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Stripping techniques for thermally sprayed coatings

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1 Scope of validity

This leaflet contains information on processes for stripping thermally sprayed coatings; it also makes recommendations to help with making a technically informed choice of a suitable process.

2 Introduction

As far as the removal of thermally sprayed coatings is concerned, a distinction should be made between stripping, total stripping and partial stripping. Stripping refers to the complete removal of the coating material from a component, local stripping is removal of the coating down to the substrate material in a limited area, and partial stripping refers to removal of part of the coating without exposing the substrate material (base material).

Stripping and removal of a thermally sprayed coating are frequently performed operations in the *manufacture, repair* and *recycling* of coated components.

In the *manufacturing phase* the sprayed coating is brought to its requisite final dimensions by means of partial stripping. In certain situations a coating that has been applied is removed locally for functional purposes. This can represent an alternative to masking areas which is sometimes more economically viable. Lastly, stripping is also carried out in the context of reworking coatings that fail to meet the relevant quality criteria.

The removal of coatings to carry out *repairs* is done on components that have a high material value and are expensive to manufacture. Power train components from gas turbines that have been provided with coatings for thermal insulation or protection against wear are stripped either for the purpose of inspection or because the coating has deteriorated through ageing. Because many components are expensive to manufacture, it makes good economic sense to remove a damaged coating with the aim of recycling the component. Where components are recoated, it is important to avoid damage to the base material.

The separation of coating and base material by stripping enables the *recycling process* to gain a benefit arising from reusing the materials because the coating material and the substrate material are cleanly separated.

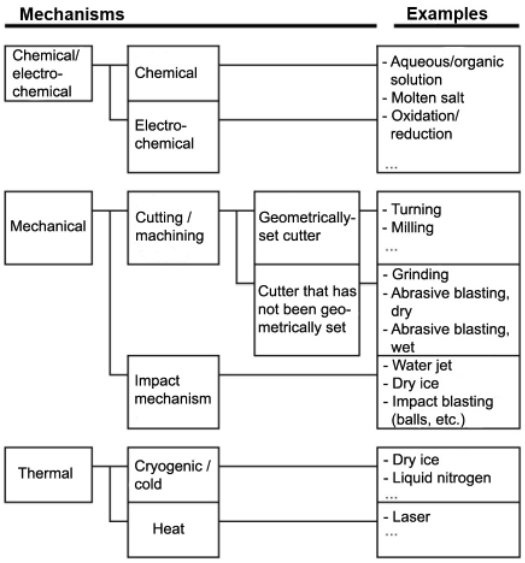
3 Stripping mechanisms

In order to remove a coating the adhesion between the coating and the substrate or within the coating must be overcome. The force required to remove the coating can be applied by means of a variety of different physical mechanisms.

The objective is to either partially or completely remove the coating, under certain circumstances also just in a limited, localised area, without damaging the substrate. To ensure that the substrate is not damaged, the mechanism involved in the selected stripping process must only fasten onto the coating rather than the substrate. In processes where this is the case a term that is commonly used is ‚selective stripping mechanism'. To enable a stripping mechanism to operate in a selective way there must be significant differences between the physical properties of the coating and substrate. However, it is not always necessary or economically viable to deploy a selective mechanism for removing a coating.

The physical mechanisms used in the removal of coatings can be divided into three categories:

Table 1. Classification of actor mechanisms for removal processes.



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Voransicht des Regelwerkes

Chemical and electrochemical:

Chemical stripping mechanisms are based on a reaction with the coating, frequently oxidation. To avoid damage to the substrate, the properties of substances used must be selected with precision.

Mechanical:

Mechanical mechanisms can be subdivided into machining techniques and impact techniques. Whilst machining processes involve a blade for removing the material, the impact techniques involve dull impact of a particle or a jet that destroys the cohesive structure of the coating, thereby removing it.

Thermal:

Thermal mechanisms can be subdivided into heat-inputting and heat-extracting (refrigeration or cryogenic) processes. The aim is to utilise stresses that are produced by differing thermal expansion or temperature-dependent changes in material properties, as for instance in cold embrittlement. Heat can be input in order to accelerate a chemical reaction that aims to weaken, melt or vaporise the coating; one must be aware here that there is also potential for damaging the substrate.

