



Värmebehandlingskonferensen, 6 – 7 november 2024 på Munktell museet, Eskilstuna.

# Abstract

AKTUELLT OM MATERIAL- OCH  
VÄRMEBEHANDLINGSTEKNIK

**SHTE** Swedish  
Suppliers of  
Heat Treatment  
Equipment

08:30 **Registrering och utställning, kaffe**

09:15 **Inledning**

*Anders Åström, Linde Gas AB, ordförande SHTE*

09:30 **What can and what does go wrong with oxygen probes. 40 years of experience in 30 minutes**

*Jean-Marie Herzog, Econox*

10:00 **Hydrogen detection of LPC (Low pressure carburizing) furnaces**

*David Nilebo, Insplorion*

**Paus 30 minuter, utställning**

11:00 **Optimizing Heat Treatment for High-Performance PM Steels**

*Maheswaran Vattur Sundaram, Höganäs*

11:30 **Macro-segregations and their role in distortions in case-hardened ring gears**

*Emil Stålnacke, Swerim*

12:00 **Lunch**

13:15 **HeatDrive - Heat Treatment and Materials Selection for Reliable Electrified Drivelines**

*Niklas Köppen, RISE*

13:45 **New Generation of Nitrocarburized and Post-Oxidized Brake Discs**

*Marcin Stoklosa, Nitrex*

14:15 **Stainihard, hardening of austenitic Stainless steel and Duplex**

*Jeroen Knippenberg, Aalberts Surface Technologies Eindhoven*

14:45 **Kaffepaus och utställning**

15:30 **Cryogenic Treatment of Metals**

*Mohmed Amine Jamli, Air Liquide France Industrie*

16:00 **Reduction of distortion by using of Fixture Hardening Machines**

*Harald Juretzko, HEES*

16:30 **Economic & Ecological Impact and Advantages of Plasma-based Surface Treatments**

*Thomas Bauer, Rübig*

17:00 **Avslut dag 1, Muséevisning och mingel**

19:00 **Galamiddag på museet för deltagare som bokat**

08:30 **A Green furnace and a green heat treatment process**

*Paweł Okińczy, SECO/WARWICK S.A & Erik Spolander CalorMet*

09:00 **Energy and Process Gas Consumption for Selected Vacuum and Atmosphere Case-Hardening Processes and Furnace Concepts – A Comparison**

*Matthias Rink, Ipsen*

09:30 **Kaffepaus och utställning**

10:15 **Decreased CO<sub>2</sub>-Emissions by Adjusting CO-Concentration During Heat Treatment**

*Sven Haglund, Swerim*

10:45 **Minskat klimatavtryck med Linde Green**

*Anders Åström, Aron Joshi, Linde Gas AB*

11:15 **Safety in Heat Treatment – Part of the Corporate Culture**

*Marco Hinsch, Aichelin*

11:45 **Lunch**

13:00 **Avfärd, studiebesök VCE, Munktellvägen 1  
Samling utanför hotellentrén Bolinder Munktell.  
Åter ca 15.30.**

*Vi reserverar oss för ändringar!*

# UTSTÄLLNINGEN

## UTSTÄLLARE

1. SHTE registrering
2. Lindqvist Industriteknik AB
3. CRONITE
4. GA Lindberg PetroSeal AB
5. BergmanLabora AB
6. KMC Ytbehandling AB
7. Svenska Tanso AB
8. Solliden Engineering AB
9. Bergsskolan i Filipstad
10. Air Liquide AB
11. Ipsen Industries Nordiska AB
12. Linde Gas AB
13. CalorMet



09:30

*Föredragshållare: Jean-Marie Herzog, Econox*

## **What can and what does go wrong with oxygen probes. 40 years of experience in 30 minutes**

40 years of experience in manufacturing and use of zirconia probes in a short speak concentrating on issues seen by users all over the planet. Everything from simple human errors to complex process related problems.

