TIP 346: Cold Spray' Deposition for Improved Service Life of New and Repaired Hydroelectric Turbines

Context

When turbine blades are initially installed, the smooth surface produces relatively little cavitation. Over time pits begin to form on the surface of the metal. These pits act as nucleation sites and increase the amount and intensity of cavitation. Once pits are large enough to act as nucleation sites, both wear rates and intensity of cavitation will increase with time.

Eventually the turbine is shut down so that skilled technicians can arc weld filler material onto the turbine to replace material lost by wear.

A solid-state repair process will dramatically extend service life and reduces frequency of outages due to blade repair if applied properly.

Description

For this project, PNNL developed a solid-state deposition process called “cold spray” for turbine repair. Cold spray is used to deposit material with dramatically improved wear resistance over traditional arc welding repair techniques. Improved properties are achieved by leveraging relevant physics to create a fine grained fully consolidated microstructure.

Repaired turbines have superior wear resistance over the original blades, and developed techniques can be used during the manufacture of turbines for increased wear resistance and service life.

Cold spray is certified and currently in use as an “in-field” repair technique for certain aluminum military aircraft and warship components. In-field repair of high-strength alloys is an emerging technology.

An important part of this research ensures that the cold spray solution developed is not only a solid state process, but a high plastic deformation process. Extreme plastic deformation occurring during the developed process produces a highly refined grain structure at the surface of the weld. This grain refinement provides significant improvement in mechanical properties including hardness, ductility, ultimate yield strength and toughness.

Steps of the repair processes developed as part of this work include:

- 3D scan of area of repair area
- Grind damaged surface
- Use cold spray to build up material in damaged area
- Grind repair area
- Non-destructive testing of deposition layer
- Final grind and polish.

This work provides data from scaled testing demonstrating service life of deposited material that matches or exceeds that of the base metal.

Benefits

This project provides BPA and utilities with hydropower assets, a model that they can use to understand and the value proposition of cold spray repair for their hydropower system. This tool calculates anticipated savings in terms of reduced downtime and increased efficiency. It generates data required for cold spray repair providers to quote the work. Using outputs from this model, utilities can perform costs analysis for a given turbine repair.

Cold spray repair providers who participated in this project will be available to repair turbines for BPA dam operators.

Accomplishments

All project milestones were meet and cavitation erosion resistance of cold spray far exceeded expectations.

Project objectives included:

- Optimize the microstructure of deposited material.
- Validate optimal properties through testing of coupons.
- Validate improved turbine life through scaled testing in hydro turbine test facilities.

Deliverables

The project established technical and economic viability of cold spray as a repair process for damaged hydropower progress. A presentation of final results was given to a BPA audience.

Final Project Report was issued as a PNNL report and made available to the public.

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Project Start Date: October, 2015

Project End Date: July, 2019

Reports

(Link to final report when available)

For More Information Contact:

Technology Innovation Office:
TechnologyInnovation@bpa.gov

Participating Organizations

Pacific Northwest National Laboratories (PNNL)
Army Research Laboratory
VRC Metal Systems
Moog
Bureau of Reclamation

Conclusions

This project has successfully demonstrated that the solid state processing, including friction stir processing and cold spray, can dramatically improve the cavitation erosion resistance of the materials in discussion, indicating the viability of solid state processing in repairing and constructing hydropower metal components.

We have provided ASTM benchmark data for incorporating these technologies into the hydropower realm. The understanding from a materials science aspect not only verified the processing methodologies, but also provided guidelines for further processing & materials optimization.

The improved cavitation erosion performance of the solid state processed coupons is a critical evidence that adopting solid state processing can provide value in increasing robustness of hydropower infrastructure, and as a result, the resilience of America's power grid.

One also needs to realize that the improved performance not only can impact the service life of the components, but also bring in a range of other benefits, including increased passing fish survival rates, reduced hydropower downtime and lessened environmental impact due to the increased power generation flexibility.

These promising results and benefits demand that further process adoption and optimization will need to be in place, and we should work with owner operators and part manufacturers for part specific development and repair integrity check using additional testing methods.