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Oxycad NT® is a heat treatment process newly developed by Safed Suisse and is based on the thermo-chemical diffusion processes – nitrocarburizing with postoxidation – and in special cases on a nal organic impregnation to increase corrosion resistance.
The following technical article shows, that Oxycad NT® combines the positive properties procedure signs of nitrocarburizing, i.e. increase of wear resistance by high surface hardness and reduced distortion. In addition the surface becomes dull black and the parts are mostly ready for installation.

Due to typical nitrocarburizing processes Oxycad NT® – used nitriding and carburizing suitable gases, at temperatures between 530 to 750 °C – to create a compound and a underneath lying diffusion layer (**Fig. 1**).

Fundamentals of nitrocarburizing

Nitrocarburizing is a thermo-chemical heat treatment process which leads to an increased concentration of nitrogen and carbon in parts surface and a creating of a nitride enriched compound and diffusion layer.

In contrast to nitriding the main target of nitrocarburizing is to create a 5 to 25 µm "white compound layer" with optimized wear and corrosion resistance. In addition the corrosion resistance of a number of alloys can be raised signi¼cantly by ¼nal postoxidizing.

In general nitrocarburizing – whether in gas, salt or plasma atmosphere – leads also to a reduction of frictional coef¼cients, by high abrasion resistance.

Suitable nitrocarburizing layers distinguish thermal stability to nearly 500 °C and an improvement of strength characteristics. Due to the low temperatures compared to case hardening and the avoidance of martensitic hardening crystal lattice changes less residual stress are achived with nitrocarburizing. According to materials composition a nitriding depth up to a few tenths millimetre is possible (**Fig. 2**).

Below compound layer the diffusion zone is suitable for supporting effects. Nitrides and carbides lead to hardness increase. The depth of the compound layer correlates to the thickness of the

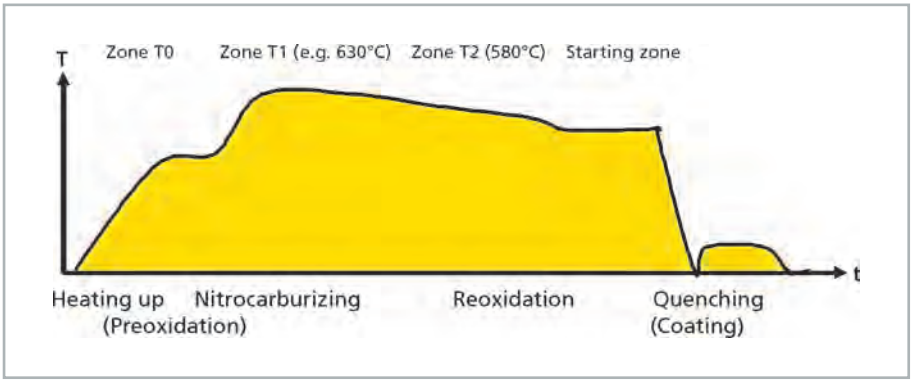

Fig. 1: Oxycad NT® process

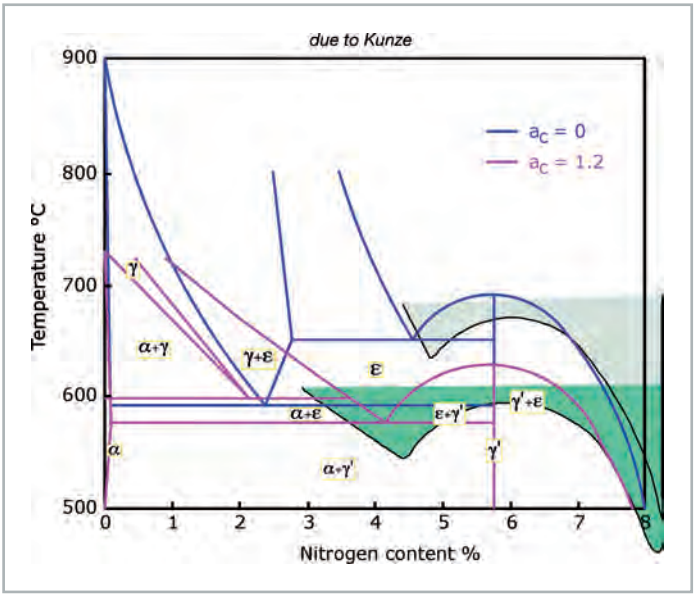

Fig. 2:
Phase diagram Fe – N in dependence of carbon activity (due to Kunze)

