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Automatic Design of Practical Fixtures

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Automatic Design of Practical Fixtures

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Abstract

Fixtures are tools used to hold parts in specific positions and orientations so that certain manufacturing steps can be carried out within required accuracies. Despite the importance of fixtures in the production of expensive devices at Sandia National Laboratories, there is little in-house expertise in mathematical design issues associated with fixtures. As a result, fixtures typically do not work as intended when they are first manufactured. Thus, an inefficient and expensive trial-and-error approach must be utilized. This design methodology adversely impacts important mission duties of Sandia National Laboratories, such as the production of neutron generators.

The work performed under the support of this LDRD project took steps toward providing mechanical designers with software tools based on rigorous analytical techniques for dealing with fixture stability and tolerance stack-up.

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Introduction

The objective of this LDRD research project was to study problems arising in manufacturing applications of fixtures. A fixture is a tool that must hold a part in a precise position and orientation in order to facilitate one or more manufacturing operations. For example, a clamp on a drill press could be used to hold a block of stock while holes are being drilled. The fixture shown in Figure 1 below holds several parts of an exhaust system while the parts are welded together.

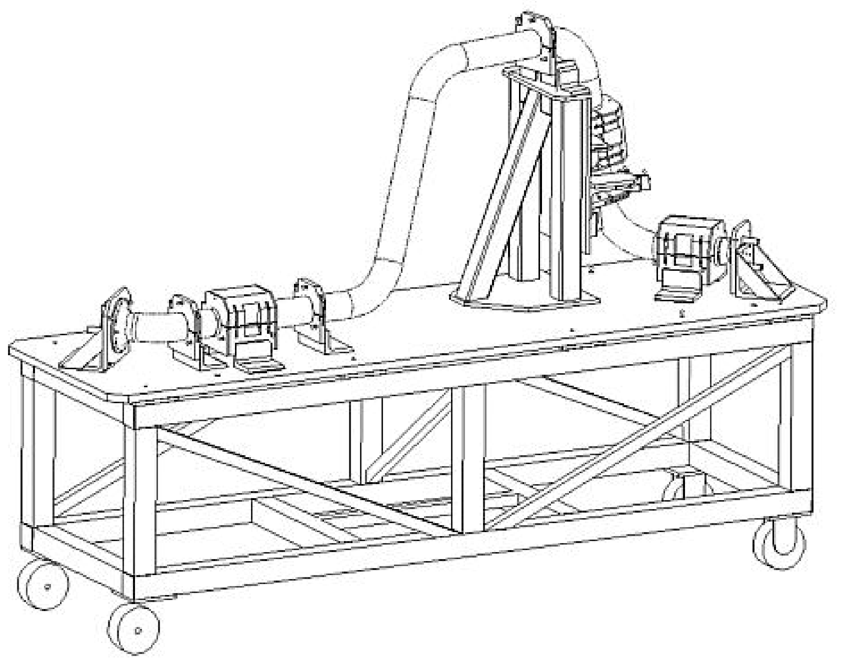

Figure 1. Mobile fixture holding parts of an exhaust system for welding.

In this project, we studied tolerance stack-up and stability issues. This LDRD resulted in multiple publications which report the technology developed in detail [1-8]. This work was presented in a number of workshops sponsored by federal funding agencies and university research seminars [9-14]. Additional information can be found at the following web site: `http://www.cs.sandia.gov/~jctrink/fixture_design.html`.

2. Application of Results to Micro-Assembly

The results of this project were successfully applied to the design of a fixture for holding a pawl for a micro-machine called the “tribology test vehicle.” Figure 2 shows the vehicle whose maximum dimension is approximately 40 mm. The dark purple pawl (about 2 mm long) on the left side of the gear must be joined with a washer by two press-fit pins (as shown in Figure 3). However, in order to complete the assembly operation, the pawl and washer must be held in fixtures so that manipulation can be easily accomplished. The two fixtures are manipulated by hand until the press-fit holes in the pawl and washer are coaxial, and then the pins are pressed.

