Experimental report

06/09/2022

Proposal: **1-02-345**

Council: 4/2021

Title: Assessment of triaxial residual stress distributions after local repair of components by means of cold gas spraying

Research area: Engineering

This proposal is a new proposal

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Samples: Ni-based alloys

Instrument	Requested days	Allocated days	From	To
SALSA	5	5	30/09/2021	05/10/2021

Abstract:

We aim at extending cold gas spraying to the repair of near-surface damaged components, made of Inconel 718. In this regard the objective is to create a fundamental understanding of local repair by cold gas spraying with regard to coating quality, local microstructure and the formation of residual stress distributions at the repair site. Here, we intend to carry out neutron stress mapping at SALSA for three different substitute geometries, which are relevant to practice and in which the local induction of residual stresses and their change in the course of a global static or a local cyclical thermal stress can have a significant effect. These are an L-structure with the repair site at the outer radius and a T-structure with the repair site at the inner radius. A sufficiently stiff, flat plate serves as a reference condition.

Experimental Report – Proposal N° 1-02-345

Assessment of triaxial residual stress distributions after local repair of components by means of cold gas spraying

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Cold gas spraying is an established process for coating substrates with identical or non-identical materials. In this process, solid material particles are accelerated onto a substrate at high velocities by means of a high pressure carrier gas. The bonding of material to the substrate is achieved by interlocking solid particles to the substrate through significant plastic deformation. The method is particularly suited for repair applications, since there are neither structural changes nor oxidation occurring during the process. Cold spray coating usually induces significant compressive residual stresses in the coating system, which can be advantageous for repair applications. Especially for repair applications there is no reliable literature data available as to which geometry, of the cavities to be worked out, is most suitable and to what extent the feature geometry and the location of the repair site in the component are influencing the local residual stress distribution and therefore also impact the mechanical integrity of a component.

Aim of the project is the extension of cold gas spraying to the repair of near-surface damaged components made of Inconel 718. In this regard, the objective is to create a fundamental understanding of local repair by cold gas spraying with regard to coating quality, local microstructure and the formation of residual stress distributions at the repair site. For the systematic investigations, substitute geometries are chosen, which are relevant to practice and in which the local induction of residual stresses and their change in the course of a global static or a local cyclical thermal load can have a significant effect. Systematic neutron diffraction studies are part of a joint research project of the Forschungszentrum Jülich and the KIT, Karlsruhe, currently funded by the German research foundation (DFG). In the first approach, the repair application is to be tested on planar samples. This will then be transferred to more complex sample geometries.

Measurement setup

In this first approach, we focused on the determination of stress mappings through the cavity in the as-sprayed condition. IN718 plates with dimension of $100 \times 50 \times 15$ mm were analysed having a machined cavity each that is 50 mm long and 14 mm wide at the very surface and have a depth of 4 mm. The cavities were filled up with IN718 by means of cold gas repair spraying using 2 sets of processing parameters (spraying temperature was varied) and the local residual stresses should be mapped in the mid-plane across the repaired groove.

A nominal gauge volume of $0.6 \times 0.6 \times 4$ mm³ was used (4 mm in x-direction of the specimen), which was defined by apertures at the primary and secondary beam paths. Using this setup, the γ-Ni {3 1 1} reflection of IN718 was analysed at a wavelength of about 1.6 Å. Triaxial residual stress distributions were determined for 55 measuring points arranged in a grid over the mid-plane cross section of filled cavity for the two specimens. Furthermore, triaxial linescans with a high spatial resolution were performed through the centre of the specimens to investigate residual stresses at the interface of filling and substrate.

Additionally, d_0 reference samples were studied, using the same set-up. The reference samples consisted of a sample of the powder used for the coating and cuboids ($2 \times 2 \times 4$ mm³), which were EDM wire cut from free-standing bar structures produced with the same coating parameters as the tested samples, as well as a cuboid ($2 \times 2 \times 2$ mm³), EDM wire cut from substrate material.

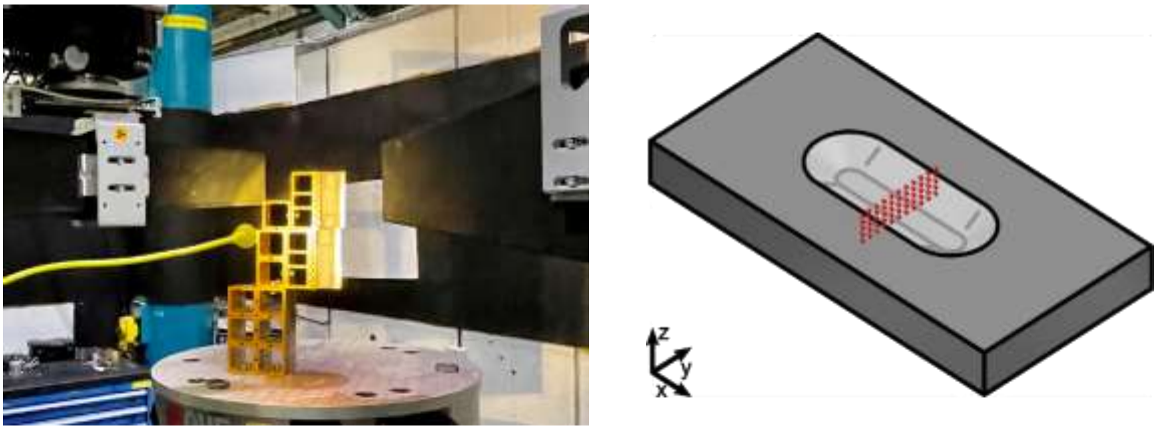

Figure 1: Two specimens, manufactured by means of two sets of spraying parameters, mounted on the hexapod for analyses in the normal direction(left) and schematic representation of specimen geometry with position of mapping points (right)

