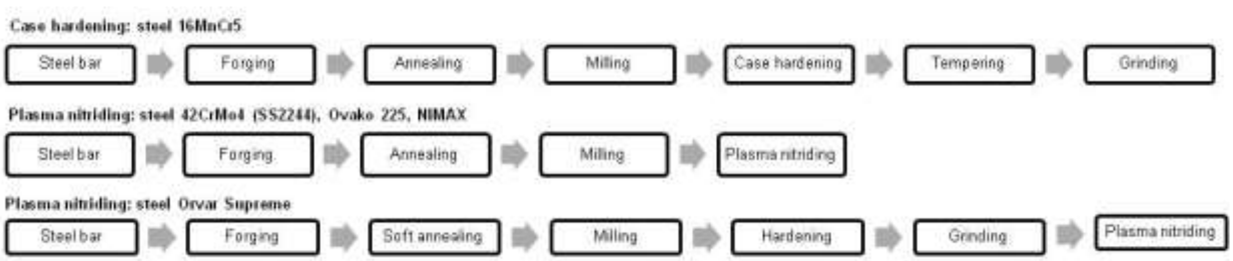
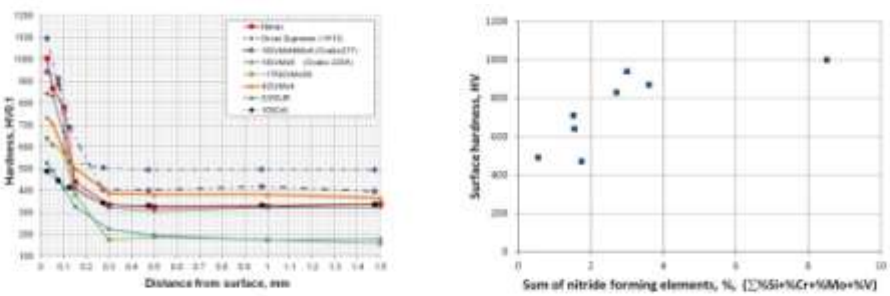


Figure 3 Manufacturing sequence used in the economical and environmental evaluation.

5. Results and deliverables

5.1 Screening tests

Wear properties are affected by the hardness of the compound layer and diffusion zone, porosity and composition of the compound layer. The ε/γ´ratio of the compound layer should be as high as possible for improved resistance to wear under high loading.
Figure 4 shows the hardness profiles for the steels and surface hardness depending on the total content of nitride forming elements.



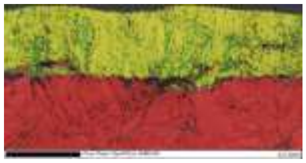
a) b)

Figure 4 *a) Hardness profiles for the steels after nitrocarburizing, 580 ℃, 120 min.*
b) Effect of amount of alloying element on surface hardness.

The composition of the compound layers have been evaluated using X-ray diffraction (CuKα) and EBSD. The result for selected steels is shown in *table 3* and *figure 5*. The composition and structure of the compound layer varies depending on steel grade. The analyse depth of the XRD-measurement is ~3 µm, which does not include the total compound layer. The EBSD images shows a clear picture of the different phases. The highest ε/γ´ ratios are obtained for steel Nimax, 42CrMo4, Ovako277 and 100Cr6. The distribution and sizes of the ε-phase within the compound layer varies between the steels.

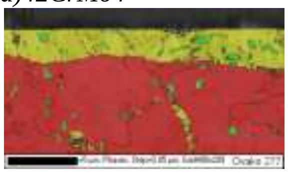
Table 3 *Compound layer thicknesses and XRD result for samples included in the wear screening test.*

		XRD	
Steel	**Compound layer thickness, µm**	**Fe_3N (ε)**	**Fe_4N (γ´)**
Orvar Supreme (~H13)	4	88	4
Nimax	6	94	1
SS2244 (42CrMo4)	9	96	3
Ovako 225A (18CrMo8)	7	90	7
Ovako 277 (16CrMnNiMo9)	6	95	3
S355JR	7	89	10
2520 (~17NiCrMoS6-4)	9	95	4
100Cr6	8	95	4

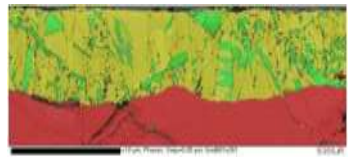


a)42CrMo4

b)Ovako 225A



c)Ovako 277



d)S355JR

Figure 5 EBSD images of steel 42CrMo4, Ovako 225A, Ovako 277 and S355JR.

