Experimental report

16/05/2025

Proposal: **1-02-372**

Council: 4/2023

Title: Local repair of components by means of cold gas spraying - (thermal) stability of triaxial residual stress distributions

Research area: Materials

This proposal is a new proposal

Main proposer: **Jens GIBMEIER**

Experimental team: Jens GIBMEIER
Florian LANG

Local contacts: Thilo PIRLING
Sandra CABEZA

Samples: Inconel 718

Instrument	Requested days	Allocated days	From	To
SALSA	5	6	22/11/2023	28/11/2023

Abstract:

In this experiment, we aim at analyzing residual stress (RS) distributions (mapping) in Inconel 718 samples that were locally repaired by cold spraying. Both the local RS distributions across the repair region and in particular the RS stability are important for e.g. the evaluation of the shakedown behavior of the components during commissioning in the medium or high temperature range. Hence, we intend to carry out neutron stress mapping at the instrument SALSA@ILL for samples in the as sprayed condition and for samples that are subjected to a thermal load that corresponds to the thermal load in real operation of the repaired components. Supplementary, local RS analyses will be carried out using laboratory methods, i.e. XRD and incremental hole drilling, on the same parts subsequent to the beamtime to get a holistic overview about the local residual stress distributions after cold gas repair spraying and subsequent thermal loading.

Experimental Report – Proposal N° 1-02-372

Local repair of components by means of cold gas spraying - (thermal) stability of triaxial residual stress distributions

Jens Gibmeier[1], Florian Lang[1]

[1]Institute for Applied Materials (IAM-WK), Karlsruhe Institute of Technology (KIT), Engelbert-Arnold-Str. 4, 76131 Karlsruhe, Germany

Cold gas spraying represents a well-established process for the coating of substrates with materials that are identical or non-identical in composition. In this process, solid material particles are propelled at high velocities towards a substrate by means of a high-pressure carrier gas. The interlocking of the material to the substrate is achieved through the significant plastic deformation of the solid particles. The method is particularly well-suited to repair applications, as neither structural changes nor oxidation occur during the process. The application of a cold spray coating typically results in the induction of notable compressive residual stresses within the coating system. This phenomenon can prove advantageous in the context of repair applications. In the context of repair applications, there is a notable absence of reliable literature data pertaining to the optimal geometry for the repair of cavities and the extent to which the geometry of the feature and the location of the repair site within the component influence the distribution of residual stresses and, consequently, the mechanical integrity of the component. The objective of this project is to extend the application of cold gas spraying to the repair of near-surface damaged components manufactured from Alloy 718. In this regard, the objective is to gain a fundamental understanding of local repair by cold gas spraying in terms of coating quality, local microstructure and the formation of residual stress distributions at the repair site. In order to conduct systematic investigations, substitute geometries are selected 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. These investigations are part of a joint research project between the Forschungszentrum Jülich and the KIT, Karlsruhe, which is currently funded by the German Research Foundation (DFG).

Measurement setup

In the context of the ongoing project, the current phase has been dedicated to the mapping of stress distributions across the repair cavity and their change as a result of different cyclic thermal loading.

The gauge volume was defined by radial collimators situated at the primary and secondary beam paths. Figure 1 shows a schematic of the specimen geometry and indicates the sample coordinate system. The mapping plane is marked in green. In two out of three measurement directions, a nominal gauge volume of 4×0.6×0.6 mm³ was employed (4 mm

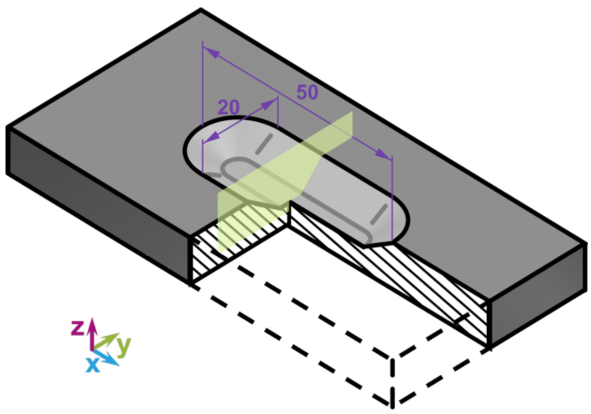

Figure 1*: Schematic of the sample geometry with the mapping plane marked in green. All dimensions given in mm.*

