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ScienceDirect

Procedia Technology 26 (2016) 235 – 244

Procedia Technology

3rd International Conference on System-integrated Intelligence: New Challenges for Product and Production Engineering, SysInt 2016

Production Monitoring based on Sensing Clamping Elements

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

Clamping errors in workpiece positioning decrease the production outcome of machine tools by causing rejects. An automated monitoring of these failures does not take place in practice, due to limited installation space for the sensor integration, especially in series production. Within the Collaborative Research Centre 653, the IFW develops and investigates a condition and process monitoring system based on sensing clamping elements in close cooperation with two industrial partners, the companies Roemheld GmbH (clamping technology manufacturer) and ReiKam GmbH (fixture construction service provider). It consists of hydraulic clamping elements with integrated sensors, decentral electronics for signal preprocessing, bus communication and a central processing unit. Measureable quantities are hydraulic pressure, the clamping stroke and the process forces. This article describes the prototypical realization and shows its usability in condition and process monitoring. Experimental results from measurements during milling operations and the comparison with a dynamometer demonstrate the performance of the sensory clamping system.

Peer-review under responsibility of the organizing committee of SysInt 2016

Keywords: condition monitoring; process monitoring; hydraulic clamping system; sensor integration; strain gauges

1. Introduction

Clamping elements of fixtures hold the workpiece in a determined position in the working space of a machine tool. Therefore, positioning failures directly influence process behavior and machining results [1].

* Corresponding author. Tel.: +49-0511-762-5210; fax: +49-0511-762-5115.
E-mail address: kiesner@ifw.uni-hannover.de

Peer-review under responsibility of the organizing committee of SysInt 2016
doi:10.1016/j.protcy.2016.08.032

To provide a reliable clamping, much research effort has been focused on computer aided manufacturing. A broad survey of recent research and trends in computer-aided fixture planning (CAFP) and design (CAFD) are given in [2-4]. Most of the CAFP/CAFD methods have the aim to determine accessible and 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 for industrial application [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. present a prototype of an intelligent fixture which improves machined workpiece quality by controlling the clamping intensity [9]. For the measurement of the clamping force, a direct sensing method with piezo-electrical force sensors is used. The direct monitoring methods can achieve a high accuracy, but due to numerous practical limitations, e.g. interferences with chips and cutting fluid, 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.

Litwinski [11] presents an advantageous approach by integrating an intelligent sensor system into already existing components of a machine tool within the Collaborative Research Centre 653. His modular clamping system determines the potential use and performance of a manual sensory clamping fixture for machine tools, but considering the robustness it does not meet the requirements 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. Because of its performance for process monitoring the system is being transferred from research to industry within a joint research project. The main subject is the development and testing of a hydraulic clamping system with sensing capabilities for the use in series production.

This paper summarizes recent results of the project that enable monitoring of the fixture conditions and process forces. This includes the measurement of the hydraulic pressure, the clamping stroke and the process forces by the clamping elements themselves. At first, this paper gives an overview of the overall concept and then focuses on the integrated sensors of the hydraulic swing clamps. After that, a comparison between a dynamometer and a compound of sensing clamping elements demonstrates the applicability for the monitoring of milling processes.

2. Overview of the sensory clamping system

The development of the sensory clamping system bases upon a representative application scenario. It deals with the hydraulic clamping for multi-axis machining of cast casing covers. The exemplary hydraulic clamping fixture in Fig. 1a is an assembly that consists of a base plate with integrated hydraulic lines, three hydraulic swing clamps with appropriate supports and one hydraulic work support.

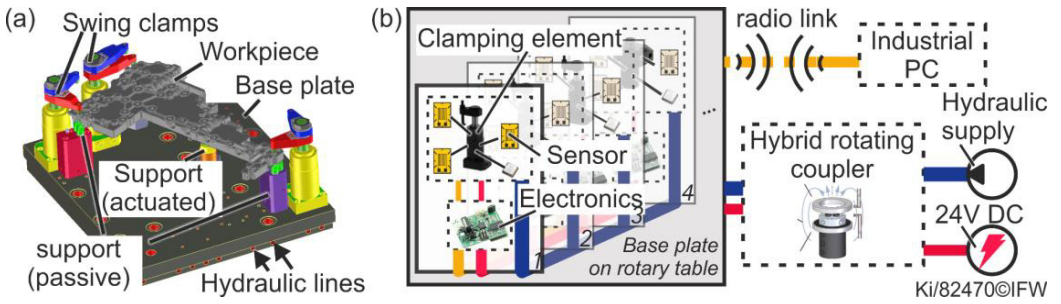

Fig. 1. (a) Hydraulic clamping fixture; (b) Overall concept for the sensory clamping system.