*Föredragshållare: David Nilebo, Insplorion*

## Hydrogen detection of LPC (Low pressure carburizing) furnaces

Low pressure carburizing (LPC) is a carburizing heat treatment done to increase the surface concentration of carbon, performed in vacuum furnaces. At high temperatures, a carbon-carrier gas, usually acetylene ( $C_2H_2$ ) is pulsed into the furnace chamber in relatively small amounts. As acetylene is introduced into the furnace, it rapidly decomposes to carbon and  $H_2$ . The treatment needs to be carefully tailored for any specific batch. The rapid decomposition makes it crucial to introduce just the right amount of acetylene during the treatment. Too much will lead to soot formation and too little will give an incomplete treatment. Due to the absence of oxygen in the low pressure furnaces, it is not possible to use oxygen/zirconia probes used to determine the carbon activity, as in conventional gas carburizing furnaces. At the moment there is no reliable tool to directly monitor the process in-situ. Any evaluation of process parameters is based on simulations and calculations before the treatment and analysis of the result afterwards.

The detection of hydrogen in real-time during the carburization process would enable direct control and efficient operation. However, due to its environmental conditions mbar pressure, low oxygen environment traditional hydrogen sensing technologies are not applicable. Insplorion is a Swedish spin-off company from Chalmers University that has developed a new type of hydrogen sensor technology (NPS) which is capable to be used in complex gas environments, with high specificity to hydrogen and fast response. In a joint project between Air Liquide and Insplorion, a custom measurement system was built to demonstrate the ability to use NPS for direct monitoring of LPC furnaces. Tests were done initially in controlled laboratory conditions to simulate an actual application and the performance was verified. Tests were also done in an actual LPC furnace to investigate its applicability for field operation.

*Föredragshållare: Maheswaran Vattur Sundaram, Höganäs*

## Optimizing Heat Treatment for High-Performance PM Steels

Powder metallurgy (PM) steel processing through the press-and-sinter (P&S) process is the most common approach for manufacturing structural components at low cost and high volume. The P&S process involves pressing powder to a near-net shape, followed by sintering to provide sufficient strength through the formation of metallic bonds between the particles. However, sintering doesn't achieve the full density and strength of wrought steel. After sintering, P&S components may have sufficient properties for some applications. However, for demanding applications, higher performance is necessary. To meet such performance levels, the properties are enhanced by performing secondary operations such as heat treatments to improve hardness, strength, and wear resistance.

The choice of heat treatment for PM steels, similar to wrought steel, depends on the application's specific requirements i.e., desired properties, material composition, and part geometry. The key distinction is that PM steels are not fully dense and can have up to 15% porosity. These pores can be both open and closed, depending on the total amount. For porosities exceeding 10%, the pores become fully open and interconnected, allowing easier gas penetration during heat treatments. This necessitates careful control of the processes. Above 94-95% of relative density, the PM steel response to heat treatment is to that of wrought steel counterparts. The common PM steel heat treatment processes are listed below

**Sinter hardening:** This combines sintering with rapid cooling (quenching) to form a martensitic microstructure, resulting in high hardness. It's a cost-effective option for parts with suitable geometries.

**Quench and temper:** Similar to wrought steel, heating, quenching, and tempering can achieve a good balance of hardness and toughness.

- **Carburising:** This introduces carbon to the surface layer, improving wear resistance. Low-pressure carburising is preferred for PM steels due to the porosity.
- **Nitriding:** This diffuses nitrogen into the surface, enhancing wear and fatigue resistance. Plasma nitriding is a common choice for PM steels.
- **Induction hardening:** Induction hardening offers rapid, localized heating for selective hardening of PM steels while minimizing distortion and decarburization.
- **Steam treatment:** Strengthens PM steel surfaces with a magnetite layer and closes the open pores. This improves wear, corrosion resistance, and dimensional stability.

The presentation outlines key considerations for selecting the optimal heat treatment for PM steel applications, emphasizing the crucial role of porosity control and process optimisation to achieve high-performance results.

