Process for Measuring Over-Center Distances

A more accurate approach enables mechanisms to be adjusted to within tight specifications.

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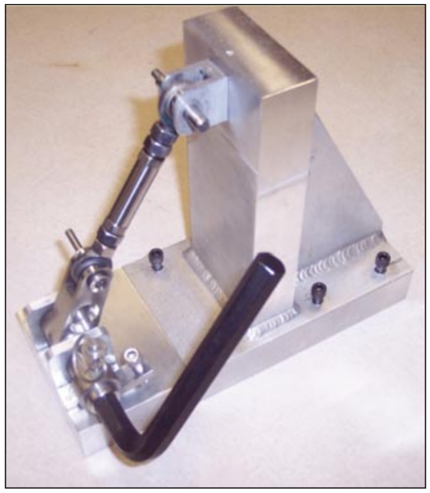
Over-center mechanisms were used in the orbiter payload bay to lock down the robotic arm during the launch of the space shuttle. These mechanisms were unlocked while in orbit in order to release the arm for use. Adjusting the mechanism such that it would not inadvertently release during launch, but could be released when needed by use of the motor, required accurate adjustments that were difficult to perform. A procedure was developed to allow these mechanisms to be adjusted to within the specifications required for the Space Shuttle Program. This approach is significantly more accurate than any other technique, and is the only technique known that met the launch requirements of the program.

Within the payload bay of the orbiters was a set of small over-center mechanisms that held the robotic arm in place. Each of these contained two straight segments connected with a pin. The upper end (called the drivelink) was connected via a second pin to a hook, whose purpose was to hold the robotic arm securely in place until it was needed on a mission. The lower end (called the bellcrank) was connected to a gearbox via another pin or axle. In practice, this mechanism was adjusted such that the over-center pin could be forced through the on-line position a known over-center distance where the residual strain in the two straight segments would lock it in place (the stowed position). The distance and the force required had to be adjusted such that this mechanism would not deploy during launch, but such that a motor could drive the pin back through the on-line position to release the robotic arm when needed.

The problem was that the over-center distance was required to be set at 0.026-in. (≈0.7 mm), which was difficult to measure to the required accuracy [±0.001 in. (≈±0.03 mm)]. Trying to find the on-line position, so that one could measure from it, was not possible because the mechanism would only stay in this position if frictional forces held it, and these forces were directional and not consistent between measurements.



In this model of the **Over-Center Mechanism**, a hex wrench is used in place of the motor, but the rest of the components were machined to match those in the field.

Some consideration was given to simply photographing the mechanism in its stowed position and measuring the distance between the center of the pin and a line connecting the centers of the outer two rotational pins, but this failed because the pin covers were not necessarily centered on the pin centers.

In order to understand the problem, a one-to-one scale model of the over-center mechanism was constructed (see figure). A hex wrench was used in place of the motor, but the rest of the components were machined to match those in the field. Several attempts at measuring the over-center position were attempted with this model, the first few of which failed. One of the advantages of having a model like this is that the dimensions of the parts were well known and the pins were all accessible, so the on-line position could be measured accurately using approaches not possible in the field.

A jig was constructed that used a depth gage to measure the distance to the over-center pin while resting on the top and bottom pin. The hex wrench was replaced with a calibrated torque wrench. Then, the drivelink (the upper half of the mechanism) was repositioned to make it difficult to push the device through the on-line position. Now, by applying a known torque, it was possible to measure a location to the center pin. Then, without changing the length of the drivelink, the top pin was disconnected, the mechanism was placed into the stowed position, the top-pin was reinserted, and the location of the center pin was measured while applying the opposite torque. In essence, this measured the location of the center pin while it was being pushed toward the on-line position from two different directions; the average of these two measurements was then the on-line position. Tests showed that this approach was accurate to ±0.002 in. (≈±0.05 mm) where at least ±0.001 in. (≈±0.03 mm) of error entered from the second measurement technique. Statistically, this new approach was accurate to ±0.001 in. (≈±0.03 mm). Making static measurements, combined with working in regions where the strain is strongly dependent on position, led to this enhancement in measurement accuracy and solved the problem.

Because the prior method used an LDT (linear displacement transducer) and strain gauges, most of the necessary structures were already in place in the field to allow the new measurement process to be transferred. The depth gauge would be replaced by the LDT and the torque wrench by a wrench and a strain gauge. But rigid mounting brackets and a target (or contact point) were needed for the LDT in order to allow an accurate position measurement.

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