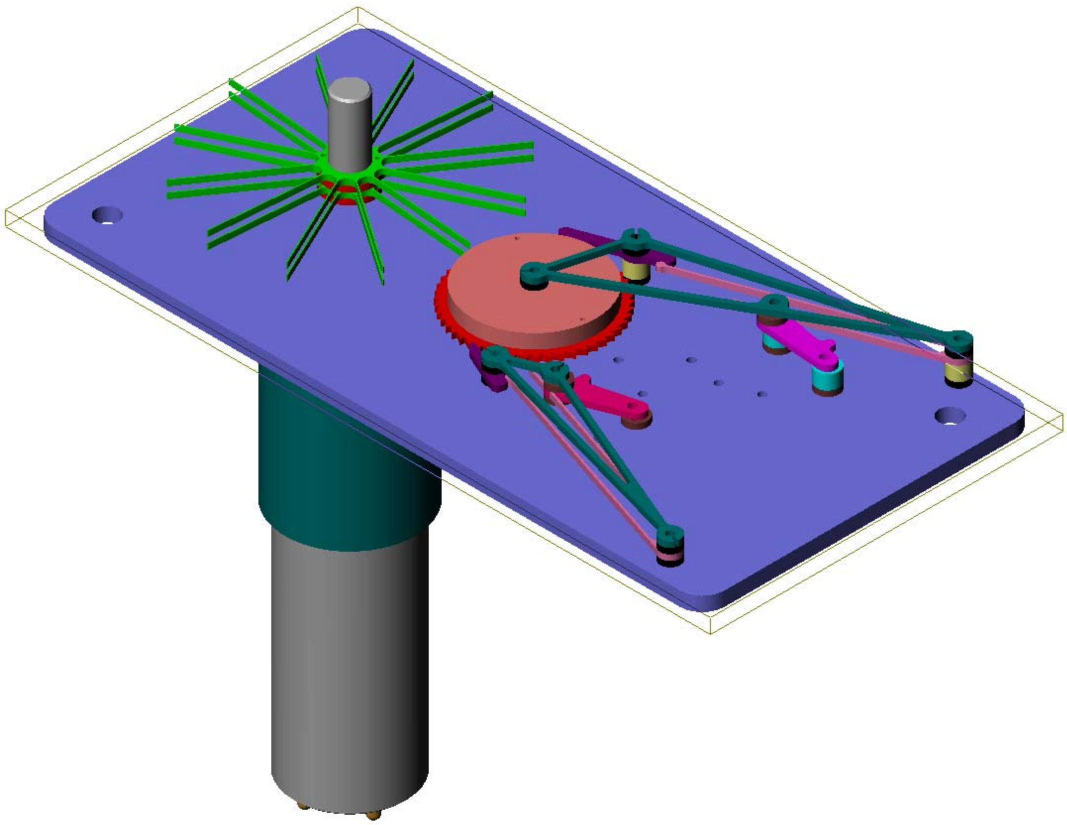

Figure 2. Tribology test vehicle. The purple pawl engaged on the left side of the ratchet gear is the part shown in the figures below.

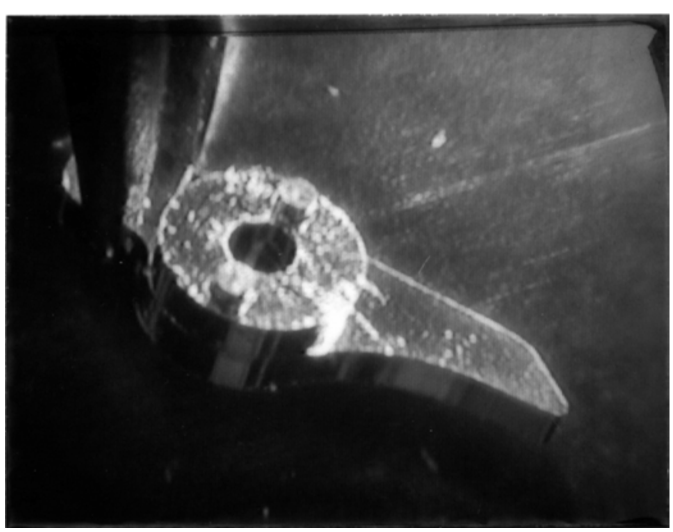

Figure 3. Pawl and washer assembled with two (170 micron) force-fit pins.

