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Linkage between quality assurance tools and machinability criteria

S. Dolinšek*, J. Kopač

Faculty of Mechanical Engineering, University of Ljubljana, Aškerčeva 6, 1000 Ljubljana, Slovenia

Abstract

This paper discusses a practical example of machining crank shafts, which are the central part of compressors made in mass production, in order to point out the importance of selecting proper machining parameters and presenting their further relation to product quality. As the shaft's dimensions varied significantly after machining in comparison to the prescribed one, an analysis of the relationship between the machining parameters and data obtained from quality assurance tools was performed. These tools are frequently used in everyday process controls, however, they are often incorrectly used, or else not all the information is turned to advantage.

All the possible causes that may influence machining accuracy are presented with the aim of determining the magnitude of each factor. Special attention is focused on the influence of variations caused by machine inaccuracies. This paper concludes with a proposal for the proper use and interpretation of statistical tools in quality assurance procedures in order to detect disturbances in the process caused by the excessive wear of the cutting tools.

Keywords: Quality assurance; Tool wear; Crank shafts

1. Introduction

In practical machining applications, one may distinguish between two different approaches for evaluating the efficiency of cutting tools with respect to their wear resistance; the first is tool life obtained on the basis of experimental tests, and the second is the process identification procedure, which considers a tool as a part of the monitoring equipment. For nearly a decade, we have believed that the basic mechanisms of tool wear and different kinds of wear produced at the tool tip can be understood (see [1]). On the basis of experimental measurements of different tool wears, and the application of proper statistical techniques, it was possible to predict the tool life and therefore the intervals of changing the tools. This was the period of intensive work on the so-called "databases on machining parameters" (some basic contributions regarding the author's participation in such efforts can be found in [2,3]).

However, in daily production practice, the situation is different: the tool changing interval is usually prescribed in advance with a high degree of safety, which increases tool costs. Consequently, the use of expensive monitoring equipment remains a distant desire. On the other hand, the quality assurance tools are widely used in workshop production as a necessary procedure in assuring product quality. By analysing the given benefits, one can easily note that all the potentials of usage of these tools are not exploited; moreover, the reality is that the main efforts in many companies are directed towards satisfying the ISO 9000 standard requirements and towards eliminating the unsuitable products. Therefore, we will usually find many possibilities for improvements if we are able to understand and explain all particular sources of variations. Such an approach will also be the easiest way to control processes and improve them.

2. Quality assurance tools — usage in the workshop environment

Every organisation which is committed to quality must examine quality at three levels: the organisational level, the process level, and the performer/job level [4]. At each of these levels the primary focus of data and information is control, diagnosis, and planning, respectively. The types of information and how it is disseminated and aligned with organisational level are equally vital to success. However, the technical comprehension of quality view measurement activities only in the terms of output from the production system.

In such a way, the examination of quality is focused mainly on performer level (sometimes called job level or the task design level), where the standards for output must be based on the quality and customer service requirements that

* Corresponding author. Fax: +386-1-2518-567.
E-mail address: slavko.dolinsek@fs.uni-lj.si (S. Dolinšek).

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originate at the organisational level and process level. These standards include requirements for such matters as accuracy, completeness, innovation, timeliness, and cost. Viewing an organisation from this perspective clarifies the roles and responsibilities of all employees pursuing quality. At the job level, it is important that all the employees understand the quality at the level where their everyday activities are performed. Good information management can provide a means of assessing progress and signalling the need for corrective action.

Most company-specific measures are related to product quality — to the product quality indicators — focused on the outcomes of the manufacturing process, such us the number of non-conformities or defects per unit. Especially, the critical defects, which may lead to serious consequences or product liability suits, should be monitored and carefully controlled. Many companies collect the wrong data, often making some fundamental mistakes: not measuring key characteristics, taking inappropriate measurements or making wrong conclusions on the basis of the data, if they make any conclusions at all. Measurements and indicators may fall into two categories. The variable type are continuous and are concerned with the degree of conformance to specifications; they require some type of measuring instrument. This type of measurement is more efficient but is time consuming and expensive.