Preliminary results

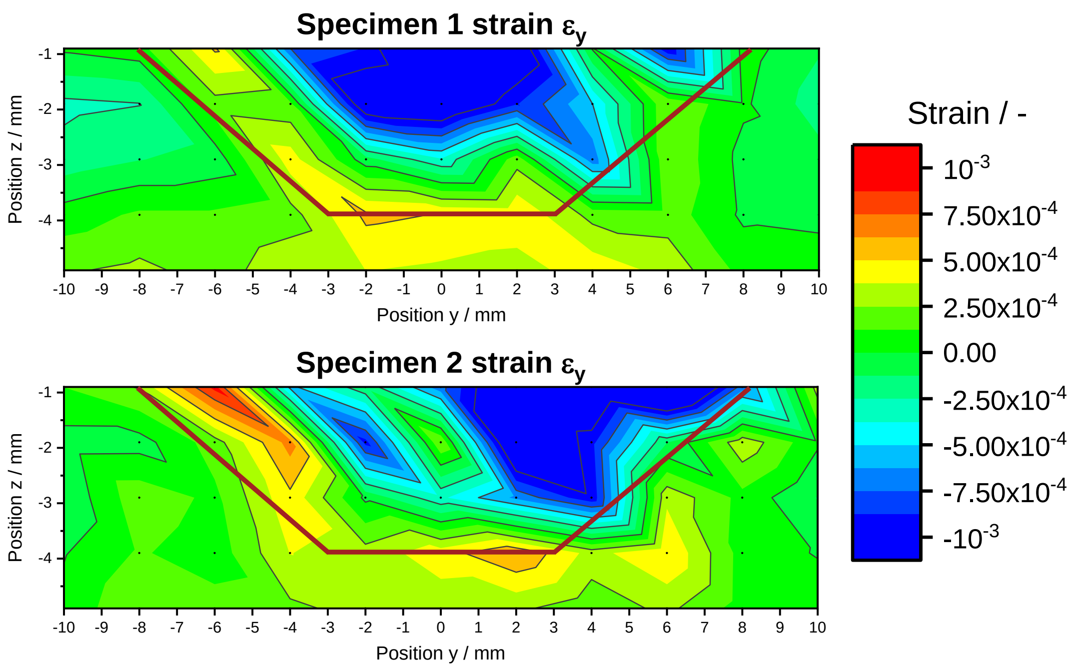

Figure 2: *Contour plots of determined lattice strain for both specimens for the y-direction in the centre of the specimens determined by 55 measuring locations. The red line denotes the geometry of the cavity.*

Preliminary results of the mapping show large lattice strains in the filled cavity as opposed to the strain in the surrounding substrate, which indicates compressive residual stresses within the filling as a result of the spraying process. A comparison of the x- and y- measuring direction shows a higher, more uniform strain distribution for the y-direction. This might be attributed to a higher degree of geometric constraints.

Preliminary results of the linescans support these findings. They, also show larger lattice strains in the y-direction compared to the x- and even the z-direction.

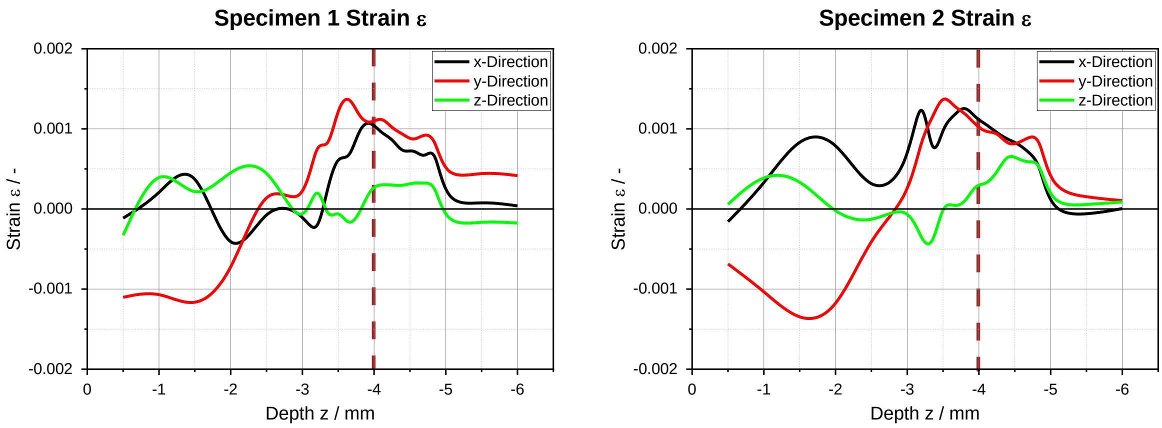

Figure 3: Preliminary lattice strain results of linescans performed in the centre of each specimen for three independent measurement directions. The dashed red line denotes

In a continuation experiment, we aim at transferring the process to more complex geometries, as e.g. cylindrical samples were a change in the constraint is expected to affect the resulting residual stress distributions. Furthermore, the effect of different substitute geometries as well as varying coating thicknesses should be studied.

We would like to thank the ILL for granting the experiment and the staff for their excellent and helpful support, which guaranteed the successful beamtime. Currently, the results are prepared for publication and furthermore the results will be presented at the 10^{th} RIPT Conference (Les Rencontres Internationales de la Projection Thermique) in Jülich, Germany.