Fatigue is affected by case depth, chemical composition and residual stresses. *Figure 6* shows the hardness for the different steels after plasma nitriding. Orvar Supreme and Nimax, containing a high content of nitride forming elements achieve the highest surface hardness. The core hardness of 42CrMo4 is at the same level as for Nimax, but the surface hardness is lower. Ovako 225A and 277 shows similar hardness profiles. The highest fatigue resistance was expected to be achieved for Orvar Supreme. Also the residual stress state will influence on the fatigue performance.

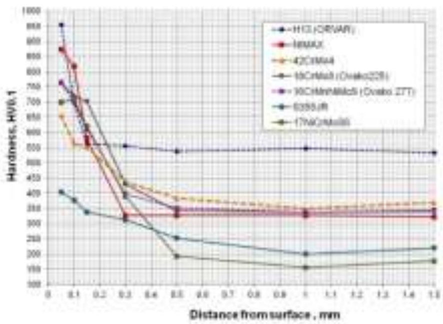


Figure 6 Hardness profiles for steels in fatigue screening test. Plasmanitrided at 540 °C for 16 h.

The compound layer thicknesses for all steels are less than 7 µm, *figure 7*. Orvar Supreme, Nimax and Ovako 277 develop none or a very thin compound layer, due to their high level of nitride forming elements.

The residual stresses have been evaluated using X-ray diffraction, to 0.3 mm depth, and the hole drilling method, to 1 mm, *figure 8*.

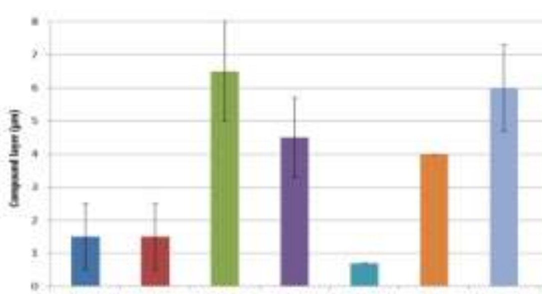


Figure 7 Compound layer thicknesses for steels in fatigue screening test.

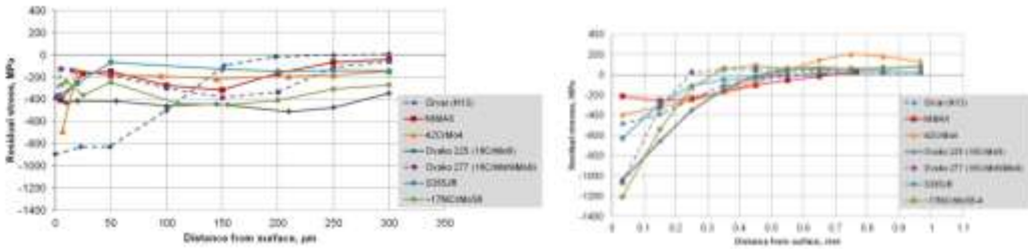


Figure 8 *Residual stresses left) x-ray diffraction and right) hole-drilling method.*

For the fatigue performance high surface hardness, deep diffusion zone, high core hardness and compressive residual stresses at the surface are of importance. A thin compound layer could be beneficial if there is a risk of cracking in the compound layer which would start a fatigue crack. Inclusions are also of great importance but have not been studied in this project.

5.2 Demonstrator components

Gear wheel

Some of the measured dimensional changes for plasmanitrided gear wheels in steels 42CrMo4, Nimax and Ovako 225A compared to case carburized gears in steel 16MnCr5 are shown in *figure 9*. The overall impression from the measurement is that the level of distortion is greater for the case hardened wheels (16MnCr5) compared to the nitrided wheels. This is expected as nitriding does not involve heating into the austenite phase. Furthermore, there seems to be less scattering in distortion level between the nitrided wheels within a given steel grade, suggesting that the distortions would be easier to predict and compensate for compared to case hardened wheels. In terms of profile deviation, Nimax is considered in level with that of 16MnCr5. However, Nimax was not annealed after forging which is most likely the cause for the higher distortion levels.

