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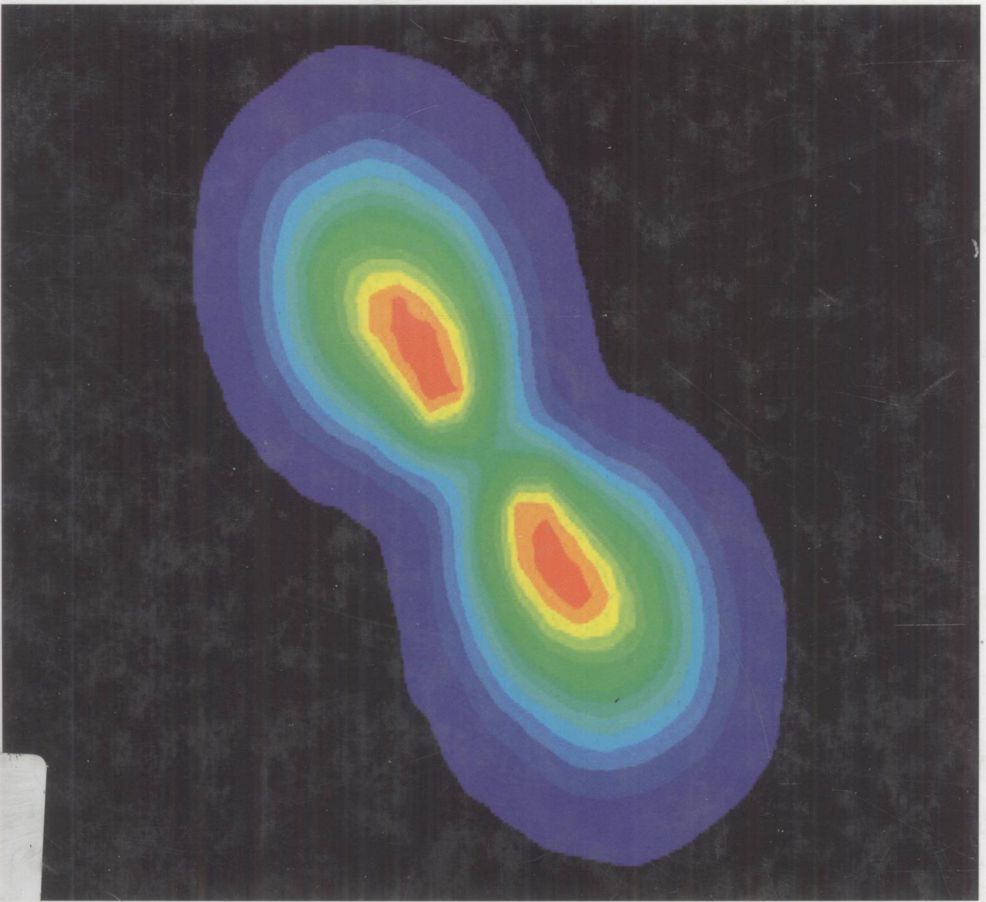

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Preface

Coatings constitute an intrinsic part of the power-generation hardware. Thousands of patents, papers and conference presentations address new coating types, new hardware and software, new process developments, new chemical compositions. A huge unpublished knowledge is stored in manufacturers "know-how".

However, sometimes coatings are still considered as an "art" and there are fair reasons for that. The thermal spray is still not a "plug and play" tool and the product quality largely depends on the deep understanding of process physics and hardware features, accumulated experience, engineer's intuition and operator's training.

This book now deals with questions that are essential for a good performance of this "art":

- Is there a given process stability? What is the ratio of deterministic and stochastic in the coating process?
- Is there an inherent process capability for a given specification that cannot be improved?
- What is the right preventive maintenance strategy?
- Is there a chance to end up with coating-process capabilities in the order of other manufacturing processes?
- What can be predicted and designed a priori by physical modeling and offline programming and what can be achieved by trial and error only?
- What can be done to describe and control quality?

This book is not a pure scientific book. It is of most value for the engineer involved in design, processing and application of thermally sprayed coatings:

To understand the capability and limitations of thermal spraying, to understand deposition efficiency – and the importance of maintenance and spare parts for quick changeover of worn equipment, to use offline programming and real equipment in an optimum mix to end up with stable processes in production after the shortest development time and in the end to achieve the final target in production:

Process stability at minimum total cost

Klaus Schneider

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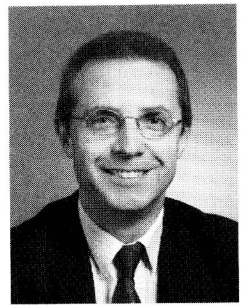

Stephan Siegmann *received his degree in Physics from the University of Basel, Switzerland. After completing the PhD in the field of Thermal Spraying, he was working as Vice Manager Research at MGC Plasma Company at Muttenz, Switzerland, in the field of waste treatment by thermal plasma at 1.2 MW. In the year 1994 he changed back to his former field of Thermal Spraying and built up a position at the Swiss Federal Institute for Materials Science and Technology (EMPA), where he is now responsible for all Thermal Spray activities.*

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Disclaimer

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1
Introduction

1.1
Requirements for Materials and Coatings in Powerplants

We do not want to write another book on thermal spraying, plasma spraying, HVOF (see Section 2.4.3) and other spraying processes. We will not repeat what is already written in excellent books, reviews, and journals. Many general descriptions of thermal spraying can be found today in the Internet on web pages of equipment suppliers, material and gas suppliers, coating shops and research facilities. Our intentions are to show some ways how to achieve a stable reliable coating production for power-generation equipment within reasonable time and at optimum cost. We will address how to identify problems and mistakes in advance. We will show how to minimize development effort and to improve product quality.

