NITRIDING AND NITROCARBURISING

WHAT ARE THE TREATMENTS?

Nitriding and nitrocarburising are low-temperature low-distortion "thermochemical" heat treatments carried out to enhance the surface properties of finished or near-finished ferrous components. They are different in terms of suitable materials, processing conditions, the nature of the surface layers imparted and the property improvements conferred.

Nitriding, conducted in gas (490-560°C) or plasma (400-590°C) for treatment times ranging up to 90 hours, involves the diffusion of nitrogen into the surface to produce a controlled depth of hard alloy-nitrides. Unlike the high-temperature case-hardening treatments (carburising/ carbonitriding), hardening is achieved without the need for quenching.

Nitrocarburising, generally of shorter duration (30 minutes - 5 hours), involves enrichment of the surface with both nitrogen and carbon to impart a thin iron-carbonitride "compound layer" supported by a nitrogen-bearing "diffusion zone". Conducted at temperatures of 560-580°C ("**ferritic nitrocarburising**") or 590-720°C ("**austenitic nitrocarburising**"), the process may be completed by quenching and can involve additional steps to promote certain properties.

Nitrocarburising is a generic term covering salt-bath treatments, such as *Tufftride* , and the equivalent processes conducted in gaseous atmospheres and known by a host of trade names.

WHAT ARE THE BENEFITS?

Favoured for components that are subjected to heavy loading, **nitriding** imparts a high surface hardness which promotes high resistance to wear, scuffing, galling and seizure. Fatigue strength is increased mainly by the development of surface compressive stresses. Hot hardness and resistance to tempering are improved and corrosion resistance is moderately enhanced. The low processing temperature and subsequent slow cooling help minimise distortion. Typical applications include gears, crankshafts, camshafts, cam followers, valve parts, extruder screws, die-casting tools, forging dies, aluminium-extrusion dies, injectors and plastic-mould tools.

In **ferritic nitrocarburising**, the resultant compound layer, with good lubricant-retention characteristics, is responsible for the major benefit of high resistance to wear, scuffing, galling and seizure. The diffusion zone contributes improved fatigue resistance if components are quenched after nitrocarburising. An increase in corrosion resistance can be improved upon further by post-oxidation treatment which imparts an aesthetically-pleasing black finish; additional polishing and oxidation steps can yield a surface finish rivalling hard chrome plating, in terms of high corrosion resistance combined with low coefficient of friction.

Typical applications of ferritic nitrocarburising encompass pressings, bearing shafts and cages, cams and crankshafts, gears, bushes, liners, pump components, sintered parts, plastic-mould and extrusion dies and tooling.

Whilst it can also increase the hardness of alloy steels, the influence of ferritic nitrocarburising on the bulk surface hardness of low-carbon non-alloy steels is moderate. **Austenitic nitrocarburising** allows the other benefits to be combined with indentation resistance by strengthening the substrate beneath the compound layer. It is possible to combine nitrocarburising with carburising/ carbonitriding, to produce a deeper underlying case for increased load-bearing characteristics, whilst incurring less distortion than in the conventional high-temperature case-hardening treatments.

WHAT SORT OF MATERIALS CAN BE TREATED?

Nitriding: For engineering components, nitriding is most effective when applied to the range of steels containing nitride-forming elements such as chromium, molybdenum, vanadium and aluminium; some, such as 722M24 (En40B), 905M39 (En41B) and 709M40 (En19), are specified in BS 970. The process is also applicable to stainless steels and to tool steels such as hot-work, cold-work and mould steels. Some cast irons also respond favourably to treatment.

Nitrocarburising: Ferritic nitrocarburising can be applied to most ferrous materials and is well established for processing tool steels, for example. Latterly, both ferritic and austenitic nitrocarburising have come to particular prominence as methods for up-grading components made from relatively-inexpensive easy-to-form low- and medium-carbon non-alloy steels.

Consult your heat treater when selecting materials for nitriding or nitrocarburising.

WHAT ARE THE LIMITATIONS?

Nitriding

- The process can only be applied effectively to a limited range of appropriate alloy-containing materials.
- Depending upon process parameters and material, nitrided case depths can range from as little as 0.05mm up to 0.75mm.
- Surface hardness depends upon process parameters, the material and its original condition. For optimum results, a steel for nitriding should be in the hardened and tempered condition and free from decarburisation. (The tempering temperature should be higher than the nitriding temperature).
- A fine-turned or ground surface finish is the most suitable for ensuring a satisfactory nitriding response. Pre-nitriding treatments may be required on certain materials subjected to gas nitriding (e.g. acid pickling/vapour blasting of martensitic stainless steels).
- A stress-relieving treatment ("stabilising") is necessary between the rough and final stages of machining of hardened and tempered high-precision components in order to minimise distortion after nitriding. (The stress-relieving temperature employed should be higher than the nitriding temperature but lower than the tempering temperature).
- On a hardened and tempered/stress-relieved part, nitriding should produce minimal distortion. However, growth can occur, the amount being a function of the treatment parameters and the material. It is fairly predictable and usually less than 0.05mm on a diameter.
- The corrosion resistance of stainless steels is reduced by nitriding.

