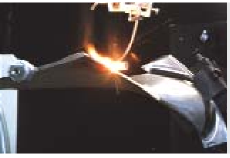


An innovative torsion-axial testing system to evaluate laser welded power train components

Task

Automotive powertrain components are frequently made from material combinations including case-hardened and multiple alloyed steels. Advanced laser beam welding processes are applied to weld these material pairs using integrated heat treatments and filler materials resulting in crack-free axial or radial round seams. A typical example is the welding of shafts and gears. During the component's application in the vehicle, these welds are exposed to a combination of torsion and bending loads. Currently there are no reliable fatigue strength values and dimensioning guidelines for laser beam welding joints for components experiencing torsion-bending loads.

Typically the weld seams do not fail when these components are tested in transmission testing stands. Thus, while these time consuming and costly tests are indispensible for quality assurance, they do not provide data that are relevant to reflect the fatigue strength of the weld seams. Therefore it was necessary to develop a new test system that directly evaluates the fatigue strength of laser-welded joints under conditions similar to the actual loading conditions. This work included the development of a test component (Fig. 1) that is on the one hand similar to typical poere train components, and on the other hand makes the welded seam its weakest joint when component failure occurs. The test machine was to be designed to allow the independent loading with bending and torsion forces. The machine was also required to be able to test real parts (i.e. drive shafts, tubes) in addition to the specifically designed test components.

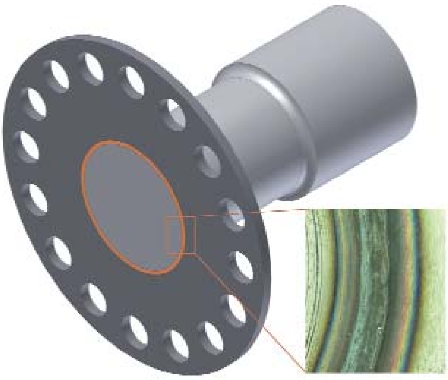
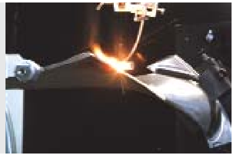


Fig. 1: Model test component (shaft-disk) with weld seam

Solution

Fraunhofer collaborated with a testing equipment manufacturer on the development and implementation of the testing machine (grant from the Federal Ministry for Education and Research, 02PB2073). Axial force and torque cylinders are mounted at both ends of the horizontal machine axis (Fig. 2). Both loading forces are decoupled using a hydraulically mounted crosshead. This setup is used to apply phase synchronized or phase shifted cyclic axial and torsion loads. The sample fixtures are mounted to the test axes using cardan joints. This method avoids additional loads caused by clamping of the welded transmission components, which naturally suffer from a certain degree of distorsion.

Fig. 2: Torsion-axial testing system



The design of the machine and the clamping system makes it possible to study in detail how the fatigue strength of a weld is influenced by factors such as welding distortion, welding depth, notches, filler material, stiffness of the seam area and the integrated heat treatment. The components are mounted using chuck cone systems for cylindrical shafts and threaded flanges. The force cylinders can apply torques as high as ±8 kNm at maximal rotation angles of ±50°. In axial direction forces can be applied of up to ±40 kN at maximal displacements of ± 50 mm. The maximal loading frequency for both axes is 50 Hz. Test specimens can be sample parts and components with diameters of up to 300 mm and lengths of up to 1250 mm. The acquisition of critical test data is performed at a frequency of up to 10 kHz and includes torque, torsion angle, axial force, axial displacement and data from strain gauges.

Results

After the machine was delivered to the Fraunhofer IWS, its function was thoroughly tested. The experiments aimed at evaluating the usefulness of specific model test component (Fig. 4). It was demonstrated that the design of the specimen was indeed capable of applying the highest loads to the welded joints, which leads to crack initiation and failure in the weld (molten or heat influenced zone, Fig. 5).

Additionally the test component also presents realistic welding conditions with respect to welding depth and thermal conductivity. The testing components are also easy to manufacture at low costs.

The first experiments were performed applying varying torsion and torsion-axial loading patterns. The test components were laser welded using shafts made from 42CrMo4 and disks made from 16MnCr5. Fig. 3 shows the results in form of a Woehler diagram. The application of the forces and torques results in stresses at the weld seam, which were calculated as equivalent stresses using FE modeling. First results indicate that a combined loading with torsion and axial forces causes the disk to bend and thus reduces the overall fatigue strength if compared to pure torsion loads.

The successful implementation of the axial-torsion test machine delivers the Fraunhofer IWS with a very important testing capability. The system provides specific material data that will enable the engineering team to properly layout and dimension lightweight laser welded components in particular for future power train components.

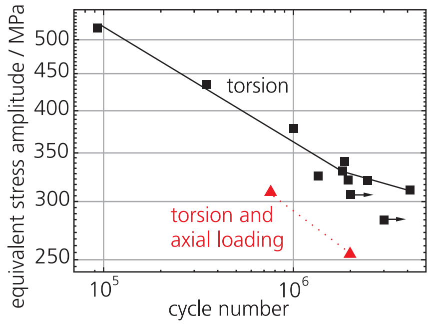


Fig. 3: Fatigue strength of welded disk-shaft test components

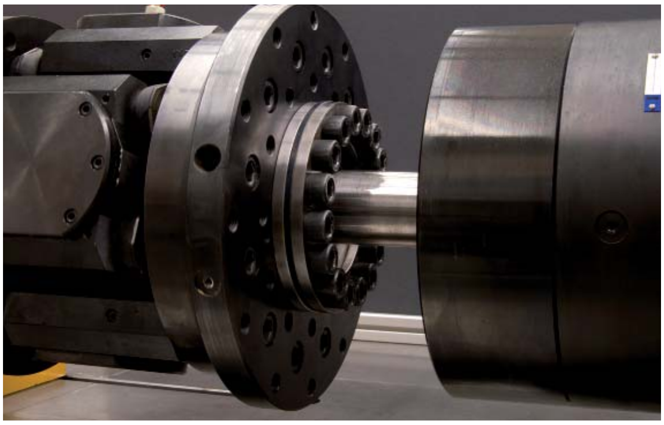


Fig. 4: Test component, clamp flange and cardan joint of the test system during a torsion experiment

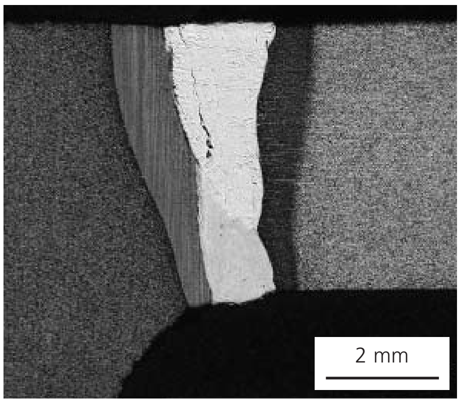


Fig. 5: Polished cross section through a cracked weld seam of a disk-shaft test component after torsion-axial loading

Contact

Dr. Jörg Bretschneider
phone:
+49 (0) 351 2583 217
joerg.bretschneider@iws.fraunhofer.de