*Föredragshållare: Emil Stålnacke, Swerim*

## **Macro-segregations and their role in distortions in case-hardened ring gears**

Emil Stålnacke, Swerim AB; Anders Olofsson, Scania CV AB; Johan Wendel, RISE AB; Patrik Holm, Ovako Sweden AB

Heat treatment of transmission components for the automotive industry is challenging, with strict tolerances that must be met alongside an ever-increasing demand for productivity. Component distortions after heat treatment remains an area of concern, with up to hundreds of influencing factors. It has been shown that systematically compensating for some of these factors can help mitigate distortion, but tracing and analyzing the influence of others may require a control of material processing, machining, and heat treatment parameters that is unrealistic in most situations. One reason for this being the lack of traceability across the value chain; from steel mills to machining and heat treatment subcontractors to final assembly. Subsequently, the presence of for example chemical macro-segregations is difficult to predict in a real component and therefore their influence on distortions is difficult to quantify.

In this work, simulations were carried out to predict the final location of macro-segregations in finished ring blanks for ring gears, given two starting conditions. Experiments were carried out to verify the simulations. Ring blanks for ring gears were produced from a hot isostatically pressed (HIP) two-steel model material, followed by case-hardening to study the distortions afterwards. Visual inspection, macro etching and hardness measurements were done to assess the location of the inner-material whereas geometric measurements were done on the finished gears before and after heat treatment.

The HIP model material showed clear movement of the “segregation” relative the base material, as is also predicted by the simulation. Results also indicate an influence of inner material on some hardening-induced distortions in the ring gear geometry.

*Föredragshållare: Niklas Köppen, RISE*

## HeatDrive - Heat Treatment and Materials Selection for Reliable Electrified Drivelines

Niklas Köppen, RISE; Emil Stålnacke, Swerim; Max Ahlqvist, Epiroc

Project partners: Scania, Volvo Technology, Volvo Trucks, SKF, Bodycote, Epiroc, LEAX, Ovako, SwePart, RISE and Swerim

Electrification provides an opportunity for the Swedish metal-, vehicle- and manufacturing industry to increase their competitiveness by providing material- and process solutions which can meet or even exceed the increased requirements on power transmitting components. One example is electrification of long-haul transports, which require compact, lightweight, and highly efficient drivelines. This work develops a lab-based methodology to assess failure mechanisms which are expected to shift as load cycles increases with the transition to electrified drivelines.

The work was performed in two work packages, where WP1 focused on the development of a lab-based methodology for ultrasonic fatigue testing (UFT) of carburised case-hardening steels and WP2 on gear-wheel fatigue, i.e. pulsator testing by using resonant testing machines. In WP1, UFT running at 20 kHz permits 10<sup>7</sup> load cycles to be reached in less than 10 minutes, testing was performed and evaluated the fatigue strength distribution supported by fractography, microstructural analyses and hardness measurements. UFT was performed with fully reversed loading ( $R = -1$ ) using compressed air cooling to avoid overheating of samples. The test matrix included several carburising steels with different cleanliness grades, carbon levels and a variety of quenching media providing 16 fatigue series in total. Based on results from WP1, fatigue testing of components with selected properties was performed in WP2.

Results suggest that the methodology to test carburising steels using a through carburizing process works as stress levels at fractures correspond well to those seen in other types of test set-ups, both by experience within the project team and in literature. The results from this work can be used to assess current manufacturing concepts, i.e. steel grades in combination with heat treatments, to optimise performance and meet the future increased requirements. Moreover, knowledge built can be exploited in further material- and process development by the industry to provide even better solutions for increased driveline performance as rotational speeds increase by at least one order of magnitude.

*Föredragshållare: Marcin Stoklosa, Nitrex*

## **New Generation of Nitrocarburized and Post-Oxidized Brake Discs**

Brake emissions are a major source of particulate matter in urban areas, increasing the total number of particles in the air and contributing to PM 2.5 pollution. The EU Commission is planning to introduce the new Euro 7 emissions standard in 2025, which will impose strict limits on particulate emissions from passenger cars and commercial vehicles [1, 2]. As particulate emissions from engines have steadily decreased in recent decades, tires and brake systems are currently the main source of particulate matter (PM) and particle numbers (PN) [3].

The corrosion of brakes has increased due to the introduction of energy recovery systems and the use of engine braking in intelligent automatic transmissions. This will increase further due to the new requirements for electromobility, which reduces mechanical braking to a minimum [4]. Conventional brake discs are made of cast iron, which rusts. When the brakes are not in use, the rust layer is no longer abraded from the brake pads and the corrosion continues deeper, leading to significantly higher brake disc wear, especially in the rear brakes. This contributes to PM and PN contamination.

