Low Cost Flexure Alignment Features

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Introduction

The alignment of components is often done using pins and slots; however, pins in holes and slots require some clearance between the features which reduces accuracy and repeatability. Removing such clearances deems the design over-constrained. True preloaded kinematic constraint between the parts to be pinned together can be obtained by treating the pins themselves as components of the assembly, and then properly constraining the pins against appropriate rigid surfaces and then preloading them against those surfaces with flexural elements. This method is particularly useful for assembling plates containing flexures cut using an abrasive waterjet or by EDM.

Design

Two plates 100 mm x 100 mm x 12 mm were made with 0.375" dowel pin restraints in their corners. All features were made using an OMAX[1] model 2626 Abrasive Waterjet Machining Center which had an accuracy of 50 microns[1]. One constraint was a right triangle with the hypotenuse as a flexural element. The flexural element preloaded a dowel pin into the corner. On the opposite corner of the plate, a groove aligned to the right triangle also had one side made as a flexure to preload a dowel against the rigid side. This allowed both plates to be made using the same part program, canceling the need for secondary machining. Figure 1 highlights these features with a black dotted circle. Another design utilized the concept of elastic averaging. The constraints consisted of equilateral triangles with all three sides functioning as flexural elements. The two constraints were positioned on opposing corners of the plates. Figure 1 highlights the features with a white dotted circle.

[1] http://www.omax.com

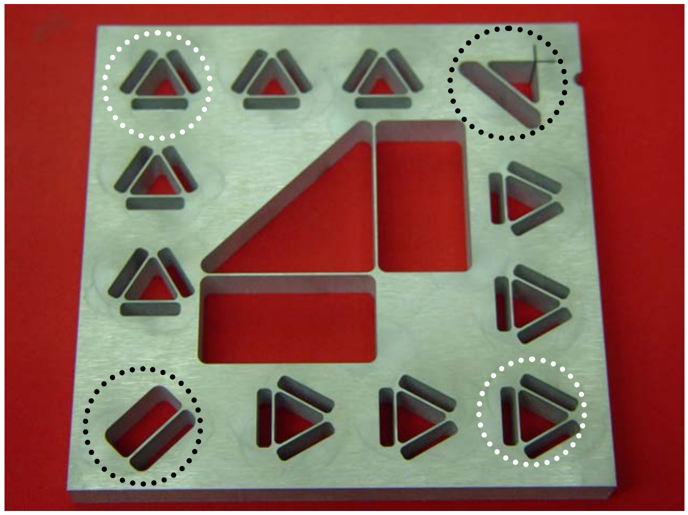


Figure 1: Machined plate with the alignment flexures

Experiment Setup:

The experimental setup used to measure the repeatability and the accuracy of the assembled plates had six mounting flexures designed to fixture capacitance probes with a uniform pressure on the probes' surface. 1/16" tapered pipe plugs where used to apply pressure to the clamping fixture. Figure 2 is a CAD model of the mounting flexures. The six probes were mounted in three pairs; probes of each pair were aligned vertically with an offset distance of 6mm between their centers. A three-pin kinematic coupling feature was added to the setup to easily mount and unmount the test plates to the same location. The coupling was created by press-fitting three (1/4") dowell pins. The setup was machined with the OMAX waterjet cutter; secondary machining was done on a Bridgeport® mill. The machined setup with the Capacitance probes mounted in place is shown in Figure 3.