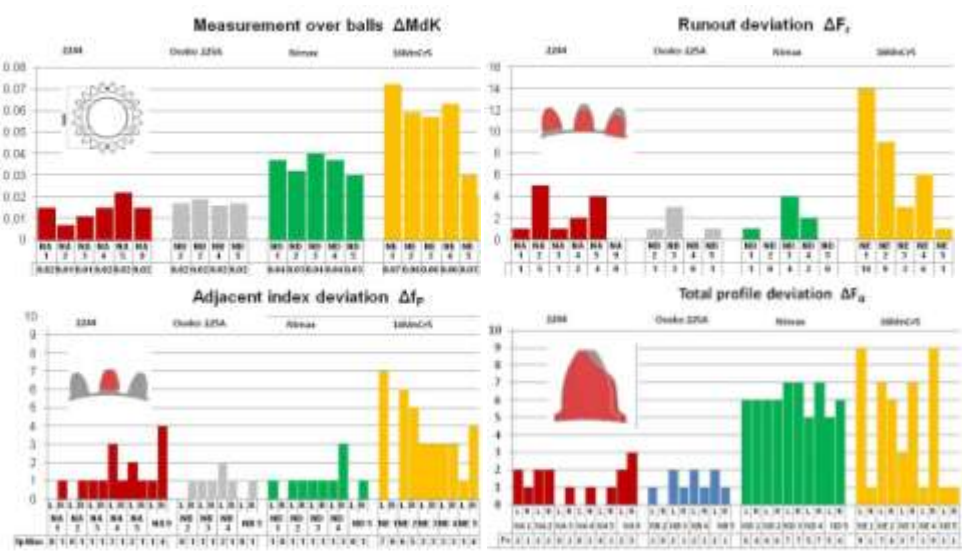


Figure 9 *Difference in dimensional deviation pre and post heat treatment.*

It is evident that the bending fatigue properties of nitrided wheels are highly dependent on the selection of steel grade. Compared to carburized steel a multiply increase in fatigue properties was obtained for the plasma nitrided wheels. These results clearly show the potential with increased performance by a proper selection of steel grade and heat treatment.

Piston

The piston is subjected to a load of 40-50 kg/mm^2, e.g 0.4-0.5 GPa. The applied load in the Tribological load scanner was 30-1100 N (contact pressure of 1-3.3 GPa). Thus, for the piston, it is the result at low loads that are of interest. It is important to keep in mind that the surface topography after heat treatment differed between the samples. All the samples were manufactured in the same way, but the effect of the heat treatment resulted in surfaces with different topography (Ra etc). This shows the importance of the surface topography before heat treatment, which needs to be adjusted with regard to the influence of the heat treatment. This is a topic that needs to be further investigated.

In dry conditions, *figure 10,* the friction at lower loads is less for plasma nitrided and nitrocarburized Orvar Supreme and plasma nitrided 42CrMo4 compared to case hardened 16MnCr5. Ovako 225 exhibits the same friction level as 16MnCr5. These steels are thus the main candidates to be used for the piston. Also other steels could be an option since the piston is used in lubricated condition. In lubricated condition, *figure 11*, the tribological properties were quite similar for all the samples. Some differences could be observed in the initiation phase, e.g. the running-in period was longer for some samples.

At higher loads, above 200 N, the friction coefficient for the case hardened samples was about 0.4. This was also the case for nitrocarburized Orvar Supreme, but the friction coefficient was higher, 0.5-0.6, for the other nitrided samples.

The Pin-on-disc testing was made at lubricated condition and the contact pressure was up to 11 MPa. Orvar Supreme sliding against 100Cr6 resulted in the slightest abrasion. The other tested combinations resulted in a higher wear rate compared to case hardened 16MnCr5 sliding against 100Cr6. The reason for this is most likely the varying surfaces topography and the testing condition in which worn off material remains on the disc where the hard nitrides works as abrasives.

