A Survey of the Automation Intelligence of Machine Tools in Taiwan

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Abstract: Due to global competition, Taiwan's single-machine tool factories are expected to research, develop, and manufacture high/intermediate-level machine tools, such as micro machine tools and intelligent machine tools. With stronger automation ability, greater processing efficiency, and improved processing quality, intelligent machine tools also integrate artificial intelligence to achieve the goal of unmanned processing. Their main functions include: automatic planning of a processing program, route, and conditions; detection and monitoring of tool status during processing; solution determination; and self-learning. Advanced machine tools are capable of accumulating experience in processing to improve successful processing capacity, as well as on-line measurement and detection in real time, so as to ensure uniformity of product quality. This study aims to investigate major machine tool manufacturers in Taiwan, and their requirements for automation technology in single-machine tools.

Keywords: Machine tool; automation intelligence; analytic hierarchy process

Introduction

Due to the impact of two energy crises at the end of the 1970s, the Taiwanese government gradually realized that the mechanical industry — displaying high energy efficiency, high added value, high technological intensity, and so forth — had wide market development potential, in line with the development conditions of Taiwanese industry. The Taiwanese government officially listed the mechanical industry as a *strategic industry* during the period 1982–1991. The government actively organized guidance work, set up the *Mechanical Industry Research Group*, assisted manufacturers with the establishment of management systems, and formulated the *Mechanical Industry Guidance Method*, so as to guide the mechanical industry with a view to realizing its great potential.

Over the ten years, from 1991 to 2000, the annual average growth rate of Taiwan's mechanical industry output was 7.0%; in this period, the growth was steady. At the same time, during Chinese economic reform, Taiwan's manufacturing systems entered the market of southern mainland China through Hong Kong and Macao. As China's integration into the global economy continued, Taiwan's mechanical exports switched from the American market to the mainland Chinese market. Machinery and equipment for manufacturing were the main exports. Globally, Taiwan became an important production and export country for industrial mechanical and automation equipment, while mainland China became the biggest export market for Taiwan's machinery.

Since 2001, the annual average growth rate of Taiwan's mechanical industry output has been 7.6%. Taiwan's mechanical industry is becoming increasingly mature and ready to enter the international market.

