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Optimization of Roughness and Residual Stresses in Path Controlled Grinding of Crankpin

Manchao Zhang*, Zhenqiang Yao, Sheng Xu

State Key Laboratory of Mechanical System and Vibration, Shanghai Jiao Tong University, Shanghai, 200240, China

* Corresponding author. Tel.: +86-21-3420-6583; fax: +86-21-3420-6583. *E-mail address:* sliders@sjtu.edu.cn

Abstract

Crankpin is generally subjected to high thermal and cyclic loads when working. Surface roughness and residual stresses greatly influences the final running characteristics of crankpin. Path controlled grinding process has been used in automotive powertrain industry. The grinding conditions are periodically changing between grinding wheel and crankpin due to the existence of the eccentricity of crankpin and constant rotation speed of crankshaft. It leads to the variation of surface roughness and residual stresses on circumference of crankpin. So the optimization of grinding parameters in crankshaft grinding is essential. This paper presents an investigation to evaluate variation of surface roughness and residual stress along circumference in path controlled grinding of crankpin. The effects of the speed and speed ratio were analyzed in detail with constant rotation speed of crankshaft. It is found that up-grinding and down-grinding exist during one revolution cycle. The results show the surface roughness Ra always keeps below 0.25 μm in all the grinding conditions, and the variations of surface roughness are little along circumference. The highly compressive residual stresses level after grinding is obtained on pin bearing. Compared to the variation of roughness, the variation of residual stress along circumference is large. Based on the results, the lower crankshaft rotational speed, lower grinding depth, and higher wheel speed are suggested to be used in the path controlled grinding of crankpin harden by induction surface hardening.

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Keywords: Residual stresses; roughness; path controlled grinding; crankpin

1. Introduction

Crankshaft is the key parts in engine. Due to the special construction of crankshaft, the conventional grinding method processing crankpin is that the crankshaft is held in place by offsetting chucks to align the crankshafts pins with main axis. Using this method, crankpin is processed as centered circle. However, the processing of main journal and pin journal could not be ground in one clamping. With increased demands for high productivity and accuracy, path controlled grinding process, allowing reduction of non-productive time and re-clamping inaccuracies is developed to machine crankshaft.

Path controlled grinding is one of the most preferentially used nontraditional grinding processes to machine the crankshaft in automotive industry. Two independently programmable wheelheads process the main and pin bearing in one clamping simultaneously allowing reduction of non-productive time and prevention of clamping inaccuracies. The contour of crankpin is achieved with the coupling actions both of the eccentrically pin bearing rotation and the grinding wheel linear movement [1]. Compared to external cylindrical plunge grinding, the contact conditions are periodically changing between grinding wheel and crankpin during the grinding process due to the existence of the eccentricity of crankpin with the constant rotation speed of crankshaft.

Crankpins are generally subjected to high thermal and cyclic loads when working [2] Surface integrity, such as surface topology, surface roughness, residual stresses, hardness, etc., greatly influences the final characteristics of machined parts [3]. As to the stress, the total stresses are a sum of residual stresses in a machine part and of load stresses produced by the action of external forces and moments. So surface integrity must be taken into consideration and controlled.

A large number of researchers have attempted to

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investigate the effects of process parameters on surface integrity in cylindrical grinding. The surface roughness is affected by process parameters such as wheel speed, feed, grinding depth and workpiece speed [4, 5]. The spark-out stage has an important role for reduction of surface roughness [6]. And the surface roughness under different cooling environment presented a wide variety [7, 8]. The amplitude of residual stresses after grinding is usually influenced by heat treatment method and grinding parameters [9, 10]. Moreover, with the correct selection of grinding conditions, the very favourable compressive residual stresses in the hardened surface layer on main bearing will be retained after grinding [11].

Although many works have been done, much attention has been paid to the cylindrical plunge grinding; few reports have been reported on surface integrity of pin bearing generated in path controlled grinding.