Figures 4 and 5 show a fixtured pawl. In the magnified photo in Figure 5, note the three contact points along the upper boundary of the pawl and a fourth contact point along the bottom. When the part contacts the upper three contact points, then the position and orientation of the pawl are uniquely determined relative to the fixture. If these contacts are maintained while the fixture is manipulated, then the pawl will be manipulated as well. This results in rotational orientation control as required for alignment at the press-fit holes in the pawl washer subassembly.

The position of the fourth contact and the stiffness and preload of the beam were designed to guarantee that the three upper contacts would be achieved even if the pawl was placed in the fixture NOT initially in contact with them. The details of this design can be found in references [1,2].

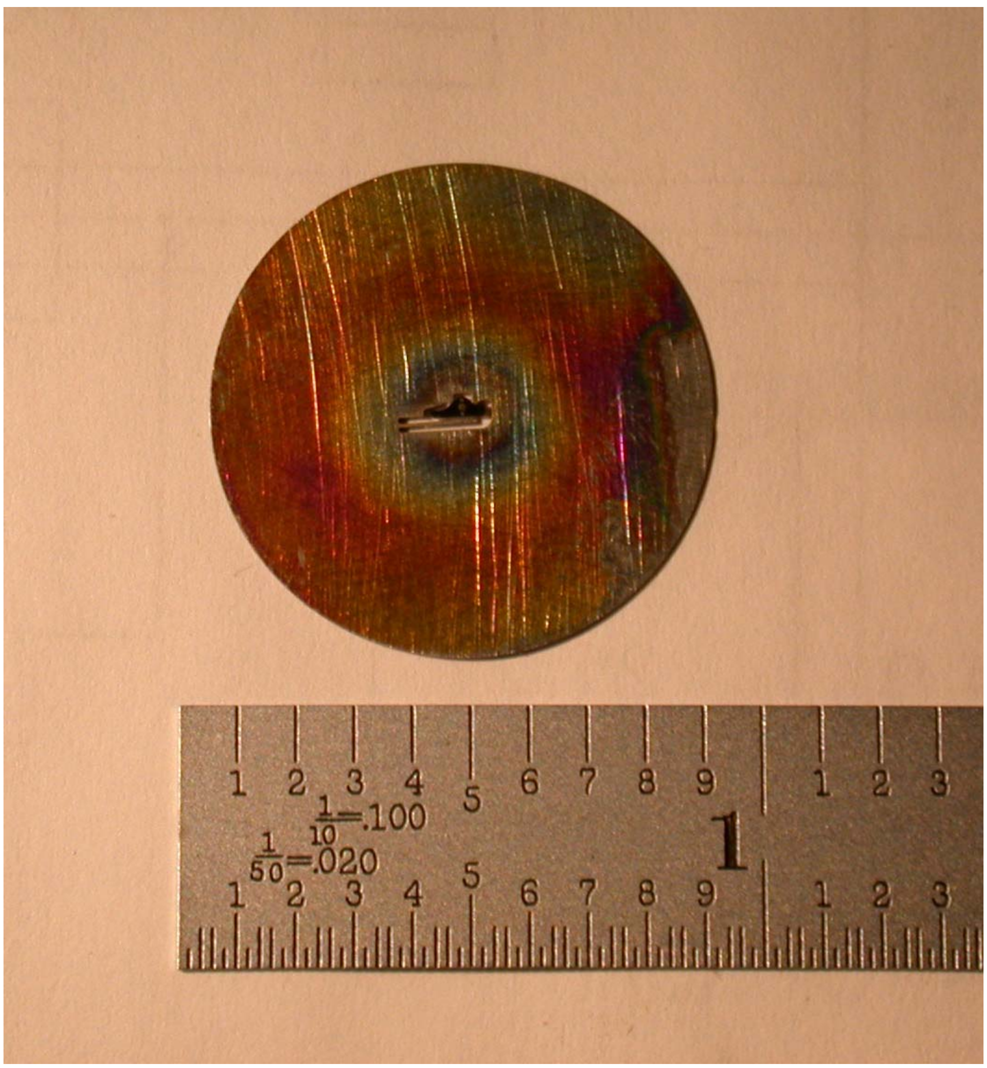

Figure 4. A pawl properly seated in a fixture.

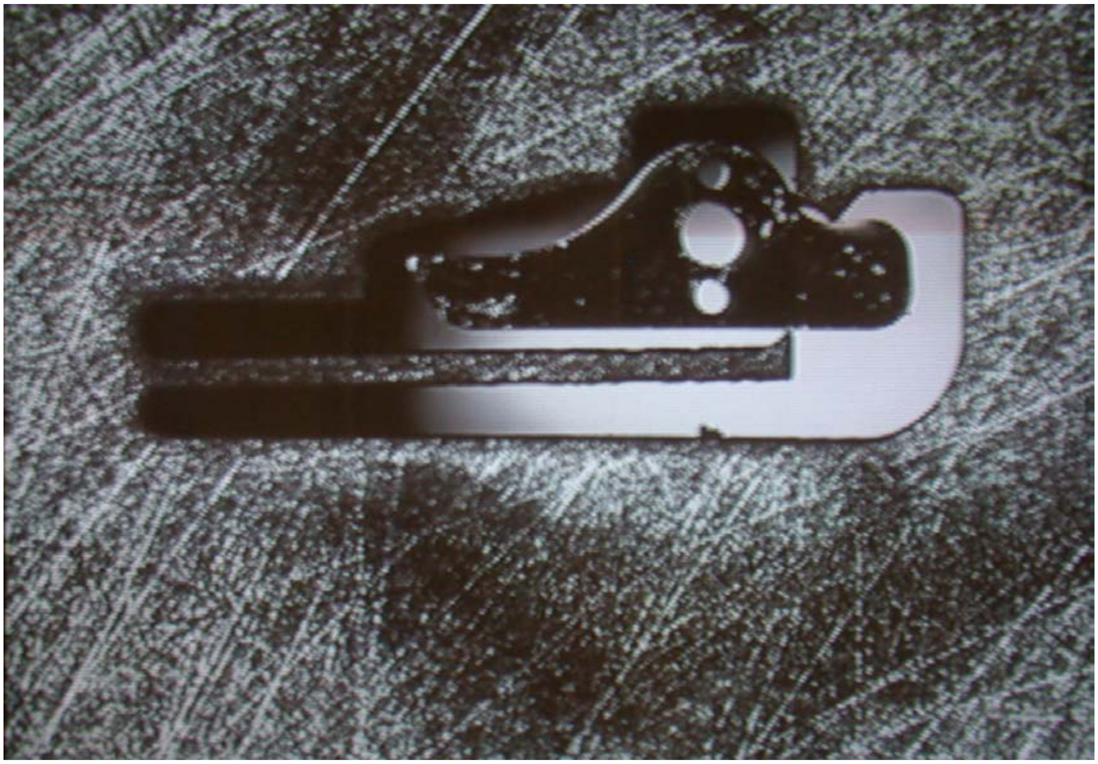

Figure 5. Magnification of the pawl in the fixture. Note that there are three points of contact along the upper boundary of the pawl and a fourth contact point on the bottom and at the end of a cantilever beam built into the fixture.

Conclusion

The research performed under this LDRD project considered difficult issues associated with the design of fixtures for the holding of parts with complex shapes. While there is much more that could be done, significant progress was made on both the theoretical and applied ends of the spectrum.

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