Chapter 17
Failure Analysis in Precision Manufacturing

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ABSTRACT

Precision manufacturing is a process to produce products with tolerances smaller than 1 part in 10^4 or 10^5. The process is based on dimensional precision, angular precision, form precision, surface roughness, kinematic precision, and surface layer alternations. There are sources of error in precision manufacturing that are enemies of precision processes. In this chapter, these sources are explored and a Markovian model is developed for evaluating process robustness and machine accuracy. An illustrative example is presented here in order to demonstrate the application of the model in industries dealing with precision processes.

1. INTRODUCTION

Manufacturing refers to a process that transforms raw materials into products for use or sale. To increase profit, manufacturing is directed toward the efficient production of products for sale to consumers. As a result, manual machining had been extended to powered machining for better efficiency, speed, and accuracy. Later, numerically controlled (NC) machining was introduced that employed a computer for motion control and process integration. Further developments of NC machining resulted in a significant achievement in manufacturing. These developments are 1) direct numerical control (DNC); 2) computer numerical control; and, 3) adaptive control (AC). In DNC, a direct connection between the computer and the NC machines is established, which allows the large master computer to manage the operation of a number of separate NC machines. In AC, one or more process variables (e.g., cutting force, temperature, power) can be measured in order...
to optimize the process. Application of these intelligent systems into manufacturing results in movement from a machine being driven by predetermined commands to being driven based on decision making (See Figure 1).

Worldwide, automation and higher precision manufacturing are two major thrusts in the development of manufacturing technology. Automation includes CAD/CAM, CIM, and FMA. On the other hand, higher precision manufacturing can be classified as follows:

1. Precision engineering deals with manufacturing products with tolerances smaller than 1 part in $10^4$ or $10^5$;
2. Micro-engineering means the physical dimensions of the component are smaller than 1 $\mu$m; and,
3. Nanotechnology refers to sizes in the range of $10^{-9}$.

Due to a very competitive market, manufacturers show more interest in precision manufacturing because of prime economic importance. Precision manufacturing is based on the following objectives (Dornfeld & Lee, 2008):

- Dimensional precision
- Angular precision
- Form precision
- Surface roughness
- Kinematic precision
- Surface layer alterations

However, achieving these objectives is a challenging task due to sources of error. Error that has no obvious cause is called random error. Conversely, there are errors associated with assignable causes. Assignable causes include geometrical cause, cutting cause, drive cause, and environmental cause. The geometrical cause in a mechanical system refers to structure, spindle, table, and machine tool. Also, the cutting, drive, and environmental causes in a mechanical system deal with table, work piece, and tool. The end results of error causes can be categorized into Contour accuracy, Surface roughness, and Dimensional accuracy. In this study, the authors proposed a reliability technique for failure analysis in such machines used in precision processes.

2. LITERATURE REVIEW

Manufacturing technology has rapidly expanded during the past decade. As a result, manufacturers sought an efficient alternative to producing products with minimum cost, while improving product quality in order to be competitive. They have spent remarkable resources and money on advanced manufacturing technologies (AMTs). The results of these investments have been mixed, as some organizations have seen significant returns while others have experienced major problems in implementation (Percival, 2009). As one of the strategic new industries, the advanced equipment manufacturing industry is the key point of the modern industrial system. The level of input-output efficiency is related closely to resource allocation of the equipment manufacturing industry and the transformation and upgrading of modern industry (Wang & Wu, 2012).
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