EDTN 202

Further Measurements on the Haas Super Mini Mill

S/N 40150, NRAO PO 207121

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1. Background

In earlier measurements, it was found that the uniformity of milled channel widths in the test pattern shown in Fig. 1 was well outside the ±0.0002" expected from the specified position accuracy and repeatability of the Haas machine, but only in the Y-direction. The distribution of channel widths in the Y-direction, measured by microscope, for the first test piece is shown in Fig. 2. These measurements are described in detail in the report on our earlier tests [1].

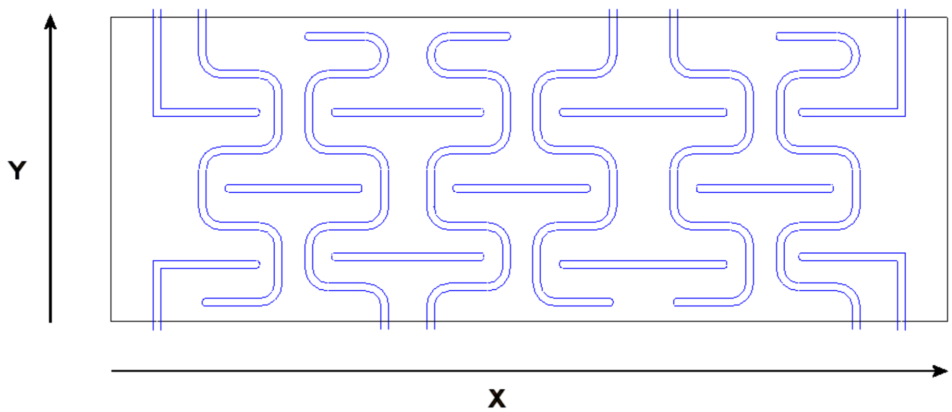

Fig. 1. Test pattern used in earlier measurements [1].

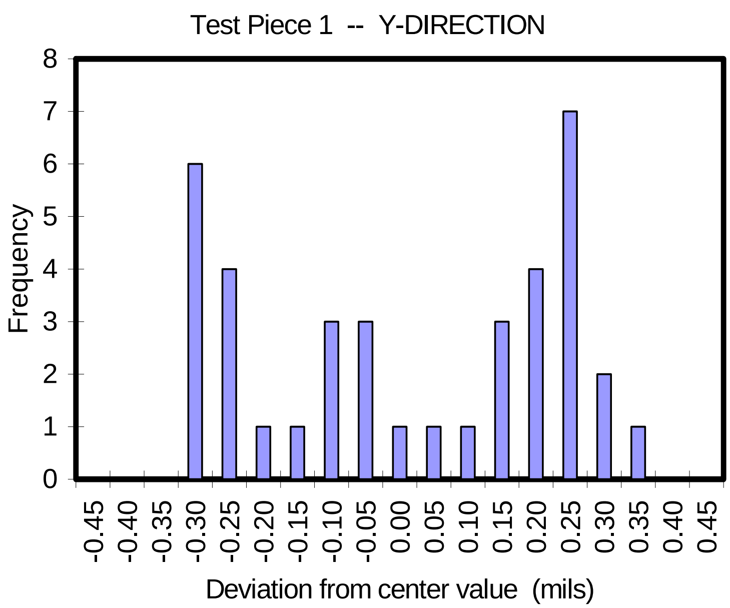

Fig. 2. Distribution of channel widths in original tests [1]. Measured by microscope.

2. New Measurements (10/5/2005)

The laser interferometer was set up to measure the Y-position of the table of the mill relative to the (fixed) spindle housing. The interferometer allows the table to be moved in the X-direction by ±0.075" without loss of measurement accuracy, so the mill was programmed to follow a series of meander paths as indicated in Fig. 3, where the X-motion of the tool in each channel is ±0.0595". The mill was stopped in the middle of each X-cut and its Y-position sent to a computer which also recorded the corresponding reading of the laser interferometer. The paths are similar to those in the earlier test pieces except for the reduced X-motion in each channel. The nominal channel widths are all 0.050", and a 0.031" end mill is assumed, operated in climb-cutting mode.