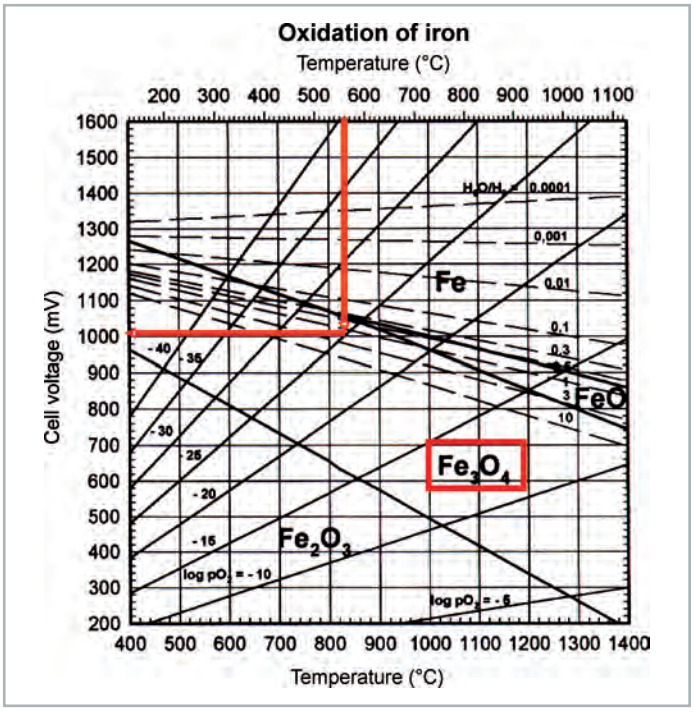

Fig. 3:
Oxide creation in dependence of temperature and the oxygen partial pressure (due to Weissohn)

Fig. 4: Conveyor belt furnace for Oxycad NT® nitrocarburizing (Safed)

diffusion layer. Basically, the more alloy elements are used for the nitriding, the higher the surface hardness, but the more slightly the thickness of the nitrocarburizing layer. An iron oxide layer is generated on the surface in addition by postoxidation (Fe_3O_4) which has an improved corrosion resistance result (**Fig. 3**).

Continuous furnace technology

The Oxycad NT® is specially developed for the continuous heat treatment processes in conveyor belt furnaces of bulk materials.

Safed – conveyor belt furnaces are equipped with a suitable measuring and control technology are suited for the optimum use and application – also due to the demands of AMS 2750 D and CQI9 (**Fig. 4**). These furnaces offer basically a high precision, reliability for reproduction and ful¼ls therefore the high demands of nitrocarburizing.

The special issues of this furnace technology are:

- Automatic, continuous ¼lling of the conveyor belt furnace
- Fast heating up and high thermal transfer by circulation
- Steady control of the atmosphere composition.

The necessary gases are:

- air,
- ammonia (NH_3),
- methanol (CH_3OH),
- propane (C_3H_8)
- water H_2O.

Quenching takes place in oil. The ¼nal covering and closing of the pores is carried out with organic corrosion prevention (**Fig. 5**).

Nowadays the processes in the industrial furnaces allow as a rule generally a steady nitriding or nitrocarburizing of the essential material dimensions. Besides, the process observation and process regulation occurs through gas analyser, oxygen probe or nitriding probe.

