CAD/CAM Integration of On-The-Machine Measuring and Inspection System for Free-Form Surfaces

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Abstract: Measurement and inspection of freeform surfaces are required in reverse engineering processes. In the conventional quality control system, a sculpured surface, after being machined in a CAD/CAM system, is moved to a coordinate measuring machine (CMM) for checking its surface accuracy. It needs a great deal of time and investment cost for transportation of the object, special jigs and fixtures, and programming of the CMM. The objective of this research is to minimize the time concerning job and capital investment by developing a compensation measurement and error compensation system usable on the machining center itself, which is called on-the-machine measuring and inspection system. In order to build an automatic quality assurance process linked with precision FMS or CIM systems, information sharing between manufacturing processes has to be studied. In this paper, an on-the-machine measuring and inspection system with error compensation capability is interfaced with a CAD/CAM system through the neutral data format, IGES (Initial Graphics Exchange Specification). The IGES translator is designed for feature-based freeform surfaces represented by NURBS (Non-Uniform Rational B-Spline) surfaces. Measuring codes are obtained through the proper coordinate transformation and the uniform sampling software linked with the IGES translator. The normal vector estimation to compensate for probing error is also proposed via surface modeling. Usefulness and reliability of the developed system is verified by on-the-machine experiments.

Keywords: CAD/CAM interface, error compensation, IGES, machine tool errors, NURBS surface, on-the-machine, probing errors, reverse engineering

1. Introduction
CMMs are highly applicable to those parts normally produced by CNC machining centers and flexible manufacturing systems for prismatic parts. In recent years, CMMs have become critical equipment for quality control in modern manufacturing processes and industries, and play increasingly important roles as measuring stations for precise and complicated workplace shapes such as free-form surfaces. However, in order to relieve bottlenecks of inspection processes on CMMs due to measuring time, difficulty of capital investment and time delay of material flow between CMMs and machine tools in the factory, on-the-machine measuring methodology are required.[1,4]

After developing touch trigger probes, probing on-the-machine has found a broad range of applications on machine tools where it is vital to automated production processes. Probing allows manufacturers in many industries to deliver precise components, minimize scrap, and maximize productivity. Many branches of the industry, particularly the Automotive, aerospace, ship-building, the appliance, and the mold and die making facilities are involved in the manufacturing of components comprising free-form surfaces. These surfaces are designed according to aesthetic and functional requirements through CAD/CAM systems or reverse engineering processes.[5-6] In order to satisfy design specifications of the surfaces, measurement and inspection of free-form surfaces are required on some of strategic points during the production processes.[1,2,4]

In this paper, an on-the-machine measuring and inspection system equipped with a touch trigger probe is studied for free-form surfaces. Using probes on machine tools for process-interrulent and post-process measurements is complex procedures that require careful thought. Because machine tools and probing processes are fraught with error sources, many of which are intrinsic to the probing system themselves. Algorithms for calibration and compensation of measuring errors have to be proposed. To make a rapid measuring system and to build precision FMS systems, an automatic quality assurance process has to be integrated with the production process.[1,5,6] But that has not been active due to the difficulty of information sharing in manufacturing processes. In this paper, the measurement system is also interfaced with a CAD/CAM system through the IGES translator. It is designed for feature-based free-form surfaces represented by NURBS surfaces and is studied to automate measuring code generation according to the coordinate transformation.

The procedure of error analysis first starts with reading through pre-processed point-data of a CAD file. After measuring point-data of a machined surface by means of the on-the-machine system, a NURBS surface can be constructed on the basis of the acquired point-data. By comparing examined points between the CAD and the interpolated data, error analysis of free-form surfaces can be done. The usefulness and reliability of the developed system is confirmed through on-the-machine experiments.

2. Compensation of Measuring Errors
In case of surface measurements using a touch probe on a machine tool, geometric errors of the machine tool, probing and fixing errors of a probe assembly and the probe radius affect the measuring accuracy.[1-4] To ensure measuring accuracy of the on-the-machine measuring system, calibration and compensation methods of measuring errors have been proposed by