M & M Precision, Penn State & NIST Team Up For Gear Metrology Research

In 1993, M & M Precision Systems was awarded a three-year, partial grant from the Advanced Technology Program of the Department of Commerce's National Institute of Standards and Technology (NIST). Working with Pennsylvania State University, M&M embarked on a technology development project to advance gear measurement capabilities to levels of accuracy never before achieved.

Responding to industry concerns about the measurement uncertainties associated with gear manufacturing process control and the competitive position of U.S. gear manufacturers worldwide, M & M contributed over $1 million of its own funds to significantly improve gear measurement accuracies and provide a proven methodology for verifying these accuracies.

Project Goals

The goals of the project included:

• Develop and implement a rational methodology for analytically representing all points on the running surfaces of all teeth on a generic gear, necessary information for transmission error prediction, analysis of heat treat distortion, etc.;

• Model the accuracy of generative gear measurement machines as a function of accuracy of the components of the system;

• Determine the accuracy of state-of-the-art generative gear measurement machines by use of the above model and comprehensive gear measurements;

• Enhance measurement machine and controls architecture and sensor hardware and software technologies to achieve submicron level accuracies in gear measurements;

• Develop statistical methods using measurement redundancies and replications to enhance measurement accuracies and to estimate measurement uncertainties;

• Develop computation algorithms and software to compensate for systematic machine-component errors and minimize final measurement inaccuracies;

• Develop procedures and artifacts adequate to verify submicron level accuracies in precision gear measurement;

• Verify the achieved level of gear measurement accuracy by implementing the above developments into an enhanced generative gear measurement machine.

Progress

A number of developments in hardware and software were necessary to achieve these goals.

Environmental Chamber. An environmental chamber was installed in the first year of the project. This room has been certified traceable to NIST to control temperature within .1°F and humidity under 45%. It has been used both to determine current day gear measurement machine accuracies and to provide the necessary environment to achieve project goals.

Enhanced Accuracy for Linear and Rotary Axes. M & M and Penn State worked together to develop models to characterize the systematic machine and component errors throughout the entire system. Software to enhance probe locations in the light of these errors (slide path, yaw, and distance errors) were integrated into the M & M 9000 gear measurement program. Rotary axis errors were derived from a set of index measurements on a set of master gears. Software separated the gear index errors used in the measurements from the rotary axis errors. The M&M 9000 can calibrate index errors on a master gear to better than 15 microinches of measurement uncertainty.

Laser Linear Measuring System. A laser linear measuring system was also developed. This system was evaluated by the Mid-Scale & Complex Form Metrology Group at NIST and shown to achieve a .2 micrometer (2 sigma) uncertainty for 800 mm displacement.

Gear Artifacts. To evaluate the enhanced measuring system with the lowest measurement uncertainties possible for profile, index and tooth alignment (lead), artifacts were designed and calibrated. NIST and the Oakridge Metrology Center Y-12 Plant measured a pin master, a 1" sphere master (under 2 microinch form errors), a lead master and an involute master. Procedures are currently being documented along with mathematical estimates of the final measurement uncertainties for all artifacts.

M&M HAS CONTRIBUTED OVER $1 MILLION TO THE GEAR METROLOGY RESEARCH PROJECT.

Final results of the research are currently being documented for NIST. Integration of this new technology into available products is underway at M & M. ○

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