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The manipulator tool state classification based on inertia forces analysis

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A R T I C L E I N F O

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A B S T R A C T

In this article, we discuss the detection of damage to the cutting tool used in robotised light mechanical processing. Continuous monitoring of the state of the tool mounted in the tool holder of the robot is required due to the necessity to save time. The tool is a brush with ceramic fibres used for surface grinding. A typical example of damage to the brush is the breaking of fibres, resulting in a tool imbalance and vibrations at a high rotational speed, e.g. during grinding. This also results in a limited operating surface of the tool and a decrease in the efficiency of processing. While an imbalanced tool is spinning, fictitious forces occur that carry the information regarding the balance of the tool. The forces can be measured using a force sensor located in the end-effector of the robot allowing the assessment of the damage to the brush in an automatized way, devoid of any operator.
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1. Introduction

An analysis of the problem of detecting damages to the Cartesian robot tool is presented in this article. A custom-made robot is applied to explore methods of position-force control of manipulators and their use in light machining, such as grinding, chamfering, and edge blunting. An appropriate precision in the robot's motion was achieved using a linear unit with ball screws [1]. A DC motor with wheel gears was used to move elements of the manipulator. The robot was operated by a dSPACE cards system, additionally equipped with force and torque sensor in the end-effector. Moreover, the robot was equipped with a head with a DOTCO 44 W low-power pneumatic drive, with a rotational speed reaching up to 100,000 rpm in conditions devoid of encumbrances. This is a pneumatic drive designed for light mechanical processing, such as grinding, polishing, and chamfering, with a motor operated by an electronic air pressure regulator. A cutting tool was attached in the pneumatic drive holder, which in this research was a brush with ceramic fibres. This is a tool used in finishing processing, e.g. grinding, deburring, and finishing edges. Due to high rotational speeds (up to 10,000 rpm), these tools need to be precisely balanced. Nevertheless, these tools can become imbalanced due to damages of fibres inflicted during processing, creating mechanical vibrations that can negatively influence the precision of processing and roughness of a processed surface. Moreover, broken fibres in the tool results in a reduced active surface, leading to a decreased effectiveness of the machining (see Fig. 1).

This work aims to present a method of creating a classifier, which on the basis of the available measurement data, obtained by means of a force sensor, assigns the current tool balance state into one of two defined classes: 1st class – a tool in operable condition and 2nd class – a damaged tool. The discussed issue corresponds to the current research trends

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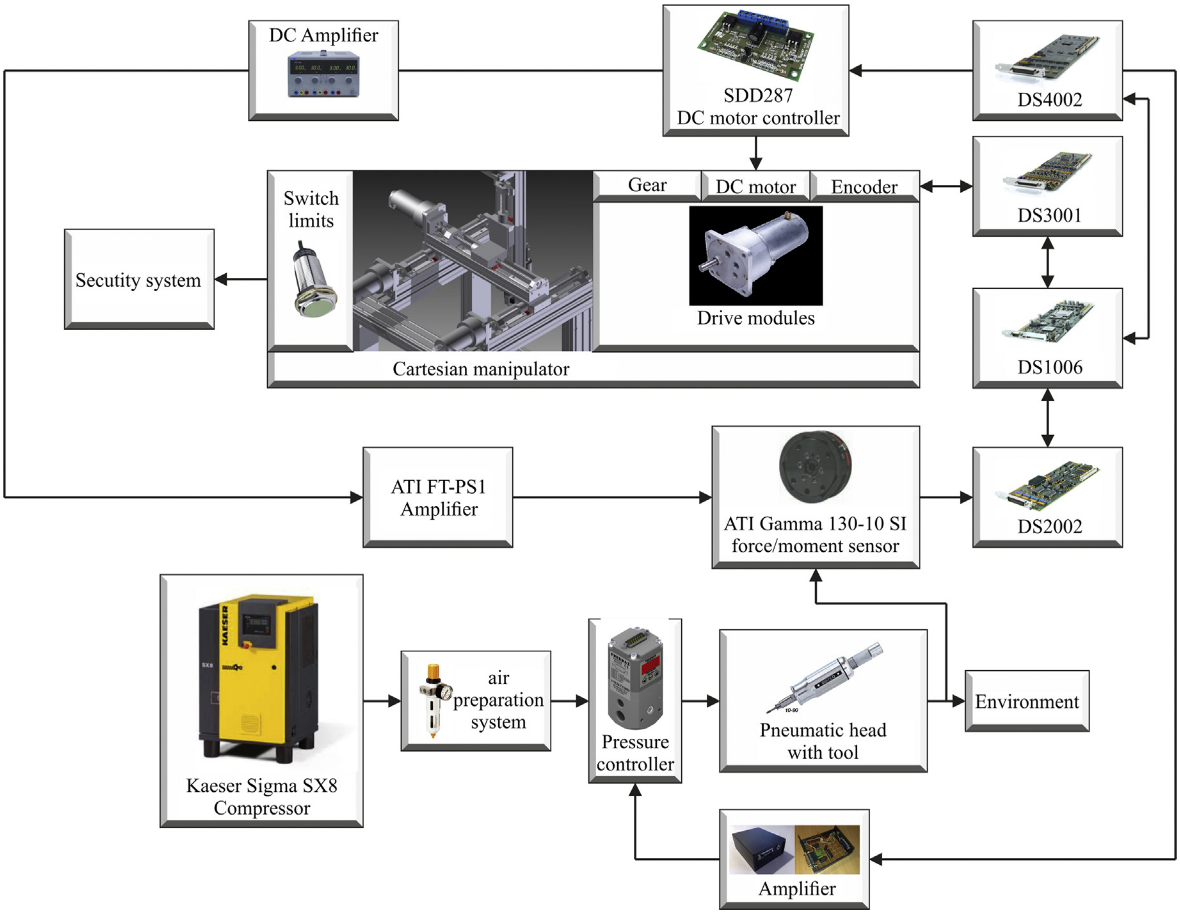

Fig. 1. Experimental stand: Cartesian manipulator and instrumentation.

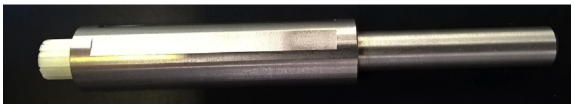

Fig. 2. Tool – a ceramic fibre brush with a protection sleeve.

concerned with condition monitoring of tools [2–8], machines [9,10], and processes [2,3,11–13]. This article is a continuation of the author's research into robot tool diagnostics. In the work of [3], the diagnoses of brushes made of ceramic fibres using an analysis of vibrations in the frequency domain is discussed. In the research, an experimental stand was used to measure the acceleration of vibrations of the head and tool. On the basis of these measurements, a classifier of the tool status in the form of an artificial neural network was created, with a classification effectiveness reaching 99.875% in laboratory conditions. In the work of [14], the method of implementing the automated on-line procedure of condition monitoring of a robot tool on a robotised stand is described. A neural system of the tool status classification, based on the features of the vibration acceleration signal in the time and frequency domain, was built. A classification effectiveness of 97% was achieved in real conditions. A common feature of both of these works is the implementation of the vibration acceleration measurement system. In this paper, a procedure of classification of the tool status based on the measurement of force obtained from a sensor, belonging to the standard equipment of the robot, is presented. Therefore, the development of a measurement system is not necessary, but only the access to the signals in the feedback loop of the force control system of manipulator. The results presented in this article are the outcome of the initial research, before implementation of the procedure for detecting the tool status on a robotised stand equipped with the IRB 140 serial industrial robot with a factory-made force control packet.

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