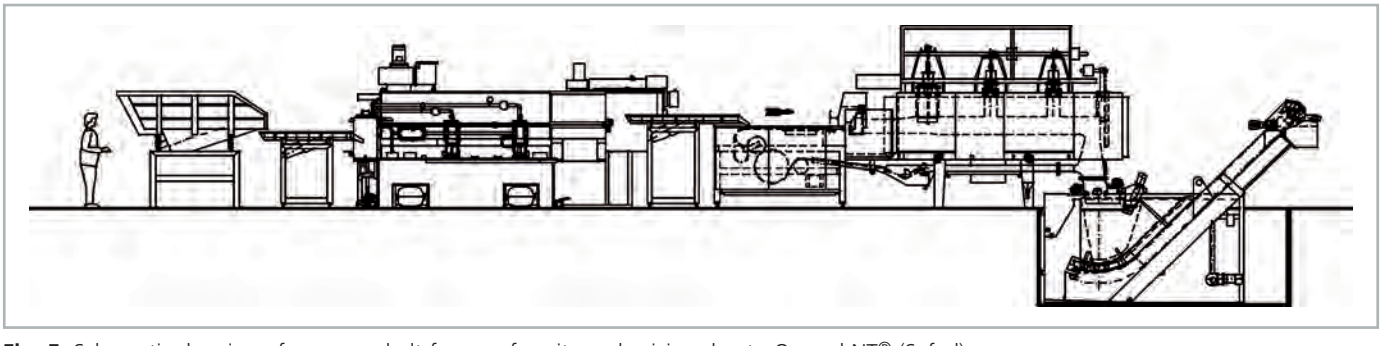

Fig. 5: Schematic drawing of conveyor belt furnace for nitrocarburizing due to Oxycad NT® (Safed)

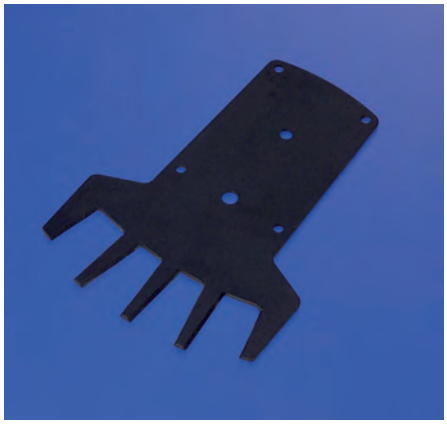

Fig. 6: Blade for gras shears, 1.2357, 50CrMoV13-14, nitrocarburizing (OXYCAD®), postoxidation, ¼nal organic coating

Fig. 7: Drive pinion for camshaft, 1.7131, 16MnCr5, nitrocarburizing (OXYCAD®)

The process regulation by nitriding coef¼cient Kn of Safed-conveyor belt type furnaces under flow arrangements and the application of a H_2 probe which is used to "in process supervision in-situ" and process documentation are „a state of the art" technology" and have been proved in a huge number of applications by which process security and ability for reproduction of the heat treatment results were improved clearly.

In addition the gas consumption and therefore the operating expenses signi¼cantly which can amount by using of ammonia absolutely up to 30 %. This could be reduced by the regulated process guidance. Moreover, the regulation of the nitriding coef¼cient Kn is the necessary base realise the exact requirement and chemical compositions of the nitriding layers.

Moreover, the process times can be minimised by a reproduceable creation of the nitriding layer. The continuous measurement of the furnace atmosphere (e.g. H_2) and the fed fresh gas, as well as the atmospheres and nitriding coef¼cient as well as the gap gas or hydrogen for the adaptation of the nitriding coef¼cient by e.g. automatic gas flow regulators is necessary for this.

Table 1: Layer composition and surface hardness of the test parts

Material	Layers			Hardness		
	Oxides	ε	γ	Surface		Center
	µm	µm	µm	*HV0.1*	*HV1*	*HV*
QSt 37	<1	24	5	720	400	--
Fer	<1	22	5	630	360	--
SPCC	1	21	7	530	360	--
S50C	1	21	6	700	420	--
SK7	1	21	5	760	415	--
9SMnPb28	1	17	4	740	410	--
Ck55	<1	17	9	600	450	--
C15	<1	25	5	660	450	--
AISI 1080	<1	26	2	625	540	--
C18B	1	23	3	760	600	180
18B3	1	23	3	760	600	235-280
19MnB4	1	22	3	770	580	210-250
P/M FeCuNiMo	1	17	3	--	240-380	--
Ovako225A	<1	13	0	890	720	--
41CrV4	<1	22	3	640	575	--
C75	<1	19	4	830	450	--
50CrV4	<1	19	4	780	500	--

Applications

With Oxycad NT®-processes nearly all kind of steels, i.e. unalloyed as well as highly alloyed steels with more than 13 % of chromium which have a tendency of passivation can be heat treated.