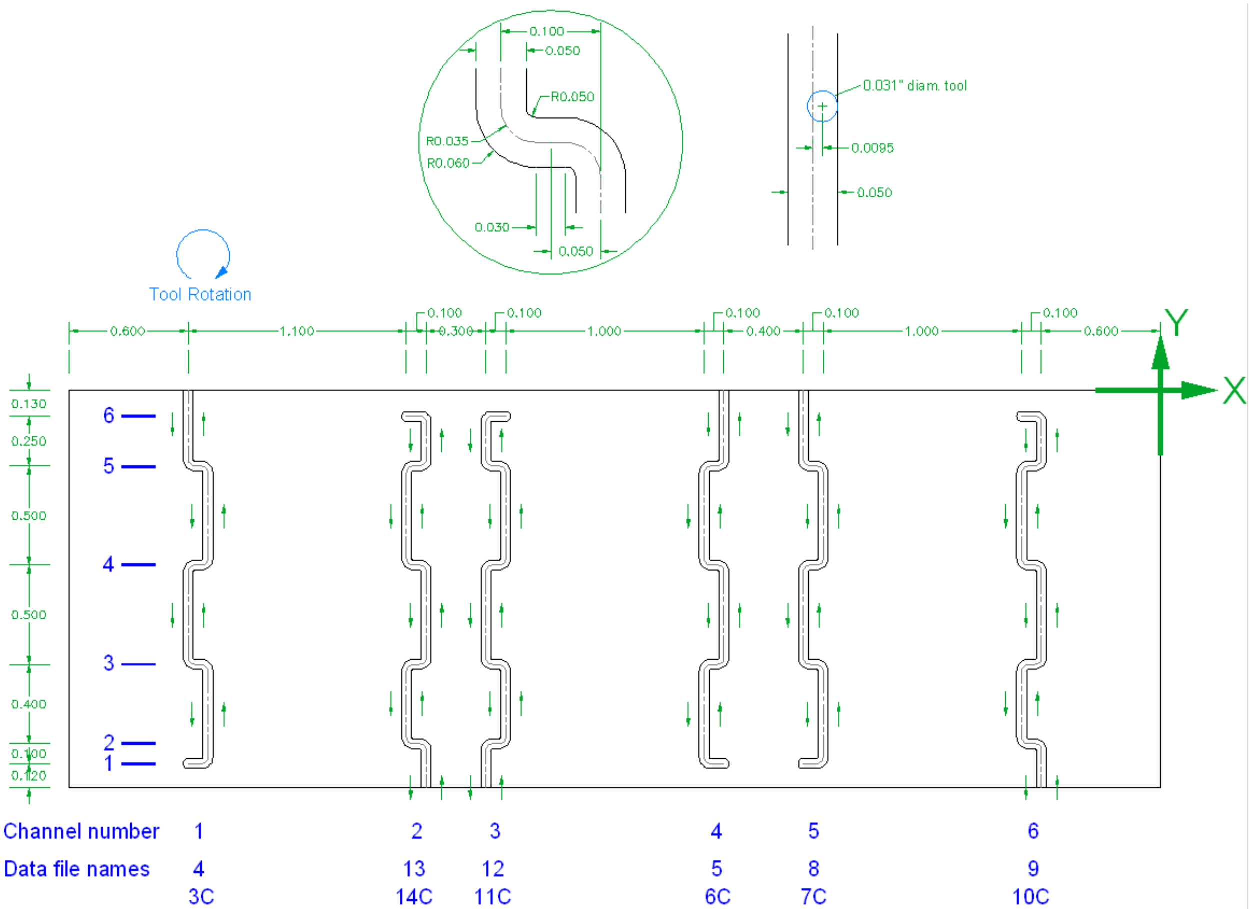

Fig. 3. Test paths used in the present measurements. The nominal channel widths are all 0.050", and a 0.031" end mill is assumed, operated in climb-cutting mode.

Fig. 4 shows the widths of the channels at each of the measurement points as deduced from the laser measurements of the machine motion. The range of channel widths and the double-peaked distribution are similar to the earlier measurements on cut metal test pieces (Fig. 2). Fig. 5 shows the same data as Fig. 4 but as a function of channel width error. In both Figs. 4 and 5, the Haas factory settings were used for the backlash (28) and friction (80) compensation parameters.