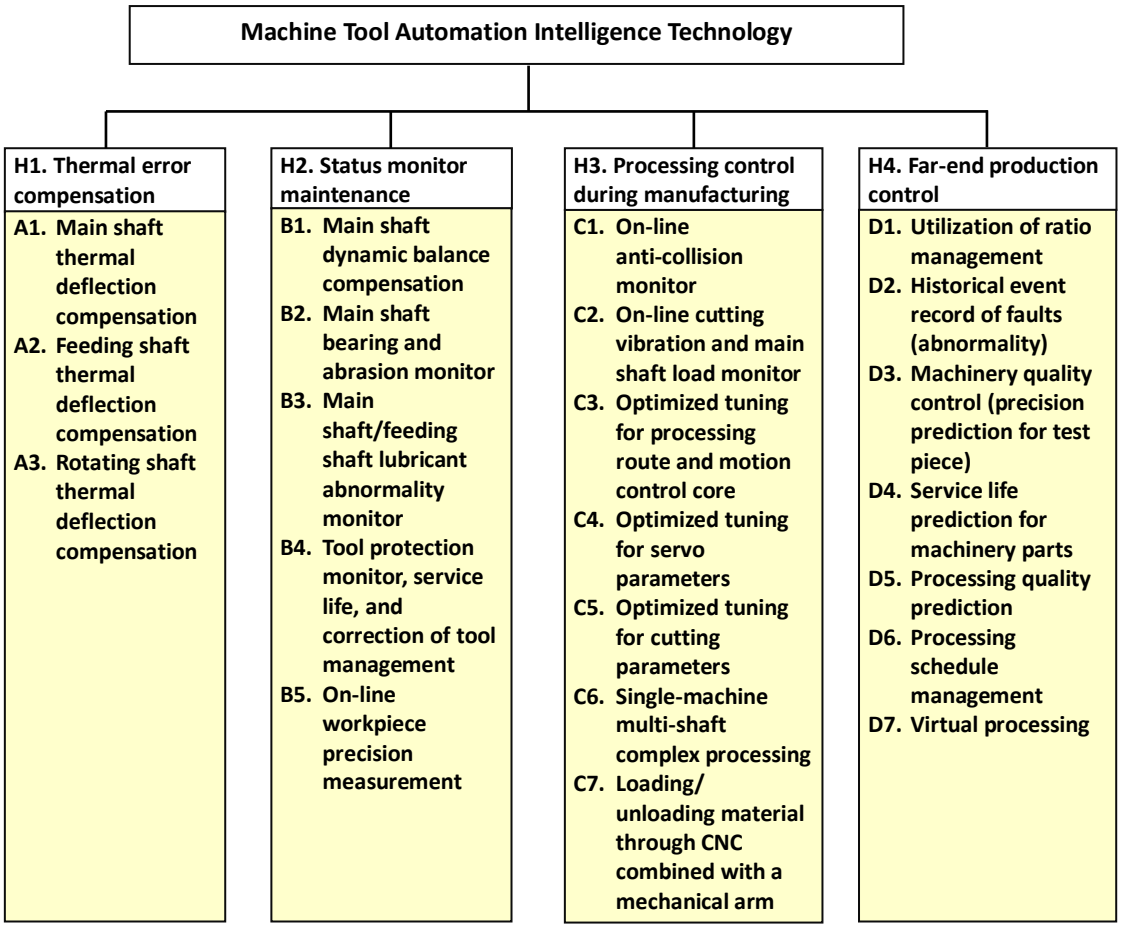

Figure 1. Categorized list of machine tool technologies.

Seesaw battles with international competition are certain to come. On the other hand, global economic activity is gradually moving towards the Asian region — especially mainland China — reinforced by the attraction of mainland China's high-speed economic growth. Meanwhile, under the impact of the global financial crisis and energy restraints of environmental protection laws, Taiwan's mechanical industry must face the urgent pressures of industrial transformation and upgrade, in addition to the pressure of increasing global competition. The automation of equipment is an important part of upgrading mechanical technology. For machine tools with maximal output and increased added value, future development will be towards machine intelligence. Therefore, this study aims to investigate the requirements of single-machine automation technology according to Taiwan's machine tool manufacturers.

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Machine tool automation intelligence technology

This study analyzes the requirements of Taiwan's manufacturers for automation technology for single-machine tools using the analytic hierarchy process (AHP). After gathering relevant information and conducting multiple discussions with professionals from the Industrial Technology Research Institute of Taiwan and Victor Taichung Machinery Works Co., Ltd., we formulated a questionnaire for machine tool automation intelligence experts. The related technologies are listed and categorized in Figure 1.

Results from AHP analysis

We issued questionnaires to experts at five manufacturers, and recovered all five questionnaires for a recovery rate of 100%. The results are as follows, with consistency less than 1 by the AHP analysis:

1. Relative importance of machine tool automation processing:

H3. Processing control scores the highest (31.74%); H1. Thermal error compensation rates second (29.01%); H2. Status monitor maintenance rates third (25.03%); and H4. Far-end production control is the lowest (14.22%).

2. Processing control:

C5. Optimized tuning for cutting parameters (6.49%) > C4. Optimized tuning for servo parameters (6.20%) > C1. On-line anti-collision monitor (4.99%) > C2. On-line cutting vibration and main shaft load monitor (4.66%) > C7. Loading/unloading material through CNC combined with a mechanical arm (4.12%) > C3. Optimized tuning for processing route and motion control core (3.63%) > C6. Single-machine multi-shaft complex processing (1.84%).

3. Thermal error compensation:

A1. Main shaft thermal deflection compensation (17.91%) > A3. Rotating shaft thermal deflection compensation (5.73%) > A2. Feeding shaft thermal deflection compensation (5.38%).

4. Status monitor maintenance:

B4. Tool protection monitor, service life, and correction of tool management (8.80%) > B5. On-line workpiece precision measurement (5.79%) > B3. Main shaft/feeding shaft lubricant abnormality monitor (4.53%) > B1. Main shaft dynamic balance compensation (4.44%) > B2. Main shaft bearing and abrasion monitor (1.46%).

5. Far-end production control:

D1. Utilization rate management (2.52%) > D5. Processing quality prediction (2.47%) > D6. Processing schedule management (2.08%) > D4. Service life prediction for machine parts (2.03%) > D3. Machine quality control (precision prediction for test piece) (1.93%) > D2. Historical event record of faults (abnormality) (1.69%) > D7. Virtual processing (1.48%).

Manufacturers' requirements for automation technology

In addition to the expert responses to the questionnaire, this survey also conducted interviews with Taiwan's manufacturers regarding their satisfaction with automation technology. The following requirements for automation technology were determined:

1. Victor Taichung Machinery Works Co., Ltd.:

(1) Optimization of the auto-tuning method (machine learning),
(2) Automatic guiding for faults,
(3) Preventive self-diagnosis (health diagnosis), and
(4) Service life management for intelligent tools.

2. Tongtai Machine & Tool Co., Ltd.:

Support for automation and intelligent open controllers is lacking.

3. Yeong Chin Machinery Industries Co., Ltd.:

All single-machine automation functions are satisfactory. Only reliability, customer trust, and stability must be improved.

4. Awea Mechatronic Co., Ltd.:

(1) Status monitoring system and software for self-learning and improvement.
(2) Choosing automation technology is difficult with so many far-end monitoring software solutions.

5. Goodway Machine Corp.:

Production management.