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NUMERICAL MODELING THE BONDING MECHANISM OF HIGH VELOCITY OXYGEN FUEL (HVOF) SPRAYED PARTICLES

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Abstract: Processing numerical model high velocity oxygen fuel (HVOF) coating. Thermal spraying technology, principle and basic characteristics of each method of application of coatings. Literature search, mapping the current trends in the numerical simulation process. Choosing approach numerical simulation, processing and evaluation of the results of the pilot study. There is described a method of modeling by the finite element method the residual stresses induced during thermal deposition of coatings. The simulation was performed in two stages. The first dynamic stage simulated the impacts of the individual particles of the coating material onto the substrate, and the next static stage included a non-linear thermo-mechanical analysis intended for simulating the process of layer-by-layer deposition of the coating, with a specified thickness, and then cooling the entire system to the ambient temperature. During high velocity oxy-fuel (HVOF) thermal spraying, most powder particles remain in solid state prior to the formation of coating. A finite element (FE) model is developed to study the impact of thermally sprayed solid particles on substrates and to establish the critical particle impact parameters needed for adequate bonding. The particles are given the properties of widely used WC-Co powder for HVOF thermally sprayed coatings. The numerical results indicate that in HVOF process the kinetic energy of the particle prior to impact plays the most dominant role on particle stress localization and melting of the particle/substrate interfacial region. Both the shear-instability theory and an energy-based method are used to establish the critical impact parameters for HVOF sprayed particles, and it is found that only WC-Co particles smaller than 40 μm have sufficient kinetic and thermal energy for successful bonding.
Keywords: HVOF, finite elements method, residual stress, technology

INTRODUCTION

Thermal spraying is a promising technology, which is formed by coating the surface of the parts used in various industries. Using this flexible, high quality and economical technology can be optimally adapted to the surface properties of components with different requirements under operational conditions. The beneficial effect of the surface layers contributes significantly to extend the life, increase the reliability and safety as well as the economic benefit of the operational or production process [1].

The aim of the solution is to map the current state of the numerical simulation of thermal spraying process [2]. The solution has the character of the initial study, the main objectives of the resolution were as follows:

- Overview of the most commonly used methods of thermal spraying technology and selection methods, which currently appears to be the most promising.
- The literature search, processing of current trends and approaches in numerical simulation of surface coating layers,
- The choice of the appropriate approach and the development of numerical simulation example - a pilot study.

PRINCIPLE OF TECHNOLOGY

Thermal spraying technology can be generally characterized as a process for coating thicknesses of the order of 0.01 to 0.1 mm by melting the additive material, the particles are accelerated and applied on a properly prepared surface of the base material. Following each of the base material, a partial or complete deformation of the individual incident particles, which are rapidly cooled to form a coating of lamellar structure.

In view of the thin deposited layer does not occur during the process of coating technology, thermal spraying or heat of the base material at 100 ° C to 150 ° C. It follows that, during application of the coating material, there is no deformation of the coated member and by or in degradation of the structure due to thermal effect on the base material [3].

The technology of thermally sprayed coatings can be formed on all common structural materials. When applying the material technology Thermal spraying is not essential chemical composition of the base material and the component or its condition. The coatings cannot be created only on the nitrided surface or already treated surfaces such chrome plating [4].

METHODS OF COATING

The most widely used method of coating application technology of thermal spraying are as follows:

1. thermal spraying flame,
2. The electric arc thermal spraying,
3. The plasma thermal spraying,
4. The thermal spraying high-speed continuous application [5].

NUMERICAL SIMULATION

During the coating process generated residual stresses, which determine the order finite elements. The simulation will be performed in two steps.

- First (dynamic) phase: simulation of the impact of individual particles of coating material on the substrate,
- The second (static) phase: includes non-linear thermo - mechanical analysis.

The process of coating so layer on the layer of the system is cooled to ambient temperature. In the calculations, we assume that the sample will have a cylindrical shape and composed of the substrate and the coating (on three different thicknesses). The accuracy of the numerical model is appropriate to experimentally verify the actual deformation of the coating [6].

In numerical simulations below were used following simplifying assumptions:

- The particles hit the substrate, which has resulted in a transformation in a relatively short period of time. Their kinetic energy is converted into thermal energy. In fact, the particles are flattened and form a so-called lamellae, which connect to the thin plate (bedrock). Other layers are sequentially deposited on it in the next cycle.
- During the cycle all the particles incident on the substrate have the same initial temperature. The layers formed from the particles in one "passage" parallel to each other.
- Coating particles are in a softened state. Within the conflict zone, the time required for heating and cooling of the particles is less than the cycle time by at least two orders of magnitude. The problem of simulating fluid dynamics is appropriate to simplify the thermo-mechanical problem.
- Influence of phase transformations on the size of the residual stress is neglected.
- The substrate and subsequent layers are in an ideal contact.