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Nitrocarburising

- Depending upon process parameters and material, the compound layer thickness after ferritic nitrocarburising is typically in the range 12.5 - 20µm, the diffusion zone being substantially deeper. Capable of producing thicker compound layers, some austenitic nitrocarburising treatments incorporating carburising/carbonitriding can impart underlying case-hardened layers as deep as 1.5mm.
- Alloy steels benefit most from being nitrocarburised in the hardened and tempered condition. (The tempering temperature should be higher than that employed for nitrocarburising). Non-alloy/low-carbon steels are usually nitrocarburised in the normalised condition. Stress relieving before final machining is advisable in order to minimise distortion in nitrocarburising.
- During ferritic nitrocarburising, predictable growth occurs in components, which must be allowed for. Increasing with compound-layer thickness, it is of the order of 15µm on diameter in a typical treatment. Growth is somewhat greater in austenitic nitrocarburising treatments.
- Components must not be ground after nitrocarburising as this will remove the beneficial thin compound layer. For load-bearing surfaces, a light lapping or buffing is often used to improve the surface finish which tends to roughen slightly during treatment.
- Nitrocarburising treatments, particularly those involving post-oxidation, are capable of imparting dramatic improvements in the corrosion resistance of ferrous materials. However, nitrocarburising reduces the corrosion resistance of stainless steels.

Component size and shape

The size and shape of a component that can be nitrided or nitrocarburised depends upon the type of equipment operated by the heat treater. Overall, items that can be nitrided within the contract heat treatment sector range from those of a few grams to components weighing several tonnes each. For large components, check the availability of suitably-sized facilities at an early stage.

WHAT PROBLEMS COULD ARISE?

A friable surface compound layer (“white layer”) forms during **nitriding**, consisting of mixed iron nitrides (as opposed to the more ductile monophased iron-carbonitride compound layer aimed for in nitrocarburising). Under conditions of mechanical loading or thermal shock, this white layer can spall, producing debris which is highly abrasive. It may therefore be necessary to control the thickness of this layer during processing to a maximum specified level or to introduce a finishing operation to remove it completely. Complete removal is often recommended on bearing surfaces (e.g. on a crankshaft).

HOW DO I SPECIFY?

All of the following information should be included if possible. *If uncertain, ask your heat treater before producing a specification:*

Nitriding

- Instruction: nitride/nitride harden. If a particular processing medium is required, indicate (i.e., gas or plasma).
- Material: identify the material used as accurately as possible using a BS number or maker’s code. Indicate its heat-treated condition (e.g. hardened and tempered).
- Case depth: specify the case depth required, indicating an acceptable range. It should be noted that maximum hardness is not maintained throughout the full depth of the case; part-way through the case, hardness begins to reduce progressively until it reaches the original (core) hardness. Thus it should be stated clearly whether the case depth required is an effective depth (to a specified hardness level) or a total depth (to core hardness level)
- Surface hardness: quote the range of surface hardness required, indicating whether the component can be tested and the area of test. As indicated previously, the surface hardness attainable depends upon the material and its original condition, as well as nitriding parameters.
- Indicate if a test piece will be supplied for assessment of the results of nitriding. This should be of the same cast of material and in the same prior heat-treated condition as the component being procesed.
- Quote any relevant customer specification/standard.
- Selective treatment requirements: a variety of procedures can be applied to leave selected areas of the surface of a component “soft”. If required, specify precisely or indicate that the part is already copper-plated if this stop-off method is chosen.
- Indicate whether any additional operations are required (e.g. vapour blast to remove possible white layer).
- Specify maximum white-layer thickness allowable, if this is a consideration.

Nitrocarburising

- Instruction: ferritic nitrocarburise or austenitic nitrocarburise. Indicate if a particular processing medium is required (i.e., salt-bath or gas).
- Material: identify the material used as accurately as possible using a BS number or makers code. Indicate its heat-treated condition (e.g. hardened and tempered).
- Specify the compound layer thickness required, indicating an acceptable range.
- For austenitic nitrocarburising, specify the case depth requirement. State clearly whether this is an effective depth (to a specified hardness level) or a total depth (to core hardness level).
- Surface hardness: Specify the range of surface hardness required, indicating whether the component can be tested and the area of test. As indicated previously, the surface hardness attainable depends upon the material, as well as nitrocarburising parameters.
- Indicate if a test piece will be supplied for assessment of the results of nitrocarburising. This should be of the same cast of material and in the same prior heat-treated condition as the component being processed.
- Quote any relevant customer specification/ standard.

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