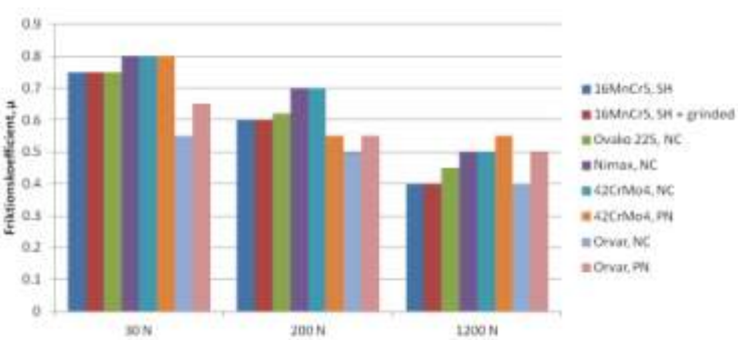


Figure 10 Friction coefficient at dry wear for different loads at 1000 cycles.

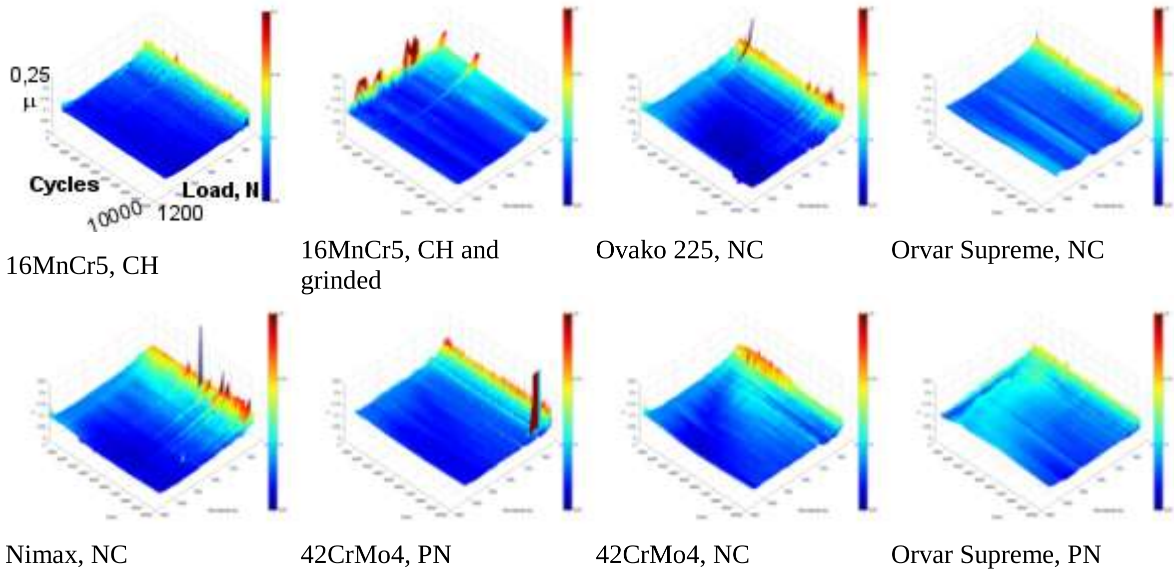


Figure 11 *Friction coefficient as a function of load and number of cycles for tested steels in the Tribological load scanner in lubricated condition.*

Masking of internal threads

The fatigue tests conducted in this study confirm that there is a difference between masked and unmasked thread from a fatigue point of view. One can thus not completely exclude that there could be a need to mask threads prior to nitriding to avoid the formation of cracks by fatigue. However, these tests were performed with bolts of very high quality and these bolts were subjected to severe fatigue, so it is possible that in a normal situation the small negative influence of nitrocarburising on fatigue performance of the threads is actually negligible.

5.3 Economical and environmental analysis

Figure 12 shows a comparison of cost shares for the different steels and heat treatments. It should be noted that no optimization or “bargain of prices” for the different posts have been made, e.g it’s based on best practice by the project group. In this case plasma nitriding was used. If alternative heat treatments could be used the heat treatment cost would be lower; about 20% less with gas nitriding and 40 % less with nitrocarburizing. But a change of heat treatment would also influence on the properties of the component and this needs to be thoroughly evaluated before a change of process. Also process times, temperatures and atmospheres could be further optimized for the nitriding processes. This kind of cost optimization was not included in this project. The benefits of lower distortions have not been taken account for, which will reduce both time and costs.

