



AXES OF ACCURACY

High tolerance machined parts: Northrop Grumman is encouraging the use of VCS to achieve high tolerance machined parts for the F-35 Joint Strike Fighter

Although it's still true to say that you can't make a silk purse out of a pig's ear, Dr Neil Calder discovers it's now at least possible to make a good CNC machine tool significantly more accurate.

Nothing in life is ever quite what it seems, and similarly no machine tool axis is ever perfectly straight or aligned. Once you add in the effects of rotational axes in 5-axis systems, and the long cantilevered axes found in larger machine tools, then inaccuracies at the tool centre point really do start to build up. In the more craft intensive precision machining industry of previous times, the black art of an operator's knowledge of a particular machine's sweet spots could achieve increases in accuracy beyond the machine's nominal. Now there is an electronic sixth sense that enables this.

Siemens has a solution to enable optimised machine tool accuracies in its Volumetric Compensation System, or VCS. Siemens cites 21 independent inaccuracies that are summed geometrically at the tool holder: six error types for each of the three linear axes (Cartesian positioning and orientation)

plus three angular errors from rotary axes. In larger machines, the volumetric error caused by an unfavourable constellation of the axis positions can reach several hundred microns.

The Sinumerik 840D control, which for some years has been one of the mainstays of the high precision machining sector and something of an unofficial industry standard for 5-axis systems, can now provide realtime internal compensation for geometric and feedback errors. The 'internal' bit is important here as the algorithms for compensating for deviations in drive and encoder positions from their nominal values are achieved within the controller rather than externally as in many other systems which interrupt the drive system to achieve compensation accuracy. The system, incorporating innovative Sinamics S120 drives, has been designed to have an architecture which is distributed, scalable, open

and interconnected. The 840D sl (solution line) VCS corrects the position, movement and orientation vector at the tool centre point, resulting in a substantial improvement in volumetric accuracies for 5-axis machines with fork head kinematics. Absolute accuracies of between $\pm 50 - 75\mu\text{m}$ have been demonstrated in practice over long machine tool beds of some tens of metres.

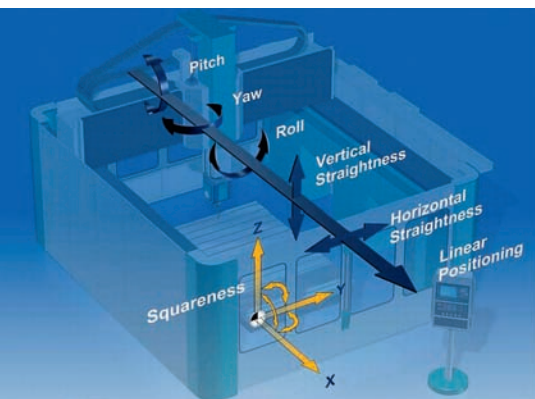
A blueprint for precision

The work here has significance for the entire F-35 Joint Strike Fighter programme supply chain as it is being taken as the technical standard for achieving required tolerances on machined components. This technology has been selected for use by Northrop Grumman to achieve high tolerance machined parts and has been the outcome of collaboration with Siemens stretching back to 2002 with a CNC technology symposium in Fort Worth,

attended by Lockheed Martin, Northrop Grumman and BAE Systems. This collaboration has involved development of the Siemens Sinumerik 840D controller to include the capability to compensate for measurable machine tool axis inaccuracies in all five axes simultaneously. Northrop Grumman Corporation Aerospace Systems is now strongly and unequivocally encouraging its supply chain to explore the use of Siemens' Sinumerik 840D sl CNC and its VCS to achieve high tolerance machined parts for the F-35 Joint Strike Fighter programme. The technical requirements from Northrop Grumman have been listed as robust machine tool design, repeatability, machine tool responsiveness, environmental temperature stability, and stable machine tool foundations.

Volumetric errors can be initially determined using state-of-the-art laser measuring equipment. The VCS has been configured to interact seamlessly and automatically with many popular systems by equipment suppliers like Renishaw, Automated Precision and Etalon to dramatically reduce the time and cost of using these systems to map a machine tool's working space in all its various dimensions. To perform the task of mapping data points and creating a high fidelity set of compensation data manually would in most cases not be viable as it is so resource intensive.

A case study of the effectiveness of



Finding the sweet spot: Numerous rotational and Cartesian errors build up at the tool centre point



Measuring geometrical accuracy: VCS in practical use on a 5-axis Breton Flymill 1000

the VCS technology was carried out by Siemens in conjunction with Italian machine tool manufacturer Breton. In this trial, a Breton Flymill – was calibrated using Renishaw XL-80 laser interferometry equipment, with optics for measuring position, rotation and translation. Without the integration of measuring equipment, machine shops were only able to identify errors and did not have the possibility of being able to directly make improvements. Users with the new VCS as part of their machine control capability can now directly use the error curves that they have measured for use in volumetric compensation. In cooperation with Siemens, Renishaw developed an automatic converter for this purpose. This simply and reliably converts the data recorded using the XL-80 into the VCS data format.

A significant improvement during this trial was indicated by the Renishaw circularity test, which uses a number of axes moving together to provide an easily verifiable toolpath. This was carried out in all three planes in space. In the YZ plane, the rectangularity error was reduced from 8.6µm/m to 0.1µm/m and circularity deviation was improved from 24µm down to 18µm.

Good shopfloor housekeeping always

plays a part here too, and there is no way of achieving very high repeatability without taking into account external factors such as thermal stability of the shopfloor environment. Coast Composites in Irvine, California, has made something of a science of this technique in high accuracy machining of Invar composite mould tools, not necessarily controlling the shopfloor temperature, but in understanding how this affects the dimensions of machine tool beds and axes. Part of the Hampson Industries group of companies, Coast Composites has devised its temperature compensation system to overcome these variables in ambient factory conditions whilst still maintaining an accuracy that often exceeds the customer specification in a range of typical materials.

It has proved that it is possible to effectively retrofit the VCS enabled controller to its older machine tools, with specific experience in using this for Henri Liné, Nicolas Correa, SNK and Amura machines. Coast also reports a changing philosophy on the shopfloor of turning every machine tool into its own coordinate measuring machine. Laser trackers are now only used for final checking of machined parts. |

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