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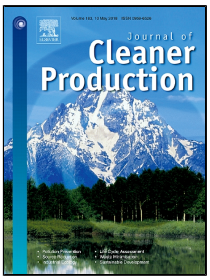

Sustainable production of micro gears combining micro reciprocated wire electrical discharge machining and precision forging

Xiang Chen, Zhenlong Wang, Jie Xu, Yukui Wang, Jianwei Li, Hongzheng Liu

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Sustainable production of micro gears combining micro reciprocated wire electrical discharge machining and precision forging

Xiang Chen [a], Zhenlong Wang [a,c], Jie Xu [b,c], Yukui Wang [a,c,*], Jianwei Li [b], Hongzheng Liu [a]

[a] School of Mechatronics Engineering, Harbin Institute of Technology, Harbin 150001, China

[b] School of Materials Science and Engineering, Harbin Institute of Technology, Harbin 150001, China

[c] Key Laboratory of Micro-systems and Micro-structures Manufacturing of Ministry of Education, Harbin Institute of Technology, Harbin 150001, Heilongjiang, China

*Corresponding author.

E-mail addresses: wangyukui@hit.edu.cn

Abstract

This paper presents a hybrid process combine micro reciprocated wire-EDM which uses reciprocated travelling wire with 50 μm diameter as tool electrode, with the precision forging, achieving the economical and high-efficiency sustainable production of micro gears. A micro gear mold with 0.1 mm module and 10 tooth number is devised, and the 14.5 μm mold fit clearance is determined by analyzing the established mold matching model and conducting the numerical simulation of precision forging. During the micro reciprocated wire-EDM of micro gear mold from SKD11, the basic experiments are performed to study the effect of the main parameters on machining accuracy and productivity, and whilst the proper machining parameters are obtained. The micro gear punch and die are successfully fabricated by micro reciprocated wire-EDM, showing good surface quality with 0.90 μm and 0.83 μm Ra respectively, and low dimensional deviations of ≤ 1.3 μm and 2.1 μm respectively. Finally, the precision forging of the micro gears are conducted on ultrafine grained (UFG) high purity copper by the machined micro gear mold. The forged micro gears have high forming precision with ≤ 4.1 μm deviation from the micro gear mold and smooth surface with 0.86 μm copied from the micro gear die cavity, verifying the feasibility of the proposed method for the sustainable production of micro gears.

Keywords: Sustainable production; Micro gears; Micro reciprocated wire-EDM; Precision forging.

1. Introduction

Sustainable production has become a hot topic in almost every field of manufacturing, aiming to achieve more economical and efficient processes (Ingarao et al., 2011). The key methods of sustainable production mainly include the optimization of energy usage and the innovation of machining techniques etc. Nowadays, many relevant investigations have been conducted. For instance, the optimal machining strategy and parameters were identified to reduce pollution and energy consumption in dry cutting duplex stainless steel (Krolczyk et al., 2017) and the machined surface was inspected, finding that the surface wave length machined by dry cutting is higher than that by cooling cutting (Krolczyk et al., 2016). The casting moulds were machined by milling along with the reverse engineering technique, which reduced the processing cost and improved the productivity (Rodríguez et al., 2012).

As significant actuating components, the micro gears are in urgent need with the development of micro-electromechanical systems (Ghayesh et al., 2013; Gupta et al., 2016). The sustainable production of micro gears with low cost, high accuracy and efficiency attracts researchers' much attention. For high productivity, Tang et al. (2007) developed vacuum casting process to fabricate micro gear mold and used it to mass produce micro gears. Huang et al. (2009) fabricated gear mold-inserts by UV-LIGA process and conducted micro injection molding tests on Tepcon M90