Branches in which this process is used are for example automotive and aircraft industry, connection technology, electronics/electrical engineering, mechanical engineering, medicine industry and textile industry, military technology and tool industry.

Waves and bolts count, e.g., in general to the special applications for internal combustion engines and compressors, precision parts for optical devices, punching and forging parts to ball plug seaweeds or ball bolts, piston

Fig. 8: Car seat components, 1.0301, C10, nitrocarburizing (OXYCAD®)

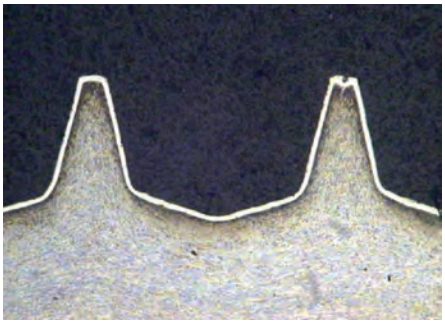

Fig. 9: Metallographic microsection of Oxycad NT® layer of a gearwheel

rods, hinges, windshield wipers, shock absorbers, bolts and springs.

In **Fig. 6, 7** and **8** some common examples are shown which were treated in Oxycad NT® processes.

Test results

The test results introduced in the present contribution show that the expected high wear and corrosion resistance can be reached by Oxycad NT®. This thermal process is therefore in addition an interesting alternative for chromium-plating, bondering or also nickelplating.

Confessed as adequately, the effect of the hardness increase in nitrocarburizing

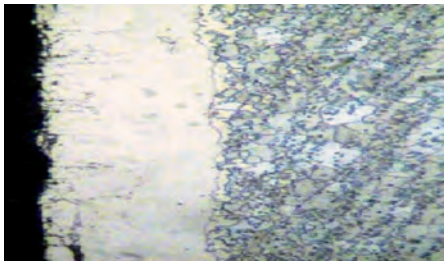

Fig. 11: Metallographic microsection (Oxycad NT®)

is not based by the martensitic hardening, but by originating the „hard and wear-resistant" iron- and special nitride as well as iron- and special carbide layers of the component.

The highest hardness occurs to aluminium and chromium nitride as well as tungsten and chromium carbide. Hence, these elements has to be alloyed to become the hardness increase for nitrocarburizing.

Nitrocarburizing does not lead to a crystal structure change, therefore dimension changes and distortion are substantially lower in comparison to case hardening.

Table 1 shows how the Oxycad NT® processes achieved test results. By variation of the process parametres the properties of the nitrocarburizing layers optimum for the uses were achieved: Oxide layer thickness (Fe_3O_4) of about 1 to 2 µm and a connecting nitrocarburizing layer thickness of approx. 5 to 25 µm with controlled porosity corresponding nitriding hardness depth (NHT) with 0.1 to 0.4 mm. The surface hardness in the series of experiments were between 500 in 1150 HV 0.5 (**Fig. 9, 10** and **11**).

The process temperatures opposed in the investigations were between 520 and 580 °C. There by it could be reached that according to material a surface hardness from up to 1250 HV appears. With wide increasing temperature the hardness of the nitriding layer decrease again (**Fig. 12**).

Conclusion

The test results have shown that Oxycad NT® on one side combines the very

Fig. 10: Metallographic microsection of an Oxycad NT® layer

positive properties of nitrocarburizing, i.e. increase of the surface hardness and high corrosion resistance.

Especially the increases in the corrosion resistance according to salt spray test this process is suited for a huge number of demands and shows an interesting alternative to combined procedure used in the past for heat treatment and galvanic technology.