Many stripping techniques involve a combination of several of the mechanisms listed above. Abrasive jet techniques, for instance, also use an impact mechanism to achieve their effect. The greater the differences between the physical characteristics of the coating and substrate materials, the easier it is to perform selective stripping.

Typical applications for thermally sprayed coatings involve metallic, ceramic and metallic/ceramic materials on metallic substrates. Since the physical properties tend not to vary greatly between two given metals it can often be difficult to perform selective removal of metallic coatings from metallic substrates.

On the other hand, any special characteristics in the properties of thermally sprayed coatings make selective removal easier. Such special characteristics include:

- Lamellar structure in the thermally sprayed coating,
- Localised incidence of microcracks initiated during solidification of the sprayed particles,
- Coating porosities of up to 15% by vol. depending on spraying process,
- Heterogeneous coating structure,
- Anisotropic coating structure.

As a result, with many spraying processes the bonding forces within the coating or between coating and substrate are weaker by several decimal powers than within the metallic substrate. For certain processes it is therefore possible to selectively remove the coating with no damage to the substrate.

4 Safety and environmental protection

For the processes described below the general and specific trade association regulations and safety regulations (UVV) [1] must be observed. Where manually-operated processes are involved, in particular, the specific safety precautions for the operator are extremely important. These include protection against noise and aerosol emissions. As regards aerosols, it is important to be aware that during stripping the resulting particles may be of a size that enables them to enter the lungs or alveoli; thus especially in the case of coating systems with a significant health implication, the protective equipment used must satisfy more stringent criteria.

In terms of environmental protection, the materials that are destined for disposal represent a significant cost factor. Depending on the process used, in addition to the removed coating materials there are also operating materials that require disposal, and the costs of so doing can be very high, especially in the case of chemical processes. In this respect processes that use no solid or liquid materials or only such materials as can be easily recycled offer a considerable ecological and therefore also economic advantage.

5 Stripping processes

The relevant processes are listed in Table 2 together with their chief characteristics.

Table 2. Overview of stripping processes.

Process	Characteristics
Chemical and electrochemical processes	
- Chemical - Electrochemical	- Widely used in practice - Almost all metallic materials, but is of only limited use for ceramic materials
- Molten salt	- Disposal of waste products is problematical
Mechanical processes	
- Machining with a geometrically set cutter:	- especially for parts with flat, rotationally symmetrical surfaces that are well separated
- Turning / milling	- Heavy tool wear on hard coatings
- Machining with a cutter that has not been geometrically set: - Grinding - Abrasive blasting	- Widely used in practice - Fast stripping rates - Selective stripping is not possible - Extremely precise processes
- Hydromechanical Abrasive water-jet cutting - High-pressure water-jet cutting	- Relatively high investment costs - Used especially for large quantities
Thermal processes	
- Laser ablation - Cryogenic processes - Liquid nitrogen-Impact blasting - Liquid nitrogen blasting - Dry ice-(Laser-)/blasting	- Prototype processes - Removal rates in some cases remain low (laser ablation) - Currently limited to certain coating systems (especially ceramic materials)

5.1 Chemical and electrochemical processes

5.1.1 Chemical

The removal principle behind the chemical processes (see DIN 8590-2, [2]) is based on a specific reaction with the coating material. A chemical is chosen that will react with the coating material, and if possible there should also be no likelihood of any reaction with the substrate material. Selecting a suitable substance is often difficult in the case of metallic coatings on metallic substrates. In the case of substrates with a low standard electrode potential such as aluminium, magnesium, zinc or tin, all of which have a negative standard electrode potential, it is difficult to find suitable substances that will not attack the substrate material.

Once the coating has been detached in the bath the next aim is to prevent it from being re-deposited; one way of doing this is to add carefully selected chelating agents [3].

The liquid chemical can be applied to the workpiece; the affected coating and the resulting sludges can then be removed by scraping or rinsing. Where there are multiple coatings the process will need to be repeated several times in order to remove all the coatings. The final cleaning operation is often done by rinsing components with water.

Voransicht des Regelwerkes