Mechanism and Machine Theory 122 (2018) 86–96

Contents lists available at ScienceDirect

Mechanism and Machine Theory

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

Research paper

Analysis of tooth profile and accumulative pitch errors of end-toothed disc and its tolerance development

Cheng Zhang, Jian-run Zhang*, Pan Tang

School of Mechanical Engineering, Southeast University, Nanjing 211189, China

ARTICLE INFO

Article history:
Received 12 May 2017
Revised 27 November 2017
Accepted 16 December 2017

Keywords:
End-toothed disc
Indexing accuracy
Processing error
Tolerance development

ABSTRACT

Tooth profile errors of the end-toothed disc describe the tooth profile deviations which mainly contain tooth trace error and tooth profile half-angle error while accumulative pitch error describes the tooth position deviation of the end-toothed disc. In traditional analysis, neither the deviation of the benchmark of tooth trace error nor that of tooth profile half-angle error is considered, while the deviations exist in engineering. Hence, tooth width error is proposed in order to describe the deviations of the benchmarks and the indexing accuracy error model is also established according to these four errors in this paper. Meanwhile, Tolerance Proportional Distribution Method is presented to establish the tolerance proportional model of end-toothed disc. Therefore, according to the indexing accuracy error model and tolerance proportional model, the pass rate model of end-toothed disc is established and a new approach for tolerance development is put forward based on this pass rate model. Finally, a simulation program is developed for random sequence generation, which replaces the processing errors measurement, and meshing process simulation, and verifies the correctness of the approach for tolerance development.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

End-toothed disc is a special contrate gear for high-accuracy indexing. End-toothed disc is widely used in the field of precise angle measurement and indexing, which has high indexing accuracy, strong bearing capacity, automatic centering and so on.

End-toothed disc was mainly used as a connector originally where the coupling stiffness was much emphasized, such as the CURVIC (a trademark of The Gleason Works) coupling. Richardson analyzed the stress state of connecting bolts of CURVIC coupling with finite element method and verified the correctness of finite element analysis results by photoelastic experiment [1,2]. Pisani et al. studied the stress state of the CURVIC coupling with two- and three-dimensional boundary and finite element methods, and predicted the stress concentration factor and peak stress [3].

The coupling stiffness is one of the basic performance of end-toothed disc. A qualified end-toothed disc requires sufficient coupling stiffness. The study of coupling stiffness of end-toothed disc has been relatively mature so far. Therefore, the focus of the research on end-toothed disc has been changed to precise angle measurement and indexing function since the precision of machine tools is becoming increasingly important with the development of science and technology nowadays [4]. More and more end-toothed discs are used in the field of precise angle measurement and indexing. As a result, precision of end-toothed disc should be researched.

* Corresponding author.
E-mail address: zhangjr@seu.edu.cn (J.-r. Zhang).

https://doi.org/10.1016/j.mechmachtheory.2017.12.015
0094-114X/© 2017 Elsevier Ltd. All rights reserved.

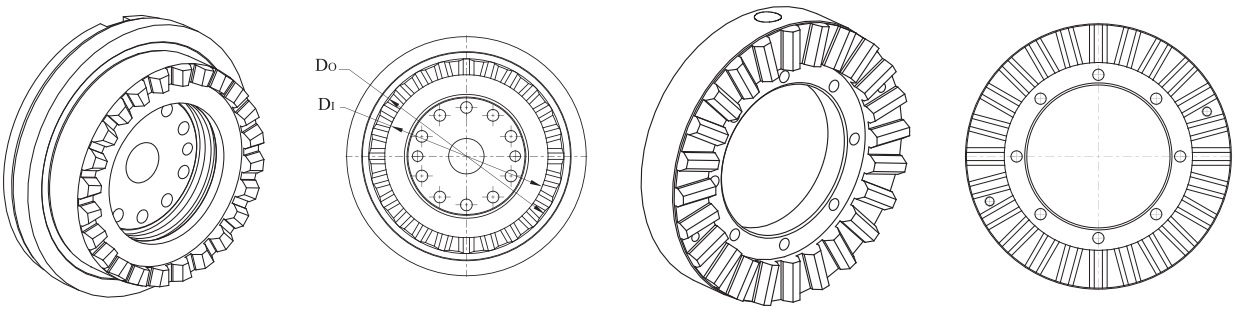

Fig. 1. Schematic diagram of the pair of end-toothed discs.