The article shows that Oxycad NT® process has the following advantages:

- Optimisation of mechanical qualities and properties
- Optimisation of corrosion resistance: >300 h in the salt spray test are possible
- Substitute for other galvanic processes
- Less distortion
- Energy ef¼cient and less of the operating expenses
- Black colouring of the surface ■

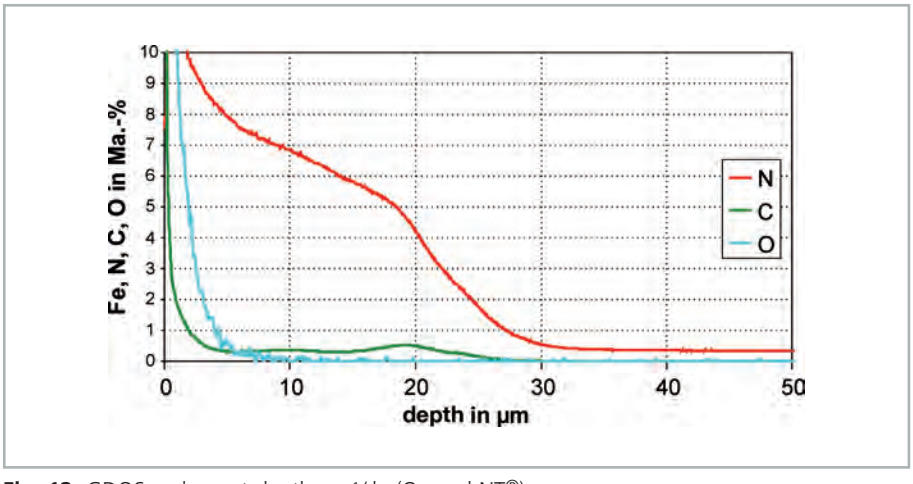

Fig. 12: GDOS – element depth pro¼le (Oxycad NT®)

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Plants and solutions for heat-treatment of precision and serial parts...

Complete heat treatment lines
consisting of loading device, hardening furnace, quenching in salt, oil or emulsion, washing machine before and after heat treatment, tempering furnace. Complemented with protective-gas generators and process control.

Mesh belt conveyor furnaces Type T/TG
with muffle and integrated quenching tank. This plant technology offers high precision, reproducibility and fulfils the strictest metallurgical demands. Hardening, carburizing, carbonitriding with oil or polymer quenching, bainite and martensitic hardening using salt-quenching, nitrocarburizing OXYCAD® .

Mesh belt conveyor furnaces Type TC/TCG
without muffle, with integrated quenching tank. Besides the advantages of the production series T/TG, suitable above all for particularly large capacities. Hardening, carburizing, carbonitriding with oil or polymer quenching, bainite and martensitic hardening using salt-quenching, austempering.

Mesh belt conveyor furnaces Type BdL/BdLT
with air-circulation by means of turbines.
Heated by gas or electricity.
Heat treatment of steel and cast iron, tempering, annealing, stabilization, aging of aluminum.
For BdLT series with integrated water cooling tank.

Mesh belt conveyor furnaces Type Bd/BdT
with muffle and cooling channel.
Heated by gas or electricity.
Bright hardening, bright annealing, sintering and annealing of iron, non-ferrous metals and stainless steel materials. Type BdT with integrated water cooling tank.

Mesh belt conveyor furnaces Type T9
with muffle and integrated quenching tank.
Compact plants with control and gas-supply board, particularly for small parts in the watch and the micro-engineering industry. Offers high precision in the smallest spaces, reproducibility and fulfils the strictest metallurgical demands.
Hardening, carburizing, carbonitriding.

... for the following industry segments :

- Vehicles
- Watch and precision engineering
- Fasteners
- Bearings and semi-finished products
- Tools
- Knives and cutlery
- Furniture and wood industry
- as well as several additional applications

SAFED
Heat Treatment Solutions

Shaker hearth furnaces Type Vi

with muffle and integrated quenching tank that are used primarily for very small parts with low production volumes.

Hardening, carburizing, carbonitriding with oil or polymer quenching, bainite and martensitic hardening using salt quenching.

Retort furnaces Type SN/SL/SG

with atmosphere circulation, also in evacuable configuration for heat treatment of charges. Austenitizing, carburizing, carbonitriding, tempering, annealing, preheating, heat treatment of light metals.

Integrated protective gas generators

with a retort integrated in the furnace for methanol or natural gas dissociation for the production series T/TG or external vaporisators for the production series TC/TCG. Controlled and reproducible gas composition.

Stationary protective gas generators

includes endothermic gas generators based on natural gas or propane as well as methanol and ammoniac dissociators.