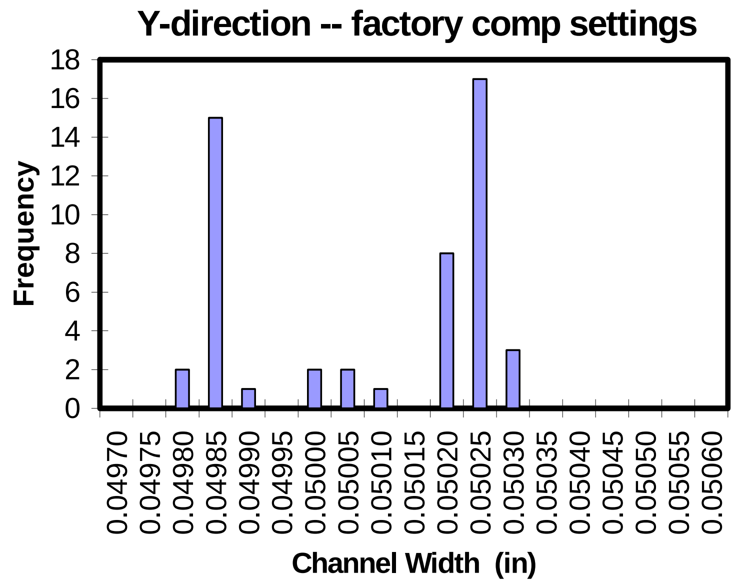

Fig. 4. Laser measurements of machine motions corresponding to channel widths in the Y-direction. (Backlash comp. 28, friction comp. 80.)

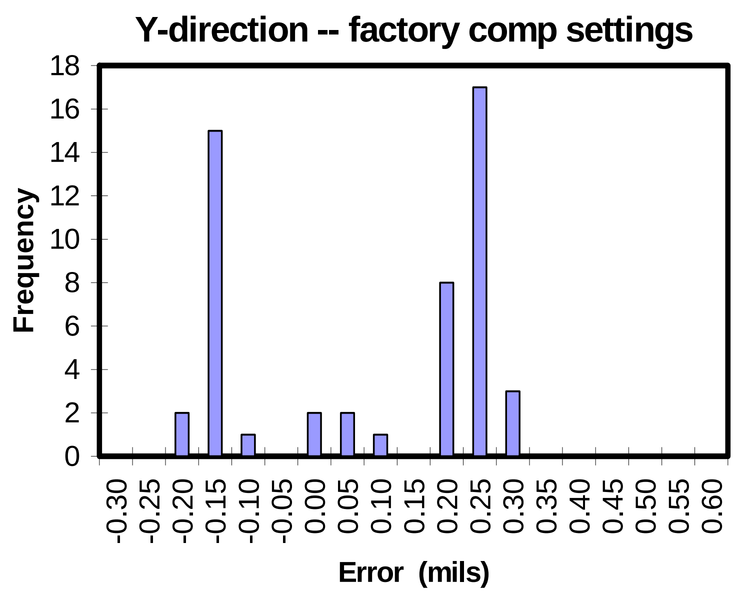

Fig. 5. Error in channel width in the Y-direction, deduced from the laser measurements in Fig. 4. Backlash comp. 28, friction comp. 80.

On the informal advice of the Jeffreys/Haas technician, Pat, the Y-axis backlash and friction compensation parameters had been adjusted earlier in an attempt to improve the Y-channel-width error. In the absence of the laser interferometer at that time, the optimization was done using a dial gauge. The result for the subsequent laser test is shown in Figs. 6 and 7 with the backlash and friction compensation set to 20 and 90 resp.

