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Condition monitoring of rack and pinion drive systems: necessity and challenges in production environments

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Abstract

Rack and pinion drives are linear actuators commonly found in feed axes of machine tools and handling systems. Despite their use in demanding production environments and the possibility of failure due to foreseen or unforeseen cause, as of this writing, no condition monitoring systems are used in such applications. This paper shows the prospects of condition monitoring of rack and pinion drive systems concerning predictability of faults and saving of resources. Additionally the current state of the art of science and technology in this field and the challenges of condition monitoring of such drive systems under the circumstances of production environments are outlined. The publication concludes the need for action and gives an outlook on ongoing developments in condition monitoring of rack and pinion drives.

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Keywords: Life Cycle; Feed drive; Machine tool; Maintenance; Service

1. Introduction

Rack and pinion drives (RPD) are linear actuators commonly found in feed axes of machine tools and handling systems. Distinguishing features are virtually unlimited maximum length of travel and constant dynamic characteristics along the travel, making them recommended for feed drive systems with long travel distances. Competing systems are linear direct drives (LDD) and ball screw drives (BSD). While being the most common type of drive system, ball screw drives can only be used up to a certain length [1].

Load and environmental conditions can lead to different kinds of damages in the components of RPDs, altering their operation characteristics. This can affect the quality of the produced parts and reduce productivity. Eventual failures of feed axes will cause stoppages of production systems.

Condition monitoring is the monitoring of parameters in machinery in order to indicate developing faults. As a prerequisite of predictive maintenance it becomes more and more important in modern production systems, where it can reduce the likelihood of unforeseen failures and stoppages. It can also help minimize the use of material and energy [2].

Therefore the existence of a condition monitoring system for rack and pinion drives is standing to reason.

Nomenclature

RPD	rack and pinion drive
BSD	ball screw drive
LDD	linear direct drive
CM	condition monitoring

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2. Rack and pinion drives

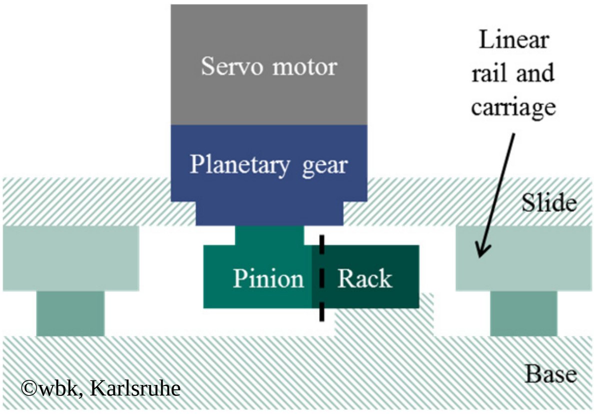

Fig. 1. Typical setup of a RPD in machine tools

2.1. Overview

The typical setup of a rack and pinion drive inside the feed drive system of a machine tool is illustrated in Fig. 1, showing a cross section in a plane perpendicular to the direction of travel. The RPD in this example consists of a rack that is coupled to the machine base and a pinion that is stationary to the slide of the machine. The dashed black line highlights the contact between rack and pinion.

Because of the power transfer on the pinion being characterized by low revolutions and high torque, usually additional gear steps are needed [1]. Shown here is a planetary gear box between servo motor and pinion. The reduction gear and the servo motor are separate components that are not part of the scope of this paper. Condition monitoring for these components can be done independently.

For accurate positioning the drive train has to be designed for high stiffness. This includes the reduction of backlash and the establishment of preload. For this purpose two methods are commonly used. One is by mechanical means, employing a spilt pinion and a spring. The other possibility is to use two RPDs with separate servo motors on the same rack [1, 3] This method also allows dynamically changing the preload and combining the feed force of the two drives via the electrical control system of the servo motors.

Not shown here is the optional lubrication system, which usually consists of a lubrication pump, tubing, and a porous lubricating pinion.

2.2. Properties

Recent scientific studies on rack and pinion drives in machine tools like [4] and [3] have covered the static and dynamic properties of feed drives. These properties are the attainable feed force, the permitted acceleration, the kinematic accuracy, and the static and dynamic stiffness of machine axes [3].

These properties directly influence productivity and the quality of the produced parts; therefore it is important to keep them at certain levels over the entire service life of the machine.

3. Necessity for condition monitoring of rack and pinion drives

Rack and pinion drives have at least two mechanical components that are susceptible to damages: the geared rack and pinion. Developing faults of the components of feed drives will lead to the deterioration of their properties and to the total failure of the feed axes.

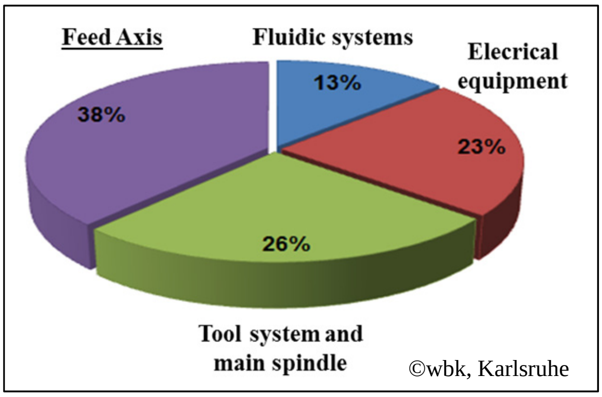

Fig. 2. Percentages of machine tool component failures [5]

Figure 2 shows that stoppages of machine tools are caused primarily by component failures of their feed axes [5].

3.1. Financial Factors

The economic importance of condition monitoring can be estimated by regarding the life cycle costs of production equipment. Figure 3 shows the cost shares of a machining centre as an example [6]. Note that the combination of costs from maintenance, service and the lack of availability is 18% of the overall costs and more than two thirds compared to the investment in the machine, including financing.

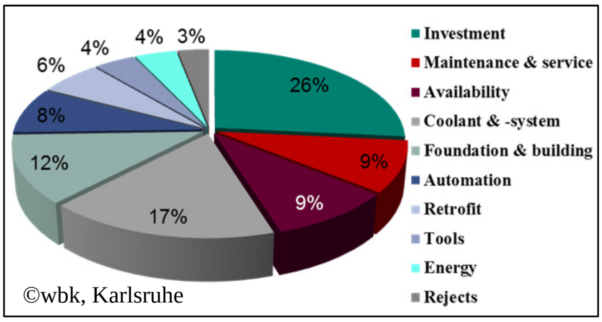

Fig. 3. Distribution of cost shares of the overall life cycle costs of a machining centre [6]