First, we will try to simplify and summarize the topic of this book:

Electric power generation today and in the future is using and will use steam turbines, gas turbines and turbogenerators, steel tubing and heat exchangers and boilers. Components consist of many parts that are welded, brazed or assembled. Each part has a specific function within the powerplant. The original equipment manufacturers (OEMs) and the powerplant customers like utilities or other power producers consider as the most important parameters of a powerplant:

- Investment cost
- Operation cost
- Long-term reliability
- Availability and scheduled, short maintenance

These parameters translate into requirements for components like material cost, optimized fuel cost, high operation temperatures and long operation times without in-operation control possibilities.

Today, all powerplant hardware is coated wherever no affordable and reliable structural material can be found that resists the operation environment.

For simplification we start with the view of a metallurgist:

Metallurgists select materials for specific applications or for a variety of applications. A powerplant is basically built from metals. The structural materials and functional materials are metals and metallic alloys:

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- Steel, low alloyed up to high chromium steels
- Nickel alloys
- Cobalt alloys
- Copper and brass

In some rare cases titanium alloys are used. This picture is completely different from aero engines where the weight of a part is important. In power-generation parts weight is only important as material cost and for rotating parts if weight causes mechanical stresses.

Designers select materials for operational conditions like:

- Mechanical stresses, loadings, strains
- Operational temperatures
- Temperature changes
- Environment, atmosphere
- Design lifetime (times and cycles)
- Expected safe operation times

and of course for cost reasons.

If a material class is not able to withstand the operational temperatures cooling is required by available cooling media that are mainly air, steam, or water. In closed-cycle cooling other media like hydrogen are being used.

In many cases a division of material properties for a variety of tasks is required. Base metal has to have the required strength. Coatings withstand the environmental attack or add additional properties like wear resistance. In cooled components thermal-barrier coatings reduce the temperature gradient within the structural material. The designer selects the structural material and the coating by iterating the loading, component thicknesses and cost.

1.2
Examples of Coatings in Gas Turbines

We promised to address powerplant components. However, when we look more closely we find the following situation:

In steam turbines thermal-spray coatings are not in standard use. In certain cases erosion damages are solved by replacing missing material by a thermal spray overlay of erosion-resistant material containing tungsen carbide or chromium carbide.

Large-scale application is found in boilers where the tubes are coated by wire spray. For example, FeCrAl and FeCrAlY coatings are used generally as high-temperature oxidation protection to resist corrosive gases in boiler atmospheres.

The more complex applications are found in gas turbines, especially at higher temperatures. Therefore we will concentrate on examples from industrial gas turbines.

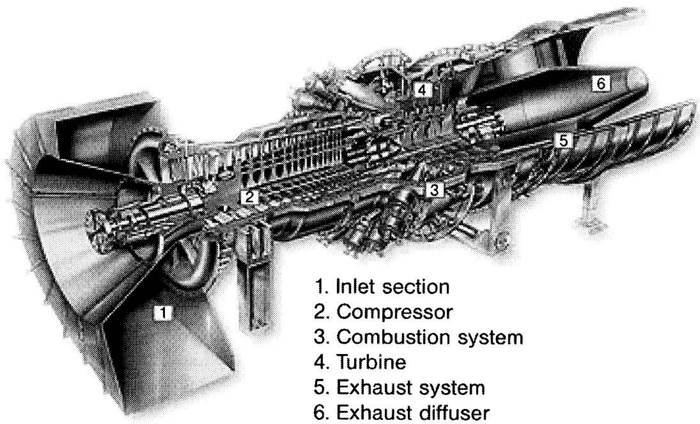

Fig. 1 Siemens Westinghouse gas turbine (courtesy of Siemens).

Basically there are three types of components:

- Large single structural components like casings
- Multiple medium-sized components with plane or slightly curved surfaces, like combustor parts
- Multiple complex-shaped components, like turbine vanes and blades

The following example of a stationary gas turbine illustrates the situation (Fig. 1):

The air intake (1) is a steel construction most probably painted with a zinc-rich paint. The compressor blades and vanes (2) are made out of Cr steels where in certain operation regimes aqueous corrosion, pitting corrosion might end up in corrosion fatigue or stress corrosion conditions. Here the OEM will decide to use higher alloyed steels, titanium alloys or protection of the parts by coating. For clearance-control purposes the counterparts of the rotating compressor blades might be coated with so-called abradable coatings.

The hot section parts in the combustor (3) and turbine (4) are made out of nickel- or cobalt-based alloys. In some cases ceramics are used. If oxidation and hot corrosion becomes important coatings are also used. In some cases for air-cooled components the cooling is assisted by ceramic thermal-barrier coatings that reduce the operational temperature of the structural material the part is made of. The exhaust (5 and 6) again is made out of zinc-plated or zinc-sprayed steel. Rotor and stator casings are steel components, sometimes coated. For certain operation conditions nickel-based alloys are used for rotor disks.

Wherever parts are rubbing against each other in operation or in order to control gaps between components wear-resistant coatings or so-called abradables are being used.

Years ago it was already noted that in aero engine components up to 80% of all components are coated by thermal spraying. Today, in stationary gas turbines probably 50% of components are coated. In earlier days galvanic processes like