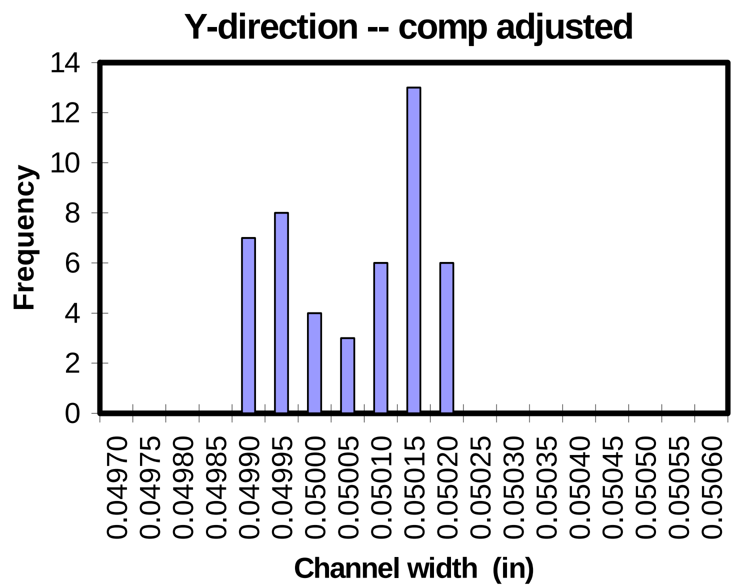

Fig. 6. Laser measurements of the channel width in the Y-direction. Backlash comp. 20, friction comp. 90.

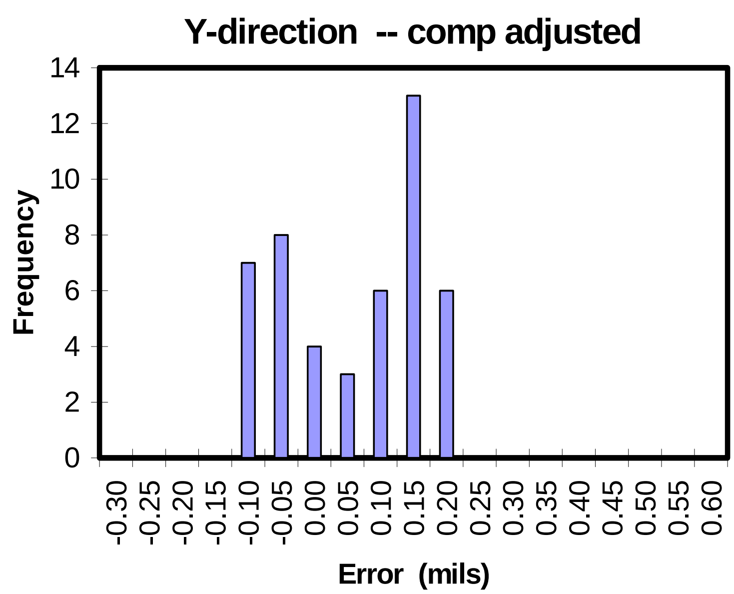

Fig. 7. Error in channel width in the Y-direction, deduced from the laser measurements in Fig. 6. Backlash comp. 20, friction comp. 90.

The distribution of Y-axis channel width errors across the surface of the test area is mapped in Fig. 8. Positive errors are indicated by yellow, negative by blue.

Y-axis errors – comp adjusted

-0.02				0.02	
	0.18	-0.11			
0.12	-0.12	0.16	-0.06	0.13	-0.14
-0.07	0.17	-0.07	0.13	-0.11	0.15
0.09	-0.04	0.10	-0.09	0.08	-0.08
	0.16	-0.01			0.13

Yellow = error > 0; blue = error < 0

Fig. 8. Map of channel width errors in the Y-direction, deduced from the laser measurements. Backlash comp. 20, friction comp. 90.

To measure the long range accuracy and repeatability in the Y-direction, the table position relative to the spindle was measured over its range of motion. This was done with the factory compensation settings (backlash 28, friction 80) and with the improved settings (backlash 20, friction 90). The results are shown in Figs. 9 and 10.