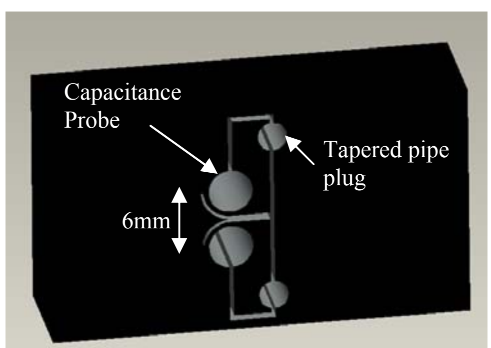


Figure 2: Solid model of the Cap-probe mounting flexures

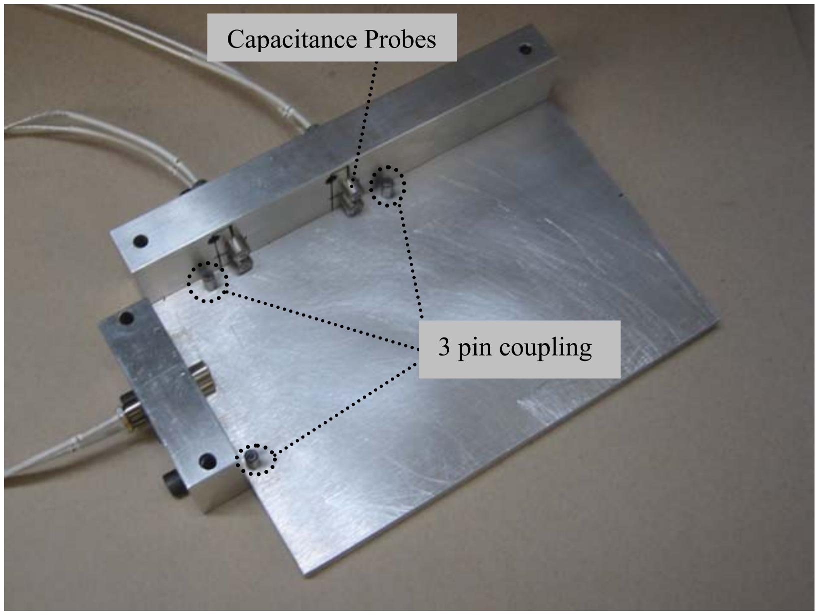


Figure 3: Experiment Setup

Experiment results

The accuracy of the experimental results were tested for via two sets of data. First the plates were placed on the experimental setup and left undisturbed. The drift in the probe readings over time was measured to be on the submicron level for all six probes. The submicron drift values are negligible and prove that the experiment readings are consistent and essentially independent of vibration, noise and temperature effects from the surrounding environment. Data from two of the probes are shown in Figure 4.

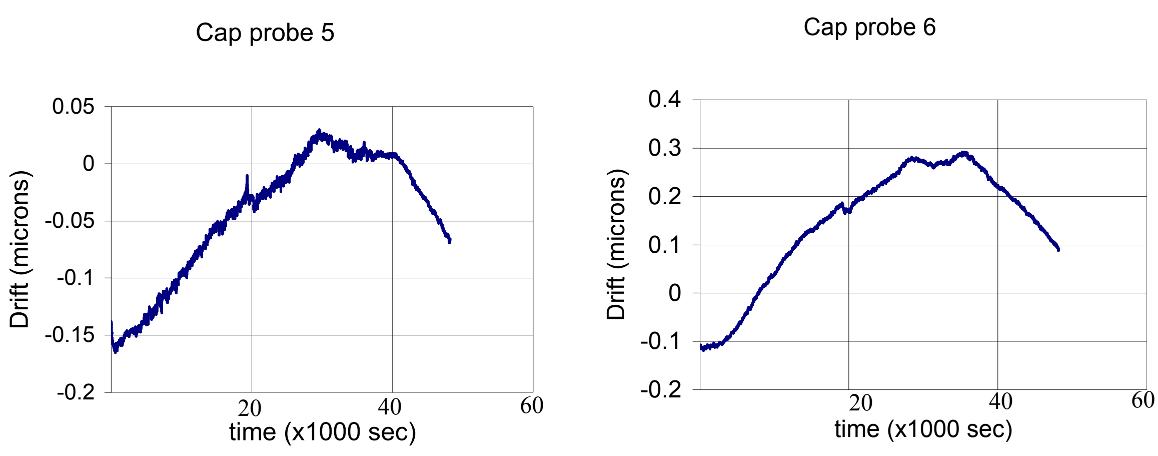


Figure 4: Cap probe drift readings

Test plates where removed and then reintroduced into the setup to measure the effects on repeatability of the measurements to repositioning of the plates relative to the probes. Charts shown in Figure 9 show the measurements of plate misalignment changing in a submicron range as well. The setup is repeatable and not sensitive to part or hand disturbances.