The application of ferritic nitrocarburizing (FNC) on grey cast iron (GCI) brake discs has proven to be a suitable technical and economic solution when combined with a stress relieving (SR) process prior to finishing [5].

Nitrex, an expert in nitriding processes, has invested in research into wear-resistant nitrocarburized and post-oxidized surfaces on cast iron and steel parts. A new generation of post-oxidation coatings is a conversion coated in-situ controlled post-oxidation called Smart-ONC® due to its “self-healing” properties. By adding an additional protective barrier, where another metal is added to the oxidation layer, high corrosion resistance is achieved and the surface is protected from damage or failure.

*Föredragshållare: Jeroen Knippenberg, Aalberts Surface Technologies  
Eindhoven*

## **Stainihard, hardening of austenitic Stainless steel and Duplex**

The use of Austenitic- and Duplex Stainless Steels in industry is widespread for their excellent corrosion resistance. However these categories of steels have an inherent downside of low wear resistance, galling and low fatigue strength and therefore result into machineparts with limited lifetime.

With classical hardening of these steel types not being an option, surface treatments are a viable way to improve mechanical performance. Gaseous Nitrocarburizing provides an increase in surface hardness which gradually transitions into the core hardness, which significantly improves wear resistance, fatigue strength and reduces galling behavior.

The Stainihard®NC process from Aalberts Surface Technologies Eindhoven B.V. is a low temperature Nitrocarburizing process developed for Austenitic and Duplex Stainless Steels, provides an increase in surface hardness up to 1400 HV0.05 with a case depth up to 10-30micron, depending on the specific alloy and process. Different activation pre-treatments and nitrocarburizing processes have been developed in order to meet customer demands in a wide range of industries, applications and materials.

*Föredragshållare: Mohamed Amine Jamli, Air Liquide France Industrie*

## **Cryogenic Treatment of Metals**

Cryogenic treatment of metals has emerged as a transformative process in the industry of heat treatment, offering substantial improvements in material properties such as, hardness, dimensional stability and wear resistance. This paper provides a comprehensive overview of the scientific principles, technical effects, industrial processes and applications of cryogenic treatment on mechanical parts. Special emphasis will be placed on recent developments in the field of thermal performances, automation, monitoring of operating parameters and safety.

The process of cryogenic treatment induces microstructural alterations, resulting in enhanced mechanical properties, the underlying mechanisms of which will be presented first in this paper, including phase transformation, stress relief and refinement of grain microstructures.

This work then highlights the industrial applications and equipment of cryogenic treatment across diverse industries, with a particular focus on the aerospace industry and the compliance with the AMS2750-G specification pyrometry. The economic feasibility and environmental impact of incorporating cryogenic treatment into conventional hardening processes are also considered, underlying potential costs saving and operating benefits.

The findings of this paper can serve as a valuable resource for metallurgists, materials science engineers and industrial end users seeking to harness the benefits of cryogenic treatment in their respective applications. The study not only advanced the theoretical understanding of cryogenic processing but also provides practical guidelines for its efficient and effective implementation in various industrial environments.

*Föredragshållare: Harald Juretzko, HEES*

## **Reduction of distortion by using of Fixture Hardening Machines**

HEES is the global leader in development, engineering and production of hardening machines as well as their integration into the heat treatment process.

Throughout the world, well-known automotive- and gearbox-manufacturer are operating with HEES quenching presses to achieve better quality of their workpieces by reducing distortion caused during the hardening process. This achieves substantial cost reductions by avoiding scrap, reduction of rework and shorter carbonization periods.

The presentation will show the point of view from a fixture hardening machine supplier and with which technology at the heat treatment one can influence the roundness and flatness.

The working principle of fixture hardening is to flow cooling medium around each workpiece in a controlled and reproduceable manner

and at the same time to keep it in shape by applying external forces. This has been proven to significantly reduce distortion caused by heat treatment. By treating individual parts and automating the process, a high level of reproducibility and dimensional stability are achieved. This means that rework costs for grinding processes, for example, can be minimized or partially saved and scrap rates can be significantly reduced. The cost savings are also visible in advance. Less post-processing means a reduction in grinding material and thus also the hardening depth. This means that oven carburizing times, which often last several days for these workpieces, can be drastically shortened. These energy savings cannot be ignored not only in terms of costs, but also in terms of the environment.