Figure 13 shows a comparison of environmental impact for the manufacturing sequences based on a simplified LCA, mainly including steel, energy and consumed gases. The latter had a very small impact. It has not been possible to take into account the different chemical composition of the steels, because it had become a too extensive study. However it can be stated that the energy consumption is lower for the nitriding sequences compared to case hardening sequence and also the emissions according to carbon dioxide equivalents. The greatest impact has the steel, whereof 2/3 is removed during milling.

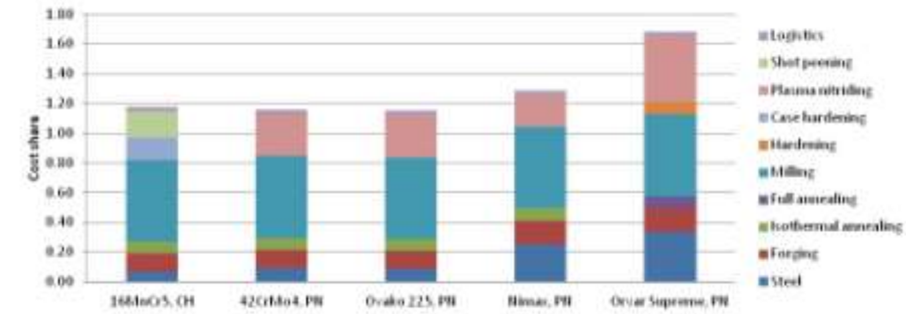


Figure 12 *Comparison of cost share for the different heat treatments. Case hardening without shotpeening is reference = 1.0.*

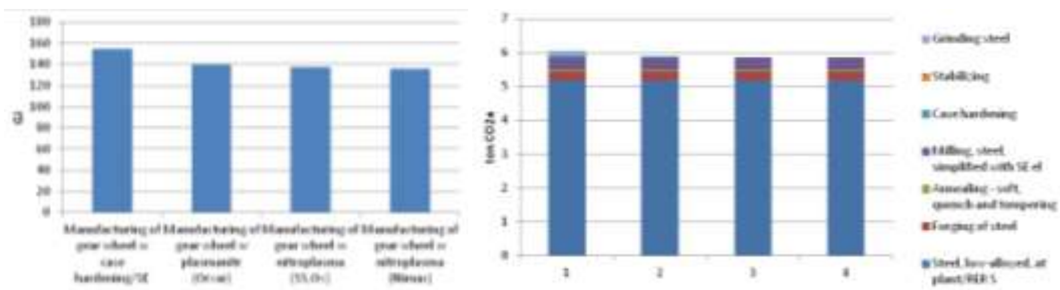


Figure 13 *Environmental impact for the different manufacturing sequences for manufacturing of 1 tonnes gear wheels. a) Energy consumption b) carbon dioxide equivalent. 1) Case hardening of 16MnCr5; 2) Plasmanitriding of Orvar; 3. Plasmanitriding of Ovako 225A and 42CrMo4; 4. Plasmanitriding of Nimax*

5.4 Delivery to FFI-goals

When implemented at companies in production, less distortions and improved component performance for heat treated components can be achieved. The project has resulted in knowledge how to use nitriding processes as an alternative to case hardening. By proper selection of steel grade and nitriding process fatigue properties superior to case hardened steels are possible to achieve. Components with low friction and high wear properties can be manufactured. Distortions are less compared to case hardening, but not neglectible and the manufacturing sequence needs to be further adopted in order to minimize distortions.

A better knowledge, understanding and development of the different nitriding processes have been achieved thanks to the project and the cooperation between the partners.

