Experimental report

16/05/2025

Proposal:	**1-02-358**	**Council:**	10/2022

Title: Triaxial residual stress distributions after local repair of practice-relevant components by means of cold gas repair spraying

Research area: Materials

This proposal is a continuation of 1-02-345

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Samples: Inconel 718

Instrument	Requested days	Allocated days	From	To
SALSA	5	5	12/04/2023	15/04/2023
			19/05/2023	21/05/2023

Abstract:

Neutron stress mapping will be carried out at the instrument SALSA@ILL for cylincrical samples of Inconel 718 where a machined cavity was filled up by means of cold gas repair spraying. Two sample states will be considered, which differ by the process temperature, i.e. again, a ´cold´ and a ´hot´ condition will be compared. The edges are chamfered with an angle cutter to improve the gas flow and to achieve a better bonding during cold gas repair spray. Furthermore, in comparison to the first experiment (1-02-345) the spray process has been optimised to eliminate surplus material being deposited on undamaged surfaces around the repair site. We intend to focus on the cross section in the middle of the repair track, to analyse RS as a result of the optimised process control and the changed constraint imposed by the cylindrical sample. Here, the local in-depth distribution of RS is of particular interest (through the repaired region and about 1-2 mm below the interface), which is only accessible non-destructively with a satisfactory spatial resolution by means of neutron diffraction (using a small gauge volume defined by 0.6 mm FWHM radial collimators).

Experimental Report – Proposal N° 1-02-358

Triaxial residual stress distributions after local repair of practice-relevant components by means of cold gas repair 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 cold gas spraying to the repair of near-surface damaged components made of Alloy 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)

Measurement setup

In this current step of the project, we focused on the determination of stress mappings throughout the cavity in the as-sprayed condition of a more practice relevant sample geometry, i.e. a sample with a radius of 20 mm. The gauge volume was defined by radial collimators at the primary and secondary beam path. For two out of three measurement directions a nominal gauge volume of $4 \times 0.6 \times 0.6$ mm³ was used (4 mm in x-direction of the specimen). For the third direction the gauge volume was $2 \times 0.6 \times 0.6$ mm³ (2 mm in x-direction of the specimen). In using this setup, the γ-Ni {3 1 1} reflection of Alloy 718 was analysed at a wavelength of about 1.7 Å. Triaxial residual stress distributions were determined for 51 measuring points arranged in a grid over the mid-plane cross section of filled cavity for two specimens, manufactured by means of two sets of spraying parameters. 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 ($2 \times 2 \times 2$ 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. In order to increase the spatial resolution on the tapered sidewalls of the sample, the sample was mounted on specifically designed mount and rotated. Due to the reduces reactor power in this cycle, there had to be a backlog beamtime to finish the intended measurements.

Preliminary results

Preliminary results of the full width at half maximum (FWHM), normalised to the FWHM value of the powder used for cold gas spraying, reveal strong peak broadening throughout the filled cavity with a rather homogenous distribution and a steep gradient over the interface between filling and substrate (see Figure 1a). The dashed line marks the geometry of the cavity, the shaded area illustrates the sample geometry. This is in agreement with results obtained from a previous experiment on flat samples and is a result of the strong plastic deformation during cold spray processing.

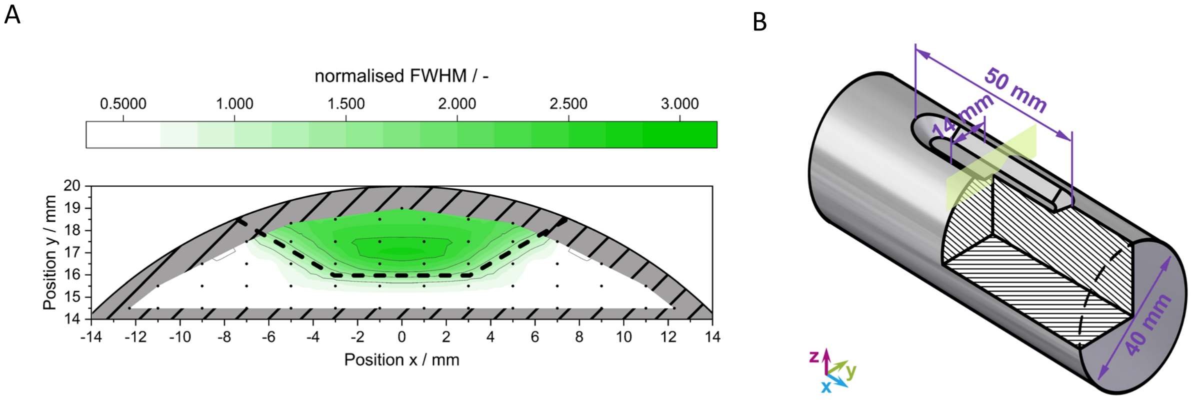

Figure 1*: A) Contour plot of Full Width at Half Maximum (FWHM) for one specimen in the centre normalised to the FWHM value in the powder. The dashed line denotes the geometry of the cavity, the shaded area denotes the sample geometry. B) Schematic of the sample geometry with the mapping plane marked in green. All dimensions given in mm.*

Figure 2 shows preliminary results of the residual stress mapping in x- & y-direction (c.f. Figure 1 B) for one specimen. The dashed line marks the geometry of the cavity, the shaded area illustrates the sample geometry. The results indicate compressive residual stresses in the filled cavity in x as well as in y-directions and balancing tensile residual stresses in the substrate material near the interface. The y-direction (Figure 2 B) exhibits higher compressive residual stresses in the filled cavity than the x-direction (Figure 2 A). This is in agreement with results from an earlier experiment on flat substrate material and might be due to the different geometric constraints in both directions. We would like to thank the ILL for granting the experiment and the staff for their excellent and helpful support.

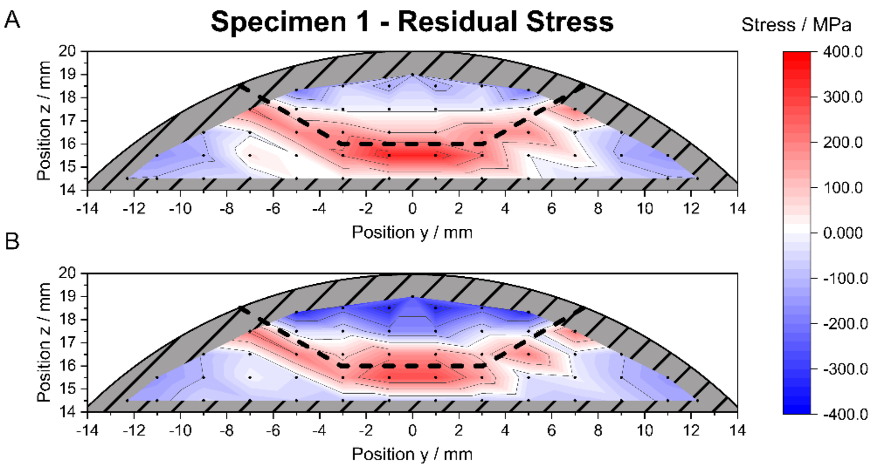

Figure 2*: Preliminary residual stress distributions for one specimen in the mapping plane in x-direction (A) and y-direction (B). The dashed line denotes the geometry of the cavity, the shaded area denotes the sample geometry.*