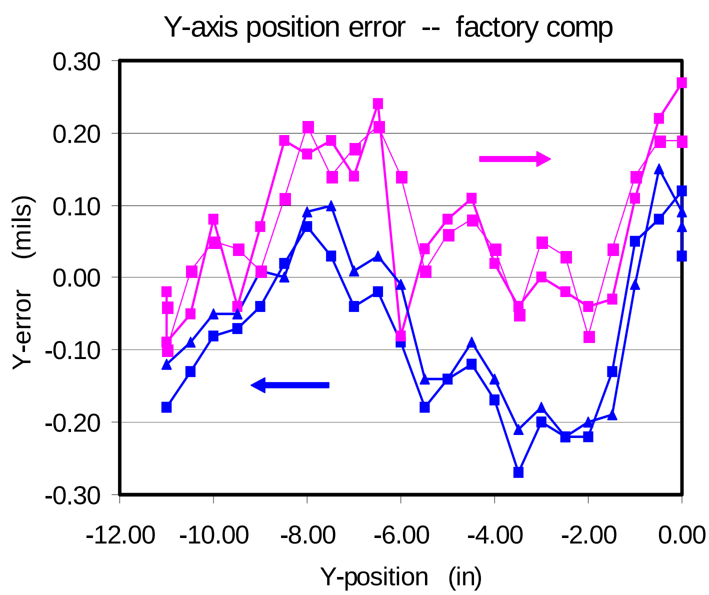

Fig. 9. Laser measurement of the Y-axis position error over two cycles. Factory compensation: backlash 28, friction 80.

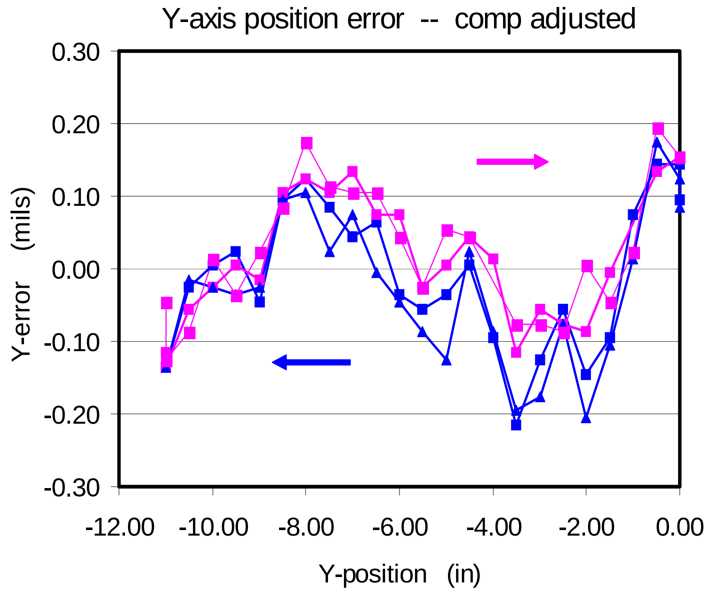

Fig. 10. Laser measurement of the Y-axis position error over two cycles. Adjusted compensation: backlash 20, friction 90.

3. Machined Test-Piece E

With the machine's Y-axis compensation parameters set to the newly optimized values, another test piece was machined to the original test pattern (Fig. 1). The channel widths in the Y-direction, measured by microscope, are shown in Figs. 11 and 12.

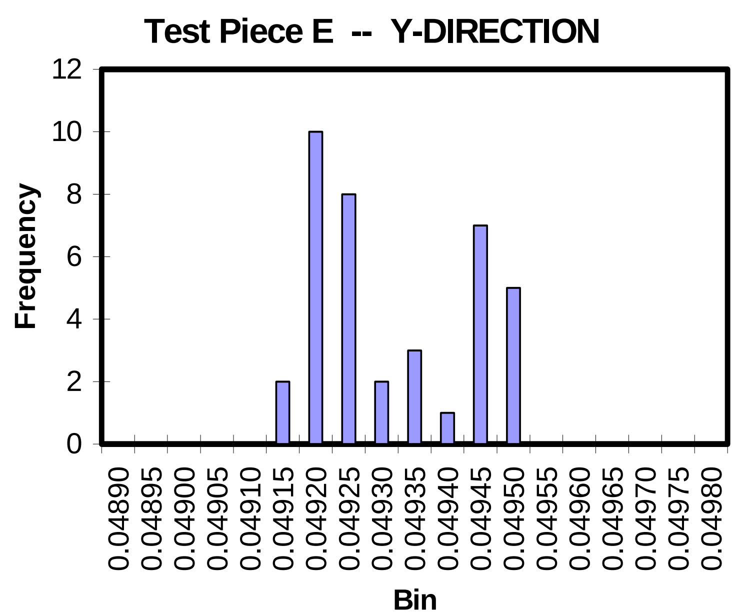

Fig. 11. Microscope measurements of the channel widths in the Y-direction for test piece E. Backlash comp. 20, friction comp. 90.

