Mechanical Systems and Signal Processing 50-51 (2015) 548–562

Contents lists available at ScienceDirect

Mechanical Systems and Signal Processing

journal homepage: www.elsevier.com/locate/ymssp

In-situ roundness measurement and correction for pin journals in oscillating grinding machines

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ARTICLE INFO

Article history:
Received 17 May 2012
Received in revised form
26 June 2013
Accepted 8 May 2014
Available online 28 May 2014

Keywords:
Crankshaft
Roundness measurement
V-block
Telescopic support
Oscillating grinding machine
Pin chasing grinding

ABSTRACT

In the mass production of vehicle-engine crankshafts, pin chasing grinding using oscillating grinding machines is a widely accepted method to achieve flexible and efficient performance. However, the eccentric movement of pin journals makes it difficult to develop an in-process roundness measurement scheme for the improvement of contour precision. Here, a new in-situ roundness measurement strategy is proposed with high scanning speed. The measuring mechanism is composed of a V-block and an adaptive telescopic support. The swing pattern of the telescopic support and the V-block is analysed for an equal angle-interval signal sampling. Hence roundness error signal is extracted in frequency domain using a small-signal model of the V-block roundness measurement method and the Fast Fourier Transformation. To implement the roundness data in the CNC coordinate system of an oscillating grinding machine, a transformation function is derived according to the motion model of pin chasing grinding methodology. Computer simulation reveals the relationship between the rotational position of the crankshaft component and the scanning angle of the displacement probe on the V-block, as well as the influence introduced by the rotation centre drift. Prototype investigation indicates the validity of the theoretical analysis and the feasibility of the new strategy.

1. Introduction

With the trend toward smaller displacement and higher revolution speed [1,2], the roundness precision of the crankshaft pin journals is affecting the efficiency, stability, and lifetime of vehicle engines. To improve machining precision and efficiency, pin chasing grinding methodology based on oscillating grinding machines has been developed and widely implemented in crankshaft manufacturing. This approach provides high flexibility in mass production [3–5]. On the other hand, because of grinding-wheel wear, servo-system response error, elastic deformation etc., oscillating grinding machines still involve problems with the contour precision control of pin journals.

To minimise elastic deformation affect, the grinding-force model has been studied and applied to a Landis CP crankshaft grinder by Walsh [6]. Besides, a path compensation scheme based on neural network has been investigated in a crankshaft grinder by Ganghua et al. [7]. However, because of its unique shape, a crankshaft component has much weaker stiffness than other regular shafts. The extent of elastic deformation of a crankshaft component is affected by the difference in internal stress, clamping stress, grinding force, etc. Moreover, the implementation of steady rests also leads to notable attitude variation of the clamped crankshaft component in an oscillating grinding machine, because the duplicated vibration

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http://dx.doi.org/10.1016/j.ymssp.2014.05.009
0888-3270/

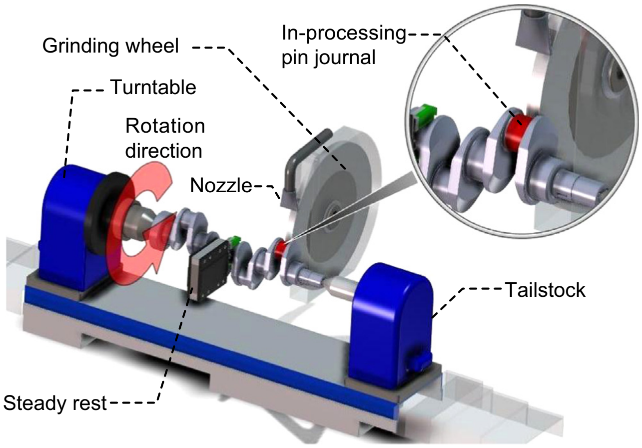

Fig. 1. Demonstration of pin chasing grinding in an oscillating grinding machine.

introduced by bearing's contour error. Therefore, the roundness error of a pin journal cannot be suppressed by merely improving the path accuracy of the grinding procedure. In-situ measurement becomes a competitive solution for pin journals roundness correction in crankshaft manufacturing applications.

Presently, several methods have been developed for mechanical roundness inspection, such as the radial method, multiprobe method, and the V-block method [8–12]. Yet, the challenges for in-situ roundness measurement of the pin journals in an oscillating grinding machine can be illustrated with Fig. 1. The enlarged red part shows the target pin journal in processing, which follows an eccentric movement during the entire manufacturing process. Such conspicuous variation of the geometrical centre is unacceptable for traditional roundness inspection means, even the V-block method. The available space left for the configuration of an in-situ measuring mechanism is also restricted by the grinding wheel, the crankshaft component itself, and the nozzle of cooling liquid, let alone the extreme environment caused by the grinding spark and the cooling liquid mist. In some commercial applications [13], the V-block method with a patent support has been reported for in-situ roundness measurement in crankshaft grinders. However, the sophisticated measuring mechanism has already shown many drawbacks, such as hard adjustment, high cost, and slow scanning pace.

In this research, a new in-situ roundness measurement strategy based on the V-block method is proposed with focus on scanning speed and stability. Measuring mechanism utilising an adaptive telescopic support is developed with simple structure and compact size. To guarantee signal integrity, a contact displacement probe sealed by purified compressed air is employed for the roundness signal acquiring. Principles of swing angle of the telescopic support and the V-block are analysed for the development of an equal angle-interval signal sampling algorithm. Hence the roundness error is extracted in frequency domain using a small-signal model of the V-bock roundness measurement method and the Fast Fourier Transformation (FFT). For in-situ roundness correction purpose, a transformation function is also derived for the CNC system of an oscillating grinding machine.

2. In-situ roundness measuring mechanism

When implementing the V-block method for in-situ inspection, because the target pin journal is firmly clamped, the function of an in-situ roundness measuring mechanism should include

a) Catching the target pin journal in all rotary positions of the crankshaft component during grinding process and scanning process.
b) Providing at least two dimensions of freedom in the normal section of the target pin journal to avoid a rigid collision between the V-block and the crankshaft component.
c) Keeping a stable scanning attitude for the probe or a mutative attitude with a fixed and known principle.

Then the in-situ measuring mechanism can accommodate the irregular motion of the V-block caused by the noncircular contour and the eccentric movement of the target pin journal. Hence flexible contact between the V-block and the target pin journal could be fulfilled as well as a stable scanning process.

2.1. Adaptive telescopic support

Considering the three principles mentioned above, based on an adaptive telescopic support, an in-situ roundness measuring mechanism is proposed. The geometrical principle is shown in Fig. 2. A contact displacement probe is placed on the axis-line of the V-block with its direction pointing to the centre of the target pin journal, O_p. The target pin journal