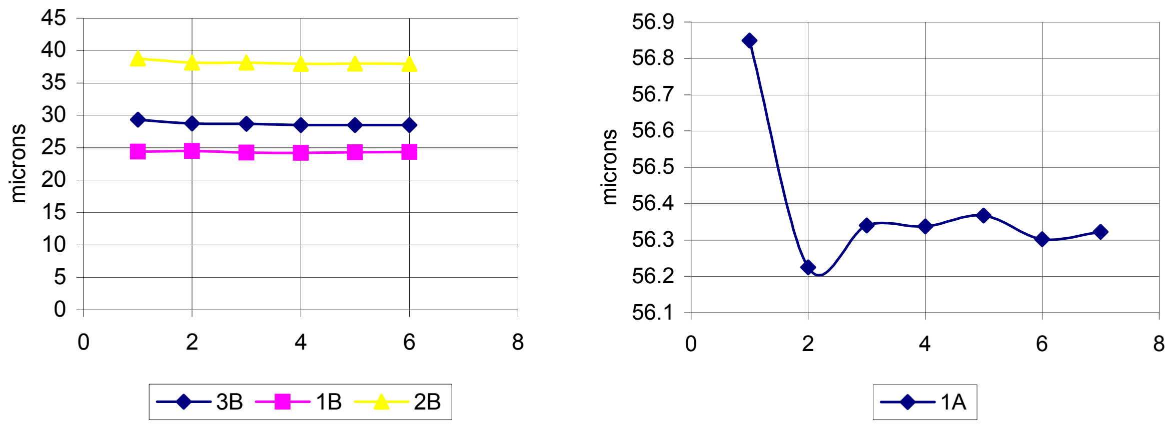
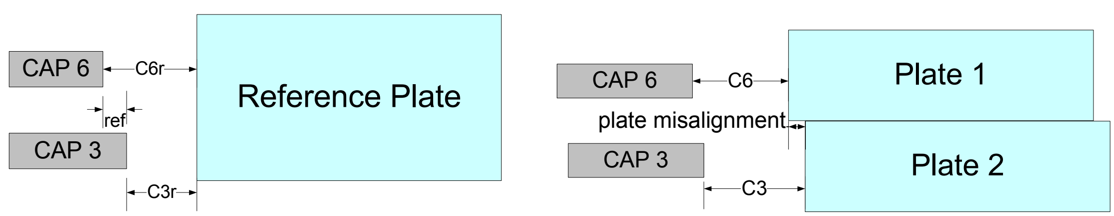


Figure 5: Charts of the results from removing and reintroducing the plate back into the setup at four points (3B, 1B, 2B and 1A)

To test the repeatability of the alignment flexures to disassembling and reassembling the plates, measurements for all six probes were performed several times in which the test plates were taken off the setup, decoupled from each other and then pinned back together again. Results were in the range of 1 to 25 microns, where the large values are likely due to friction and shear at the flexure features. To measure the plate alignment a reference surface was used to measure the offset distance between the capacitance probes on the setup. Afterwards the plate misalignment, δ, was calculated based on the simple formula as shown in Figure 6. The alignment of the plates was in the range of 30 to 60 microns. A CMM machine was used to scan the test plates and the misalignment due to the water jet cutter resolution was corrected for. The corrected alignment was 13 to 43 microns.



$$\delta = C_3 - C_6 + (C_{6r} - C_{3r})$$

Figure 6: Plate misalignment δ

Conclusion

An abrasive waterjet cut part can be 1/3-1/4 of the cost of a wire EDM cut flexure. Further cost reduction can be achieved and the taper created by a waterjet can be mitigated using the new alignment method. Thinner parts can be cut which saves cutting time and costs: cutting two 12 mm thick parts and then accurately aligning them reduces the total machining time by 40% as compared to machining a 24 mm thick part. Cutting thinner parts reduces the taper generated by the water jet, and the two plates can be assembled back-to-back. This reversal cancels the effect of the taper and places the shear center of the assembly at the center of the part. In addition to that damping materials can be sandwiched between the two plates. Future work will include studying the applicability of the features on plastics and sheet metal [4].

References

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