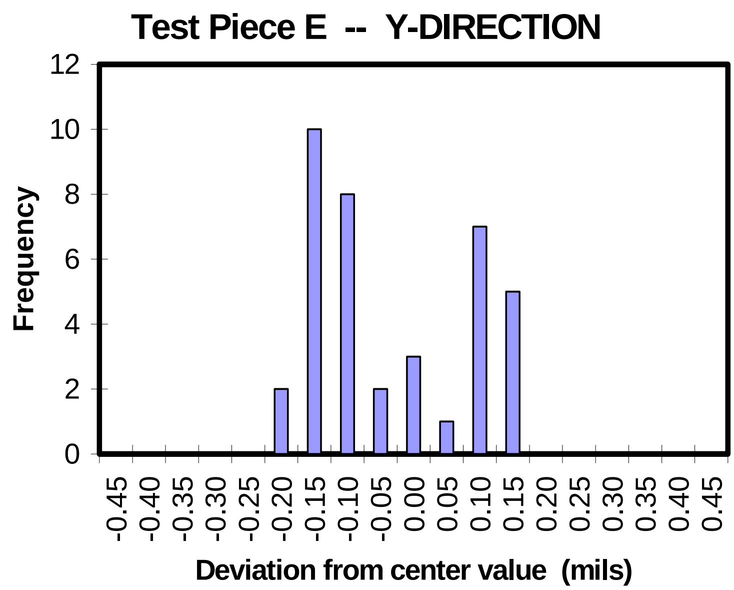

Fig. 12. Distribution of channel widths in the Y-direction, deduced from the above microscope measurements, for test piece E. Backlash comp. 20, friction comp. 90.

The distribution of Y-axis channel width errors across the surface of the test-piece is mapped in Fig. 13. Positive errors are indicated by yellow, negative by blue.

Test Piece E Y-axis Channel Width Deviation (mils)

			-0.07		0.03						-0.07	
	-0.07		-0.12		-0.12		-0.12		-0.12		-0.17	
0.18				0.18				0.18				0.03
	-0.12		0.18		-0.12		0.13		-0.12		0.13	
		0.18				0.13				0.08		
	-0.07		-0.07		-0.07		-0.12		-0.12		-0.17	
0.03				0.13				0.13				0.13
	-0.02		-0.07		-0.12		0.13		-0.02		-0.07	

Yellow = error > 0; blue = error <.

Fig. 13. Map of channel width errors in the Y-direction, measured by microscope on machined test piece E. Backlash comp. 20, friction comp. 90.

The channel widths in the X-direction, measured by microscope, are shown in Figs. 14 and 15. X-axis backlash and friction compensation were left at the manufacturer's factory settings: backlash 13, friction 100.

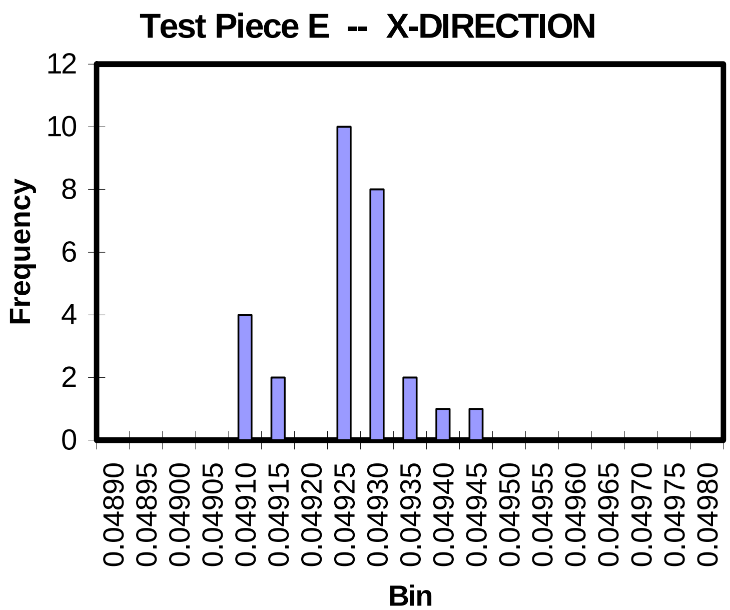

Fig. 14. Microscope measurements of the channel widths in the X-direction for test piece E. Backlash comp. 13, friction comp. 100.

