COST 526
"Automatic Process Optimization in Materials Technology"
(APOMAT)

Half-Yearly Report

To be sent to **V.Tesch@access.rwth-aachen.de** until **February 28, 2003**

1. Reporting Period	**1.7.2002 – 31.12.2002**
Project title	Numerical Calculation of the Process Parameters, which Optimise the Gas Turbine Blade Coating Process by Ther. Spraying, for given Spray Paths
Project leader	F. Lavers
Organization	ALSTOM (Switzerland) Ltd Dept. GFH, H4/3 1 CH-5242 Birr
Main collaborators involved	Dr. M. Balliel, C. Pedretti, G. Guidati, P. Ryan

2. Funding Situation

Amount of money received specifically for COST – 70 kCHF received from Swiss BBW 2002-10-30, 159 kCHF committed by BBW 2002-06-17 with official project start 2002-07-01.

Other resources partially used for the project kEuros

3. International Collaboration
(mention group and type of work done in collaboration during the reporting period)

Participation in the Working Group Meeting in Budapest + project progress report

✓ YES

❒ NO

Yes, participated in WG Meeting Budapest.
Project progress report is part of this 2nd half-year report, section 6.

4. Industry participation
(mention name of companies and work done in collaboration during the whole project)

ALSTOM (Switzerland) Ltd = PL

5. Meetings, visits, exchange of scientists, short-term scientific missions	**Location, date**

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6. Progress within the reporting period (Not exceeding 3 pages, including tables and figures)
See attachment.

7. List of publications a) Published
-
b) Submitted for publications
-
c) In preparation
-

6. Progress within the reporting period

The Swiss ministry for education and research (BBW) has paid CHF 70’000 out of its committed funding of CHF 159’000 with a project start of 2002-07-01.

Objectives

The blading of a gas turbine has to be protected from the hot gas stream. This can be achieved by different techniques, such as cooling air, metallic coating or thermal barrier coating (TBC). The present project is concerned with the process of applying TBC on a turbine blade. Specifically, the project targets the following points:

- The development of criteria and strategies for the optimization of the coating process, which include the coating thickness, porosity distribution and the total coating time as parameters of the objective function.
- The development of methods for the optimization of a spray path for complex 3D shapes by taking into account equipment, process and tooling limitations.

Offline simulation tool

The offline simulation tool for the coating process is used for manual spray path generation. The complete set-up consisting of robot, a plasma spray gun and a blade is taken into account. Fig. 1 shows a sample process for manual spray path generation including coating thickness prediction.

Optimization environment

For the offline spray path generation the optimization software Java Optimization Environment (JOE) developed by ALSTOM (Switzerland) Ltd is planned.
One of the main strengths of the available optimization software is that it can handle noisy objectives. These can occur when the optimizer is coupled with a predictive software such as the above offline simulation tool. Specific algorithms (response surface techniques) allow to find good solutions with a relatively small amount of evaluations. This is especially useful in the present case where a complete prediction with the offline simulation tool may require a few minutes.