FFI goals - Sustainable Production Technology (Programbeskrivning FFI HP 130614)

Goal FFI Sustainable Production Technology	Comment NitroVBC
Product requirements for reduced weight and increased passive safety, which in turn require new or improved materials and manufacturing processes are complied with.	A major increase in fatigue properties have been achived demonstrated by the gear wheels. This can be used for weight reduction of components
Use of tools for virtual manufacturing preparation in order to perform fast and accurate impact and optimization studies has increased rapidly	-
Manufacturing Flexibility and production of series sized manufacturing solutions in order to significantly increase the manufacturing process and sustainability (from an ecological and economic perspective) has increased	Typically nitriding processes are performed in batch furnaces, resulting in greater flexibility than current pusher furnaces that are adapted for equivalent heat treatment of large series
Production of vehicles with conventional and new powertrains will take place in the same production system	-
40% higher productivity in manufacturing preparation	-
30% higher productivity of production processes	Process times are less for nitrocarburising compared to case hardening and no tempering is performed. Reduction of distortions make operations like grinding and direction can be removed
30% less environmental impact in the manufacturing processes	The energy consumption in the production of gears with plasma nitriding was approximately 10-15% lower than for case hardened gear wheels.

6. Dissemination and publications

6.1 Knowledge and results dissemination

Result from the project has been presented at the following conferences/seminars:

- AGA/Bodycote seminar 2010. ”Utökad användning av nitrerprocesser”
- SHTE: Aktuellt om material och värmebehandlingsteknik, 28-29 sept 2011. Utökad användning av nitrerprocesser för minskad formförändring och högre prestanda
- FFI Mötesplats för framtidens maskinverkstäder 22 maj 2012, Katrineholm. ”Utökad användning av nitrerprocesser”
- Extending the use of nitriding processes to reduce distortion and fuel consumption. 6th International Quenching and Control of Distortion Conference Including the 4th International Distortion Engineering Conference, 9-13 sept 2012, Chicago
- The 4th Heat Treatment Symp. and Exhibition, 24-25 October 2013, Istanbul, Turkey. Extending the Use of Nitriding Processes to Reduce Distortions and Fuel Consumption
- VBC Membership meetings 2011, 2012 and 2013 (planned 2014)

FFI

6.2 Publications

- Fatigue and wear properties of nitrided steels - including environmental and cost analysis, Troell, Hawsho, Senaneuch
- Screening of steels after plasma nitriding and nitrocarburising. Haglund, Troell
- Fatigue properties after different nitriding/nitrocarburising processes. Persson, Haglund
- Wear testing of nitrided and nitrocarburised steel – Pin-on-disc. Troell
- Extending the use of nitriding processes to reduce distortion and fuel consumption. Troell[1], Haglund[2] and Hawsho[3], [1]Swerea IVF, [2]Swerea KIMAB, [3]Scania AB. Proc. of the 6th Int. Quenching and Control of Distortion incl the 4th Int Distortion Engineering Conf, 2012, Chicago

7. Conclusions and future research

There is a great potential for increasing component fatigue and tribological properties by a proper selection of steel grade and nitriding process. Hardness, compound layer thickness and composition as well as residual stresses are affected. In this project the fatigue limit has been increased by 80% compared to case hardening. Also lower friction has been achieved, but the influence on the surface topography and tribological properties depending on steel and nitriding process needs to be further investigated in order to establish a maximum performance. Better control and regulation of nitriding processes is needed for improved process and part quality. Further improvements of the properties by introducing post processes like oxidation and use of active liquids are also of interest. Other important areas are evaluation of residual stresses and layer properties.

8. Participating parties and contact person

Participating companies and contact person have been: AGA Gas, Anders Åström; Atlas Copco, Richard Johanson; Bodycote Heat Treatment, Solmaz Sevim; Gnutti Powertrain, Istvan Nagy; Ovako, Kristofer Eriksson; Parker Hannifin, Hossein Ghotbi; Sarlin Furnaces, Olle Pelz; Scania CV, Ninos Hawsho; Inomec/Stresstech, Per Lundin; Uddeholms, Henrik Jesperson; Volvo CE, Henrik Edin; Swerea IVF, Eva Troell (project manager); Swerea KIMAB, Sven Haglund

FFI
FORDONSSTRATEGISK
FORSKNING OCH INNOVATION

Adress: FFI/VINNOVA, 101 58 STOCKHOLM
Besöksadress: VINNOVA, Mäster Samuelsgatan 56, 101 58 STOCKHOLM
Telefon: 08 - 473 30 00
ivss@vv.se
www.ivss.se