MATERIAL MODEL

For a modelling quick storylines involving a large plastic deformations are used in most cases material model Johnson-Cook, describing stress as the product of stress, strain rate and temperature effects [7].

EFFECT OF INITIAL TEMPERATURE BALLS THE SIZE OF THE RESIDUAL STRESSES

As we mentioned above, the initial temperature of the balls have changed the interface T = 1540-1640 [K] a step dT = 10 [K]. During the simulation we consider a constant speed v_0 = 450 [m / s] balls on impact on the substrate. We did so because, in order to better traceability of the change in stress at a given temperature balls.

Table 1: The resulting values obtained by numerical simulation

Temperature WC-Co [K]	Residual stress von Mises [MPa]	Peeding stress [MPa]
1540	259	210
1550	290	220
1560	260	200
1570	270	200
1580	284	190
1590	228	175
1600	242	165
1610	200	170
1620	216	150
1630	193	200
1640	205	200

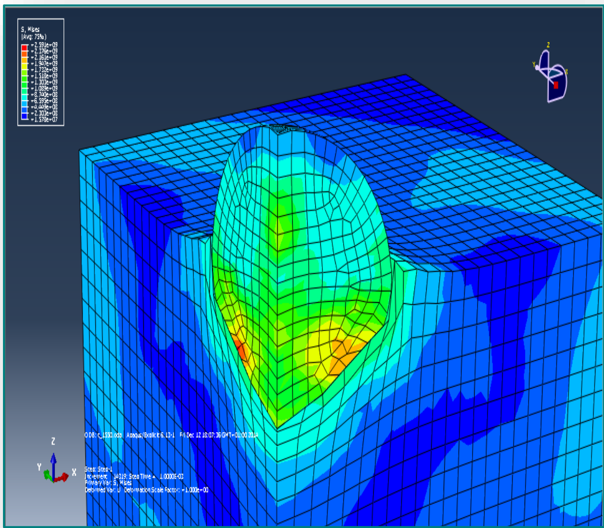

Figure 1: Residual stress at 1540 [K] by von Mises at an impact speed of 450 [m / s]

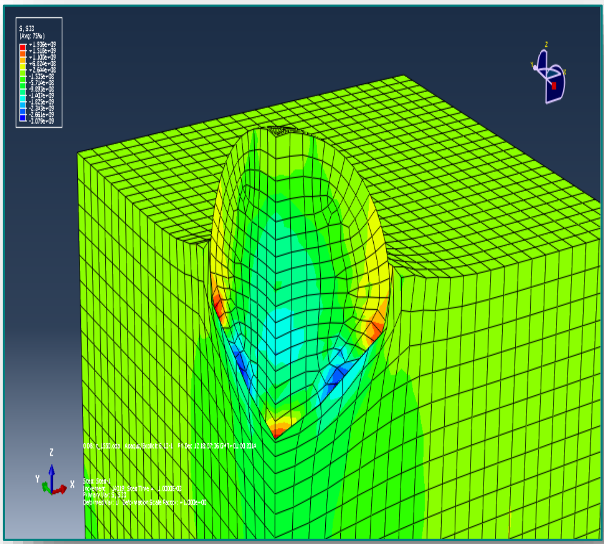

Figure 2: Peening stress at 1540 [K] at an impact speed of 450 [m / s]

The results of the simulation can be seen in the previous figures. The biggest plastic deformation originated in the place where the ball a maximum radius has changed with the connection to the substrate. In these places happened a max. stress.

CONCLUSION

To create a mathematical model of HVOF thermal spraying method, we used a quarter model of the incident particles to the base material St. program working with ABAQUS finite element, which we further evaluated. However, in this model were used for simplification of the model, which may distort the results, eg.:

» simulate only one particle,
» adiabatic process between the incident particle and the matrix,
» material properties,
» the impact of discretization model for the calculation.

Therefore, we can say that from constructing a mathematical model becomes rather complex matter in which it would be necessary to engage in a number of experts in various technical fields. Since it is necessary to determine the behavior of the material due to changes in the material constants during the process of thermal spraying. We argue that this model is only illustrative and for more reliable results it is better to do a technological test on a sample. Thanks to this knowledge would recommend experimentally determine these constants with the help of metallurgy, making the task has become trivial with the multidisciplinary. In view of this, it is necessary to do a comparison of the correlation mathematical model with measurements such as strain gauges or with X-ray or neutron diffraction.

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Note

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