Experts estimate that 60–90% of total quality costs are the result of internal failures (scrap, rework, process failures) and external (customer complaints, product recalls, warranty claims), which are not easily controllable by management. The most common way of reacting to high failure costs is by increasing inspection. If no information from inspection is fed back to production workers to improve the process, such actions only increase appraisal costs and the overall result is little.

The true purpose of inspection is to provide information to control and improve the process — meaning better prevention of poor quality — and clearly to reduce internal failure costs. Assuring the quality of products depends on the use of sound analytical techniques, including statistical analysis, metrology, statistical process control and reliability. Process control, beside the procedures included in the quality assurance system (such as the ISO 9000 series), also includes monitoring the accuracy and variability of equipment, operator knowledge and skills, as well as the accuracy of measurement results and data.

Because unwanted variations can arise during production in process, inspection is needed throughout the production process. Although, a strong foundation of managerial practice is absolutely essential for success, the quality and the costs of quality are made on the factory floor. When the production operator assumes the role of inspector, the occurrence of special causes of variation can quickly be recognised and immediate adjustments to stabilise the process can be made. Done properly, this can eliminate the need for independent inspection activity.

3. An example of quality assurance process in production of casting parts

The example presented is taken from a company which produces compressors. One of the central parts of the compressor is the crank shaft, which is made from raw material (lamellar cast iron DIN 1691:05.85). Machining operations consist of rough turning, drilling and milling operations and final grinding. The first operation is turning, and the important dimensions to be controlled are the diameters in points Φ_L (left, tailstock side) and Φ_R (right, chuck side) ($d = 19.25 \pm 0.05$ mm). The shaft and measuring points are presented in Fig. 1.

Since the prescribed dimensions of the crank shaft varied significantly, we tested the process and tried to establish significant influences on its variations. Generally, the main influences on accuracy of the machined part might come from the workpiece material characteristics, machine tool influences and cutting tool inconsistencies. However, as the judging parameter of the non-conformance of the turning part is the measured diameter of the shaft, we should further incorporate the influence of the measuring equipment and environment, operator's influence and also the measuring strategy. All possible causes which could influence machining accuracy in such a way are presented by fishbone diagram in Fig. 2. However, the main purpose of our study was to establish the influence of the cutting tool wear.

For machining the shaft, the most proper tool materials are those made from white ceramics which have high resistance in higher temperatures, good toughness and are chemically inert, but their disadvantage is in brittleness. The cutting insert is designated as DNMX 120708 T02020 and the tool holder is CDJNR 3225. The characteristic wear at the insert (Fig. 3) was measured at the flank face to the tool using optical instrumentation. The tool life was determined on the basis of fractures at the tool tip. Fractures are the consequence of the specific machining conditions in relation of cutting tool properties, therefore the full utilisation of ceramics was not achieved (the tools are changed after 250 machined parts).

The next step was to relate the dimensions of the shafts with the measurements of the tool wear. The shafts were sampled after machining in the same periods; seven samples were taken each time, starting at the beginning of the cutting (first sample consisting of seven measurements), the

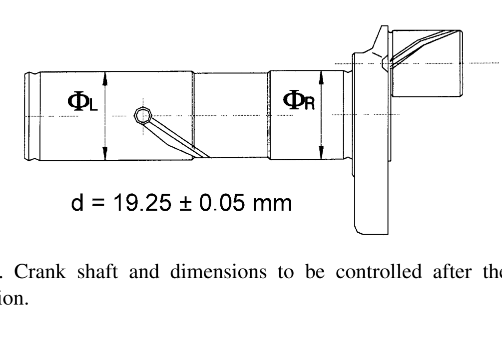

Fig. 1. Crank shaft and dimensions to be controlled after the turning operation.