In the lecture, a corresponding machine and tool concept will be presented, and practical experiences will be reported including an outlook on new developments and innovations.

*Föredragshållare: Thomas Bauer, Rübig*

## **Economic & Ecological Impact and Advantages of Plasma-based Surface Treatments**

Plasma-based surface treatments represent a cutting-edge technology with wide-ranging applications across various industries, offering significant economic and ecological benefits.

Economically, plasma treatments enhance the durability, functionality, and performance of materials, leading to cost savings through increased product lifespans and reduced maintenance needs.

These treatments improve surface characteristics like adhesion and resistance to wear or corrosion, reducing material.

Ecologically, plasma-based methods offer an environmentally friendly alternative to traditional chemical treatments, as they typically require fewer harmful substances.

Additionally, plasma treatments can be performed at low temperatures, further reducing energy usage.

Overall, the adoption of plasma-based surface treatments presents a dual advantage: boosting economic efficiency while promoting ecological sustainability.

*Föredragshållare: Paweł Okińczy, SECO/WARWICK S.A, Erik Spolander, CalorMet*

## **A Green furnace and a green heat treatment process**

The industrial landscape is evolving rapidly, progressing from Industry 2.0 to 3.0 and now 4.0. Regulations like the Paris Agreement, Fit for 55, and CSRD are driving this transformation, pushing industries toward electrification and increasing demands for sustainability across Environmental, Social, and Governance (ESG) factors.

This raises the question: What changes have occurred in the heat treatment industry? Are we witnessing significant transitions in our sector?

According to data from CalorMet, the average age of furnaces in Sweden is approximately 30 years. Large furnaces are typically gas-heated, while smaller ones tend to be electrically heated. Through modernization efforts, CalorMet collaborates with customers to transition from gas heating to more efficient gas systems or, ideally, to electrically heated furnaces. However, some customers face limitations in electrifying their furnaces due to insufficient power supply capacity.

Innovative, sustainable technologies such as Low Pressure Carburizing (LPC)—introduced in the 1990s—and plasma nitriding—which saw wider industrial adoption in the 1960s—still hold a relatively small market share.

Today's joint presentation from CalorMet and Seco/Warwick will focus on how we can accelerate the transition with incremental and major steps, without overhauling everything at once.

*Föredragshållare: Matthias Rink, Ipsen*

## **Energy and Process Gas Consumption for Selected Vacuum and Atmosphere Case-Hardening Processes and Furnace Concepts – A Comparison**

Nowadays, there are two common process routes, gas carburizing and low-pressure (gas) carburizing (LPC). For both processes there is a variety of different equipment types available on the market such as batch furnaces, automated multi-batch furnace lines or continuous pusher type furnaces. But which of them provides the lowest carbon footprint? Which of the two processes provides better parts?

This presentation shows a fair comparison of energy consumption and country related carbon footprints for the case hardening process of a typical gear part in LPC and gas-carburizing. The case depth is kept constant, and the carburizing temperature is evaluated at three different levels while only the equipment type varies. The importance of insulation, furnace size and process parameters is discussed.

*Föredragshållare: Sven Haglund, Swerim*

## Decreased CO<sub>2</sub>-Emissions by Adjusting CO-Concentration During Heat Treatment

By tradition heat treatments such as carburizing or through hardening is carried out in an atmosphere with 20% CO. The carbon potential is controlled by propane addition, reacting with CO<sub>2</sub> so that the CO/CO<sub>2</sub> relation is kept constant.

However, in carburizing, only a few per cent of the added carbon is taken up by the heat-treated components. The rest is burnt at the outlet and transformed into CO<sub>2</sub> emissions. For through hardening the situation is even worse, where all the added carbon will become CO<sub>2</sub> emissions.

Since the carbon potential is basically controlled by the CO/CO<sub>2</sub> relation it is possible to reduce the CO concentration in the furnace, and thus the CO<sub>2</sub> emissions, without changing the carbon potential.

