Press Release

Digital weld measurement instead of blanket oversizing: potential savings of several hundred thousand tons of steel

Whether it's an offshore wind turbine tower, a slewing crane, or an excavator arm - load-bearing steel structures are systematically oversized because the quality of their welds is not objectively assessed. The ORka3D joint research project, funded by the BMWE, has developed a method that uses 3D scanning and artificial intelligence to capture the actual geometry of each individual weld and evaluate it on a case-by-case basis. With precise predictions of fatigue strength, sheet metal thicknesses can be reduced by up to 40 percent without compromising safety. Across the industry, this represents a potential savings of several hundred thousand tons of steel and several million tons of CO_2.

Every weld is unique and features a geometric notch at the transition to the base material, from which most fatigue cracks originate. Because this notch varies depending on the welding process, torch guidance, and even the welder's performance on a given day, regulations have so far relied on a blanket safety margin: they generally assume the least favorable permissible geometry. The actual - and often significantly better - quality of the fabricated weld is not considered. The result is the persistent overdesign of components, using more material than necessary, and an enormous, untapped opportunity for resource savings.

The ORka3D joint research project, funded by the German Federal Ministry for Economic and Energy BMWE — »Optimization of Resource Use in Welded Structures through Automated In-Line Service Life Assessment Based on 3D Scans« — has addressed precisely this issue. A consortium led by the Fraunhofer Institute for Mechanics of Materials IWM has developed a method that captures the actual weld bead surface via 3D scanning and automatically derives a component-specific service life prediction from it, rather than estimating it — as has been done until now — based on generalized notch classes.

»The geometric notch at the weld transition has been known for decades as a weak point, but the issue remained unresolved until now because every weld is geometrically unique. Using high-resolution 3D scans and neural networks, we can now objectively capture and evaluate this individuality for the first time — which

could make the design of welded structures much more materials-efficient,« explains project manager Dr. Jan Schubnell of Fraunhofer IWM.

How the method works

A 3D scanner captures the weld surface with a pixel pitch of up to 5 micrometers. An algorithm automatically extracts key geometric parameters from this data, in particular the weld transition radius, which has been neglected in standards up until this point. An artificial neural network uses this data to derive the individual notch shape factor and a component-specific service life prediction, rather than applying blanket notch failure classes (so-called FAT classes). The method was validated on approximately 400 test specimens as well as on real-world structures such as pipe joints and crane booms.

With this data-driven assessment of fatigue strength, the notch class could be raised from FAT90 to as high as FAT140, which corresponds to a reduction in sheet thickness of up to 40 percent and a halving of welding time. And this is achieved while maintaining structural safety, since the verification is based on individual measurement data rather than on blanket safety factors.

Leverage not just for the energy transition

The potential is particularly evident in the example of wind energy: For a 10-megawatt offshore wind turbine with a tower weight of approximately 600 tons, optimized weld evaluation can save about 180 tons of steel without compromising safety. Given the planned expansion of offshore wind capacity to 30 gigawatts by 2030, this amounts to up to 360,000 tons of steel and CO_2 savings in the millions.

The project partners are working to incorporate the results into regulatory frameworks through their participation in expert committees, with the goal of expanding the conservative FAT class concepts to include an individualized, data-driven assessment.

The method also applies to bridge construction, crane manufacturing, and construction equipment — sectors that process many millions of metric tons of steel each year in Germany.

Funding

The ORka3D project, »Optimization of Resource Use in Welded Structures through Automated In-Line Service Life Assessment Based on 3D Scans,« was funded under the 7th Energy Research Program by the German Federal Ministry for Economic Affairs and Energy BMWE.

In addition to the Fraunhofer institutes IWM and LBF, the project involved industry partners Liebherr, Volvo Construction Equipment, and Salzgitter Mannesmann Forschung, as well as sensor manufacturers GOM, Micro-Epsilon, and Quelltech, and the engineering service provider Jörss–Blunk Ordemann (JBO).



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For the ORka3D project, a scientist at Fraunhofer IWM is investigating weld seam specimens using cyclic 4-point bending tests until cracks form. The crack initiation sites, strain fields, and failure cycles are precisely measured and correlated with scan-based weld defects. The resulting database will enable future predictions of each weld's service life from simple 3D scans, helping to save steel.

The **Fraunhofer Institute for Mechanics of Materials IWM** conducts research to promote sustainability in industrial value creation. For industrial companies and public sector clients, the institute opens up new avenues and spaces for innovation aimed at enhancing the durability and safety of components, improving resource efficiency in process chains, and increasing the energy efficiency of machines. To this end, the institute creates digital representations of materials in manufacturing processes, components, and machines, making their behavior and properties calculable. The institute empowers companies to use materials in a data-driven manner as the key to competitiveness and sustainability.

The **Fraunhofer-Gesellschaft**, headquartered in Germany, is one of the world's leading organizations for applied research. It plays a major role in innovation by prioritizing research on cutting-edge technologies and the transfer of results to industry to strengthen Germany's industrial base and for the benefit of society as a whole. Founded in 1949, the Fraunhofer-Gesellschaft currently operates 74 institutes and research units throughout Germany. Its roughly 30,000 employees, predominantly scientists and engineers, work with an annual business volume of 3.6 billion euros; 3.2 billion euros of this stems from contract research.

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