Rotary drum washing machines Type TRAS

Loading the parts as bulk material, they run continuously through a drum of stainless steel with several zones : washing, dephosphating, rinsing and drying with hot air. Configuration according to the application and the desired cleaning result. Optimal cleaning result for flat and dipped parts.

Belt type washing machines Type TPAS

Loading the parts as bulk material or in a defined position (e.g. by robots). They run through the plant on a conveyor belt of stainless steel with several zones: washing, dephosphating, rinsing and drying with hot air. Configuration according to the application and the desired cleaning result. Optimal cleaning result, even for delicate parts.

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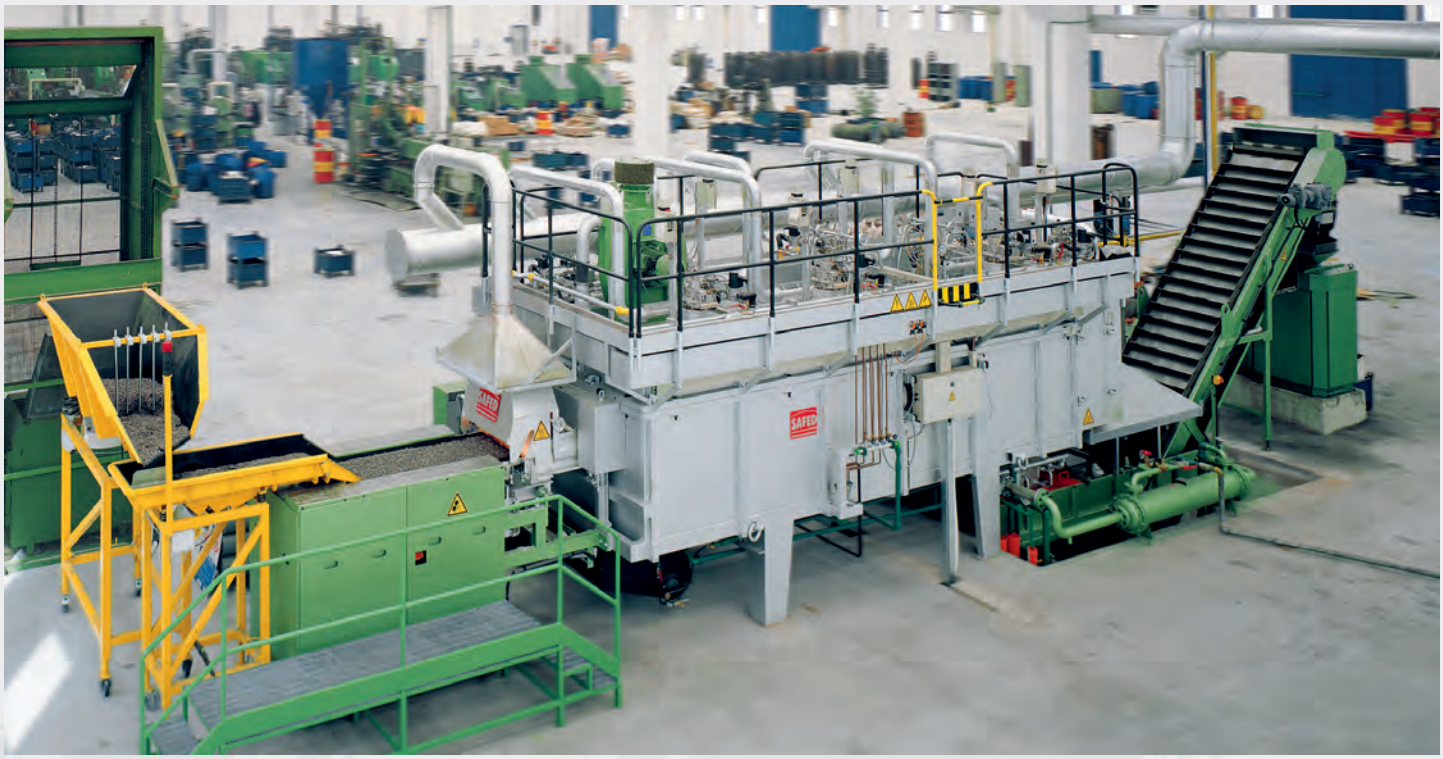
Heat Treatment Solutions

Typical OXYCAD® NT heat treatment line



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