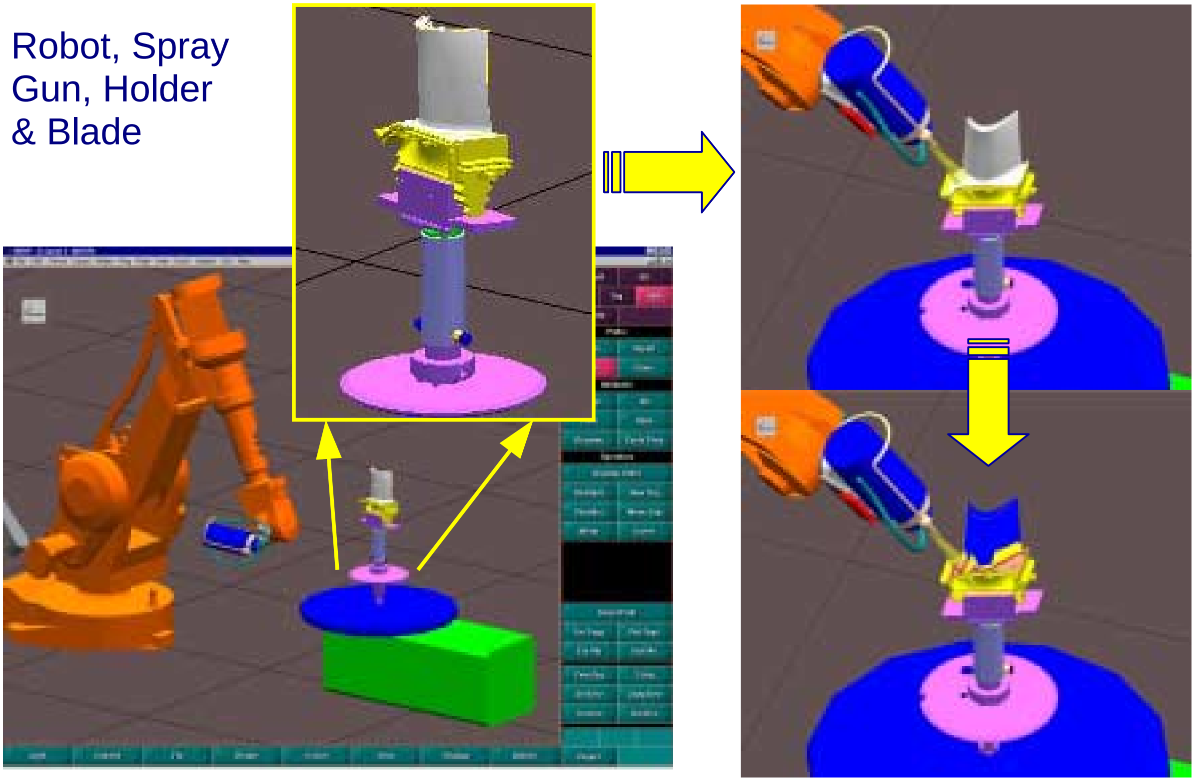


Figure 1: Offline process steps for spray path generation (sample).

Optimization strategies

To find the best optimization strategy, the following approach is employed:

- Coating strategy

This step aims at defining the most appropriate coating strategy. Considering the high number of variables in a spray path definition for a blade/vane, a reduction of variables is needed for both, easier manual input and for numerical optimization.
To achieve this the idea was projected to partition the surface to be coated into subdomains, which can be treated individually. Such subdomains are worked on in sequence with the spray result of all previous subdomains as starting condition for the next subdomain. This ensures that so-called 'overspray', e.g. spraying of surfaces adjacent to a primarily targeted surface, is taken into account at subdomain boundaries, see Fig. 2.

- Parametrization

This step requires a parametrization of a spray path for each subdomain as defined in the coating strategy. This means that the possible spray paths have to be described in a mathematical form with a limited number of free parameters. Fig. 3 shows as an example the spray path parametrization of a concave side airfoil with 7 parameters.

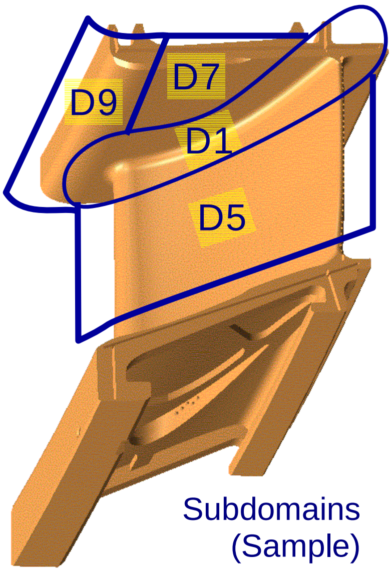
Both, coating strategy and parametrization are not finalized and need to be reviewed once more offline programming experience is accumulated.

Subdomains for Local Optimization

Idea: Decoupling for Reduced No. of Parameters
⇒ Easier Solution

How?

- Divide Coated Blade Surface into Subdomains 'Dn'
    - Use Design Features - Fillets, Edges, Surfaces
    - Add Neighbouring Areas to Include Detrimental Overspray in Local Optimization
        - Avoids: Overspray Only Visible as Starting Condition for Other Subdomains



Subdomains (Sample)

Figure 2: Sample of a spray strategy for a gas turbine vane.

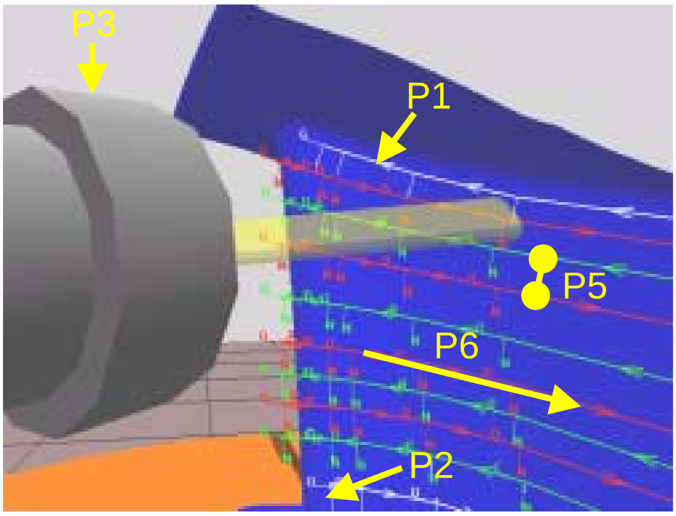
Subdomain "Concave Side Airfoil"

Method: Alternating Passes Aligned to Fillets

- Position of First & Last Pass at Fillets (P1,P2)
- Turning Positions for Passes at LE & TE (P3,P4)
- Distance between Passes - Mean (P5)
- Traverse Speed (P6) & Distance Gun - Airfoil (P7)
- Overspray (e.g. at Fillets)
    - Preceding Coating Results as Start Condition
    - Generate Coating Also Outside Subdomain

Optimization

- Parameters P1-P7
- Review Parametrization & Target Function based on Results



Parametrization (Sample)

Figure 3: Sample of a spray path parametrization for an airfoil side.