This objective of this paper is to design the grinding process parameters by investigating the surface integrity in path controlled grinding. A series of experiments has been carried out to investigate variation in terms of surface roughness and residual stresses along circumference of crankpin which influence the reliability of components. In addition, analyses on speed of crankpin and wheel were also investigated. This paper provides a well fundamental understanding the path controlled grinding process of crankpin.

2. Experimental procedures

2.1. Specimen preparation

The material used in experiments was commercial 40Cr alloy. It is the reason for choosing 40Cr that it is used typically for ship crankshaft manufacturing. The main chemical composition of 40Cr is shown in Table 1. The pin bearing had the dimensions of 80 mm (diameter) ×35 mm (width), and the eccentricity is 67.5 mm. Quenched hardening and induction surface hardening according to the GB (Chinese standard) were used gaining the surface hardness of HRC 52±3.

Table 1 Chemical composition of 40Cr.

C%	Si%	Mn%	S%	Cr%
0.42	0.29	0.7	0.01	0.98

2.2. Experimental Setup

The grinding experimental platform used for path controlled grinding of the pin bearing grinding is shown in Fig. 1. All grinding tasks were carried out on an orbital grinder H-405BF supplying a spindle with maximum speed of 6000 rpm and drive motor rated up to 37 kW. The nozzle setup of coolant keeps a settled position. Cubic boron nitride (CBN) grinding wheels have been widely used in industries as an effective precision grinding method, and often they produced very good results [12]. The CBN grinding wheel with diameter of 600 mm and width of 38 mm with grit sizes 126 (KREBS&RIEDEL Inc. Germany) was used throughout experiments. Before each grinding test, the wheel was dressed

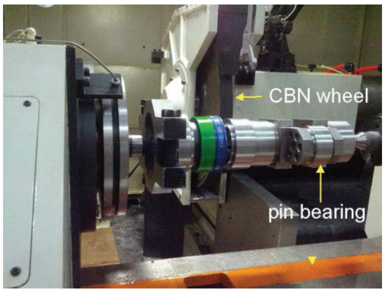

Fig. 1 Experimental setup

with same parameter using diamond roller dresser with diameter of 150 mm (KUNTZ Inc. Germany). The grinding has been applied under flood emulsion cooling for each test and hydraulic pressure was set to 0.39 MPa. A water-based coolant was used in these tests with dilution ratios 1:15. The grinding conditions and dressing conditions are given in Table 2. Each test there is ten revolutions during loaded grinding and spark-out grinding.

Table 2 Experimental conditions

wheel	CBN(φ600)
Wheel speed V_s (m/s)	75,80,85,90
Grinding depth a_p (mm)	0.005, 0.01,0.015
Rotation speed V_w (rpm)	15,25,30,35,50
Dresser	Diamond roller dresser (φ135)
Wheel speed (m/s)	30
Dressing speed (m/s)	24
Dressing depth (mm)	0.003
Dressing feed (mm/min)	200

2.3. Measurements

The measurement started from the rotation angle 0°. Twelve measurement points were taken along the grinding direction with separation angle of 30°. The measurements of surface roughness Ra were taken on a surface roughness meter Mitutoyo SJ-201(Japan) across grinding direction. The cut-off used was 0.25 mm. An average of five readings of roughness was recorded. The X-ray diffraction technique using sin2ψ method was used. A Proto-iXRD X-ray diffractometer equipment (Canada) was used for the residual stresses measurements. The radiation power supply was 20kV and 4mA, and the radiation source used is Cr_K for canning in the 2θ range of 156.41°

3. Analysis of Path Controlled Grinding of Crankpin

For path controlled grinding, the crankshaft is held between head stock and tailstock centres in these tests, the crankpin is eccentrically ground with an angular infeed grinding process. To well understand the process during crankpin path controlled grinding, the speed and grinding ratio are investigated. It is assumed that the rotation speed of crankshaft is constant in this analysis. It is assumed that the