in the x-direction of the specimen). In the third direction, the gauge volume was 2×0.6×0.6 mm³ (2 mm in the x-direction of the specimen). In utilising this configuration, the γ-Ni {3 1 1} reflection of Alloy 718 was examined at a wavelength of approximately 1.52 Å. Triaxial residual stress distributions were ascertained for 50 measuring points distributed in a grid over the mid-plane cross-section of the filled cavity for three specimens. Subsequent to cold gas spraying, all three specimens were restored to their final geometry. One sample was employed as a reference sample without any thermal loading. One sample was subjected to 3000 cycles of localised thermal loading in a burner rig test stand. The final sample was subjected to thermal cycling in an oven, utilising the equivalent target temperature range employed for the second sample.

Furthermore, d0 reference samples were examined using the same configuration. The reference samples comprised the same powder that is used for coating the samples and cuboids (2×2×2 mm³), which were EDM wire cut from free-standing bar structures produced with the identical coating parameters as the tested samples. Additionally, a cuboid (2×2×2 mm³) was EDM wire cut from the substrate material.

Preliminary results

Figure 2 and Figure 3 show preliminary results of the residual stress mapping in x-, y-direction and z-direction (c.f. Figure 1) for the reference and the furnace specimens, respectively. 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 and balancing tensile residual stresses in the substrate material near the interface. This is in agreement with results from an earlier experiments. For the furnace specimen, the residual stress level decreased, which is in good agreement with complementary incremental hole drilling analyses results, performed on the same sample subsequent to the experiment on SALSA. We would like to thank the ILL for granting the experiment and the staff for their excellent and helpful support.

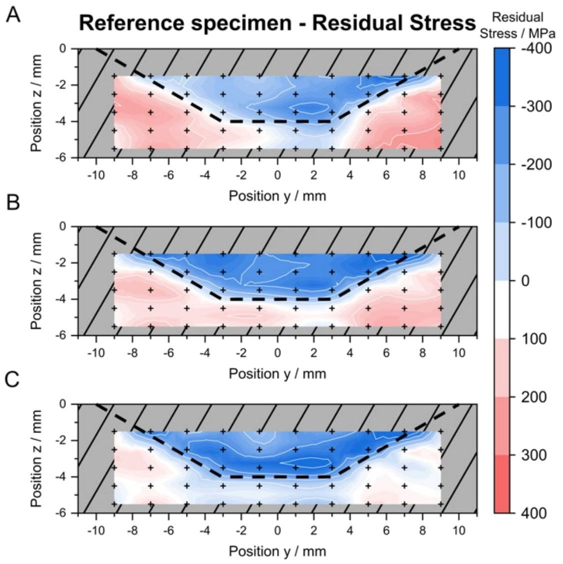

Figure 2*: Preliminary residual stress distributions in the mapping plane for the reference specimen without thermal loading in x-direction (A), y-direction (B) and z-direction (C). The dashed line denotes the geometry of the cavity, the shaded area denotes the sample geometry.*

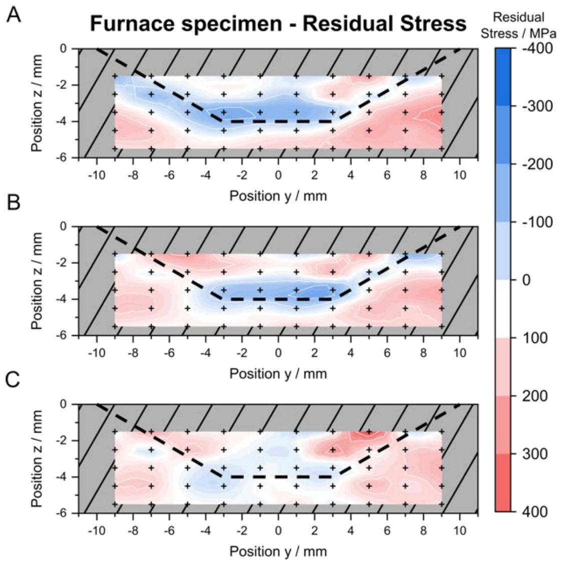

Figure 3*: Preliminary residual stress distributions in the mapping plane for the furnace specimen with cyclic thermal loading in x-direction (A), y-direction (B) and z-direction (C). The dashed line denotes the geometry of the cavity, the shaded area denotes the sample geometry.*