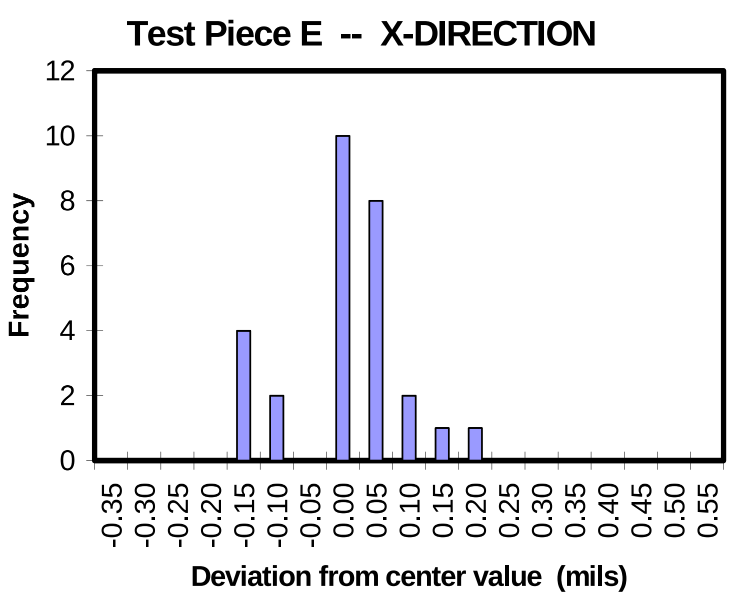

Fig. 15. Distribution of channel widths in the X-direction, deduced from the above microscope measurements, for test piece E. Backlash comp. 13, friction comp. 100.

The distribution of X-axis channel width errors across the surface of the test-piece is mapped in Fig. 16. Positive errors are indicated by yellow, negative by blue.

Test Piece E X-axis Channel Width Deviation (mils)

	0.09							0.04	-0.01					
0.04														0.19
		-0.11	0.04			0.04	0.04			-0.16	-0.01			
	-0.01			-0.01	-0.16			-0.11	-0.01			-0.01		
		-0.16	-0.01			-0.01	-0.01			-0.16	0.04			
0.14				-0.01	0.04								0.04	0.09

Yellow = error > 0; blue = error <.

Fig. 16. Map of channel width errors in the X-direction, measured by microscope on machined test piece E. Backlash comp. 13, friction comp. 100.

4. Summary and Discussion

Accuracy on Small Distance Scales:

Much of the intended work for the Haas milling machine is on millimeter wave circuits, in which the waveguide channels are typically 0.020"-0.100" wide. Thus our focus in this report is on channel width accuracy, which is a good indicator of dimensional accuracy on small distance scales.

Comparing Figs. 5 and 7, it is clear that our adjustments to the backlash and friction compensation have greatly improved the Y-axis channel width error. In both X- and Y-directions, the widths of our 0.050" test channels are now within the ± 0.0002" spec.

As the improved Y-axis backlash and friction compensation settings were determined (in the absence of the laser interferometer) using a dial gauge to measure the table position relative to the spindle, it seems likely that the accuracy in both X and Y directions might be further improved by adjusting the backlash and friction compensation while doing laser interferometer measurements.

Accuracy Over Large Distance Scales:

In the report on our earlier laser measurements [1], there was a large, almost linear, position error in the X-direction, ± 0.0009" over a distance of 14" ([1], Fig. 16), which is well outside the specifications of the machine. This could easily be corrected using the internal correction table in the machine which allows corrections to be specified every half inch.

In the Y-direction, with the adjusted compensation settings, repeatability was never worse than ± 0.0001", regardless direction of approach − see Fig. 10. The Y-position error was within ± 0.0002" and had an almost sinusoidal variation over the 11" range of motion, as seen in Fig. 10. This would be easy to improve using the machine's internal correction table.

5. Reference

[1] A. R. Kerr, A. Marshall, M. Meek, D. Parker, J. Shelton, "Initial Evaluation of Haas Super Mini Mill S/N 40150, Rev. 2a," NRAO Electronics Division Technical Note 202, 28 Sep 2005.