If a furnace is equipped with the possibility to control the CO level in-situ in the furnace it could be possible to design the furnace recipes so that the CO concentration is high when needed, i.e. when the material takes up large amounts of carbon, and low when not needed.

Research within the ongoing Vinnova funded project “Dynamic control of gas processes during heat treatment of steel, DynaSty” has shown that for electrically heated furnaces, CO<sub>2</sub> emissions can be reduced with 50% for through hardening and with 25-40% for carburizing. A digital twin of the process was developed within the project, and furnace recipes optimized so that the duration of the heat treatment is same as with standard recipes, but with much lower emissions.

In this presentation heat treatment with adjusted CO-concentration is discussed and preliminary results from the DynaSty-project is presented..

*Föredragshållare: Anders Åström, Aron Joshi, Linde Gas AB*

## Minskat klimatavtryck med Linde Green

Värmebehandlingsindustrin ställer om och minskar sin klimatpåverkan. Man minskar och eliminerar användandet av miljöskadliga ämnen, minskar sitt restavfall och återvinner både material och värme effektivare än man någonsin gjort. Inom branschforat Värmebehandlingscentrum har man nyligen kunnat påvisa möjligheten samt även realiserat omställningen av processer innehållandes kolmonoxid till ett lägre klimatavtryck. Genom ett aktivt arbete och noggrant utvärderande har man lyckats verifiera att produkter kan produceras klimatsmartare utan att tappa vare sig produktivitet eller kvalitet. Vid sätthårdning och neutralhårdning används i regel endogas eller skyddsgasatmosfär genererad av kväve/metanol. Mängden kolmonoxid, hydrogen samt nitrogen kan variera beroende på syfte och tillverkningsmetod. Tillsammans med ugn och materialspecifikation bildar atmosfären ett system som både skall buffra mot eventuella störningar och samtidigt erbjuda ett processfönster som är tillräckligt stort för att värmebehandlingsresultatet skall vara repeterbart över tid utan att produktionstakten och utbytet blir lidande.

Inom projektet DynaSty (ett projekt finansierat av Vinnova) har man således lyckats minska klimatpåverkan från processgasanvändandet med upp till 50% genom att processa smartare. Trots detta så står skyddsgasatmosfären för en stor andel av klimatavtrycket även om Sverige har en förmånlig mix av olika energislag med låga CO2 utsläpp.

Presentationen kommer att visa hur Sveriges med övriga Europas integrerade energimarknad påverkas av olika aktörers medvetna klimatval på kontinenten och genom dessa val späder ut det som betraktas som CO2 fri energiframställning med energi producerad av både kol, gas och olja. Vidare kopplas detta ihop med den industrigas som produceras i Linde's luftseparationsanläggningar, syrgas, argon och nitrogen samt hur värmebehandlingsbranshen aktivt kan välja att reducera sina CO2 utsläpp till att närma sig noll genom att välja Linde Green.

*Föredragshållare: Marco Hinsch, Aichelin*

## **Safety in Heat Treatment – Part of the Corporate Culture**

Although European directives provide a framework for both equipment manufacturers and plant operators, national laws and regulations as well as standards are essential to specify the safety requirements for thermal processing equipment. However, it is up to each heat treatment facility operator to interpret, implement and comply with these regulations. This clearly shows whether safety in heat treatment is part of the corporate culture.

This contribution outlines the basic aspects of plant safety from the perspective of a plant manufacturer and presents selected key issues with application examples. A key element is the risk assessment required by the Machinery Directive (Directive 2006/42/EC) - since 2023 the Machinery Regulation (Regulation (EU) 2023/1230). Regardless of the standards/guidelines used, the system manufacturer is forced to deal with the risks of his system during the product life cycle. This shows that for some technical challenges there is no clearly defined design, but it is the responsibility and experience of the heat treatment equipment manufacturer to find appropriate safe solutions.

Ultimately, however, it is up to the plant operator to decide whether to make regular safety inspections of his plant part of his regular activities, to take a close look at the state of the art, and to initiate the appropriate modernization of safety features and equipment.