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Sensor integration for a hydraulic clamping system

Berend Denkena, Dominik Dahlmann, Johann Kiesner*

Institute of Production Engineering and Machine Tools (IFW), Leibniz Universitaet Hannover, An der Universitaet 2, 30823 Garbsen, Germany

Abstract

Failures in workpiece positioning influence the machining conditions and outcome of machine tools directly. Hence, the monitoring by a sensor integrated clamping system to avoid rejects is subject of the presented work. The overall aim is to integrate sensory capabilities in a hydraulic clamping system typically used in series production within a joint research project. This paper gives a general survey of the targeted application and focuses on the sensor integration. It shows the qualification of strain gauges for indirect measurement of oil pressure in the hydraulic clamping element and the potential use of the same strain gauges to measure further monitoring objectives.

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1. Introduction

Clamping systems hold the workpiece in a defined position in the working space of a machine tool. Hence, positioning failures directly influence process behavior and machining results. Approximately 40 % of rejects are due to dimensioning errors that are attributed to poor fixture design [1].

The design and fabrication of a clamping fixtures can take up to 20% of the total manufacturing cost [1-3]. Its quality often relies on the designer's experience and is based on his understanding of the product. To reduce this reliance, but still provide a reliable clamping, much research effort has been focused on computer aided manufacturing. A good survey of recent research and trends in computer-aided fixture planning (CAFP) and design (CAFD) are given in [1] and [3-4]. Most of the CAFP/CAFD methods have the aim to determine accessible and

* Corresponding author. Tel.: +49-511-762-5210; fax: +49-511-762-5115.

E-mail address: kiesner@ifw.uni-hannover.de

collision free locations of fixture points that ensure part immobility under the application of external forces and moments. Boyle et al. conclude that many of the CAFD approaches have been tested for simple workpieces that are unrepresentative of those encountered in industry, thus the effectiveness of developed techniques cannot be stated with confidence [4]. On this account, despite the accurate effort in the phase of fixture planning and designing, malfunction or failure during machining cannot be excluded.

Nevertheless, to ensure a reliable and sustainable manufacturing, different developments were done to enable machine components to monitor the machining processes [5-7] and to interact with manufacturing processes by using mechatronic systems [8]. Nee et al. [9] present a prototype intelligent fixture which is capable of improving machined workpiece quality by controlling the clamping intensity. For the measurement of the clamping force, a direct sensing method with piezo-electrical force sensors was used. The direct monitoring methods can achieve a high accuracy, but due to numerous practical limitations, they are characterized as laboratory oriented techniques [10]. To enable suchlike applications in industrial environment, sensor systems are needed, that are more suitable for practical applications, at machine shop level.

An advantageous approach is presented by Litwinski [11] by integrating an intelligent sensor system into already existing components of a machine tool. He investigated a modular clamping system within the Collaborative Research Centre 653. The system determines the potential use and performance of a manual sensory clamping fixture for machine tools, but regarding the robustness it is not suitable for industrial use yet. The system is characterized by integrated sensors for measuring cutting forces as well as accelerations and temperatures. The collected information allow conclusions on the current process state and the detection of process failures. The use for process monitoring offers outstanding performance, therefore, the system is being transferred from research to industry within a joint research project.

The aim is to develop a hydraulic clamping system, which is typically used in series production, with sensing capabilities in cooperation with two partners from industry, a clamping technology manufacturer and a fixture construction service provider. Error conditions such as wear, overload, incorrect setting and improper use should be recognized to enable process and condition monitoring. In addition, the sensor integration, high system robustness, power and data transfer to rotating systems and the consideration of cost aspects set special requirements to the application in an industrial environment.

At first, this paper gives an overview of the overall concept and then focuses at the integration of strain gauges into hydraulic swing clamps to provide the fixture with sensing capabilities.

2. Overall concept

The development of the sensory clamping system is carried out on the basis of a representative application scenario. It deals with the hydraulic clamping for multi-axis machining of cast casing covers.

The simplified system structure is shown in Fig. 1a. The exemplary hydraulic clamping fixture (see Fig. 1b) is an assembly which consists of a fixture plate, three hydraulic swing clamps with appropriate supports and one hydraulic work support. The supply of oil for the hydraulic clamping elements within the fixture is realized by drilled hydraulic lines inside the fixture plate.

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