Tolerancing decisions can profoundly impact the quality and cost of manufacturing products. An amount of research has been devoted to the development of tolerance analysis [5–8] and synthesis [9,10]. An approach including a vectorial dimensioning and tolerancing model allowing gear conventional tolerancing practice and geometric tolerancing practice was proposed by Bruyère et al., based on Tooth Contact Analysis and Monte Carlo simulation [11]. In the paper published by Cao et al. [12] a quasi-Monte Carlo method based on good point set was proposed which provides more accurate analysis results with less calculation amount compared with Monte Carlo simulation method. A discrete geometry approach for tolerance analysis of mechanism was proposed by Schleich et al. [13] to help to incorporate results from different validation applications. The integrated tolerance analysis of systems is mainly considered in reality. The "integrated tolerance analysis of systems in motion" approach was presented by Wartzack et al. [14] and Stuppy et al. [15]. On this foundation, this method was extended by Walter et al. [16] in which the appearing interactions was expressed by meta-models that can be easily integrated into the functional relation. In addition, the time dependence of the deviations has also been studied in recent years. Particle Swarm Optimization was applied to the time-variant tolerance-optimization problem by Walter et al. [17] to determine the tolerance range. Although a large amount of literature is related to tolerance analysis according to the literature review about tolerance analysis above, little of the literature applies to end-toothed disc.

With the improvement of CNC system, modern machine tools adopt error compensation system to ensure and improve the accuracy, such as feed system and temperature control system [18,19]. However, error compensation technology is difficult to be used for end-toothed disc since the indexing of the end-toothed disc is discrete. Therefore, the tolerance analysis for end-toothed disc is necessary for the purpose of both high precision and low manufacturing cost.

Usually, tooth profile deviations and tooth position deviation of end-toothed disc should be analyzed before the tolerance development. Hence, tooth profile and accumulative pitch errors of end-toothed disc are analyzed in this paper. The definitions of accumulative pitch error, tooth trace error and tooth profile half-angle error are firstly introduced. However, the tooth profile deviations of end-toothed disc cannot be fully reflected by tooth trace error and tooth profile half-angle error since neither of benchmark deviations of mentioned two errors is considered in traditional analysis, which exist in engineering. Therefore, tooth width error is proposed to describe the deviations of benchmarks, in order to completely describe tooth profile deviations, and the indexing accuracy error model is established according to the four errors in this paper. Simultaneously, tolerance proportional distribution method (TPDM) is presented to establish the tolerance proportional model of end-toothed disc based on the standard tolerance table which can reflect the difficulty of processing indirectly. According to the indexing accuracy error model and tolerance proportional model, the pass rate model of end-toothed disc is established and a new approach for tolerance development is put forward based on this pass rate model to enable high-precision assemblies to be manufactured at lower costs. Simulation program for the meshing of end-toothed discs is developed to verify the correctness of the proposed approach for tolerance development in the end, according to random sequence generation of MATLAB which replaces the processing errors measurement.

2. Analysis on the influence of the processing errors of end-toothed disc among indexing accuracy

The processing error of end-toothed disc is one of the determinants of its indexing accuracy. Therefore, it is a prerequisite for the design of end-toothed disc to identify the main processing errors and analyze the influence of which among indexing accuracy by fully grasping the meshing characteristics. In this paper, a pair of end-toothed discs of a servo turret is taken as the analysis object, as shown in Fig. 1. In this section, three processing errors are introduced for the pair of discs, including accumulative pitch error, tooth trace error and tooth profile half-angle error [20]. Moreover, in order to completely describe tooth profile deviations, tooth width error is proposed to describe the deviations of the benchmarks of both tooth trace error and tooth profile half-angle error. Then, the indexing accuracy error model is established according to the four errors.

The nomenclature about the parameters of the end-toothed disc used in this paper is shown in Table 1. All the parameters below use the description in Table 1 without special instructions. The inner circle of end-toothed disc whose diameter

Download English Version:

https://daneshyari.com/en/article/7179256

Download Persian Version:

https://daneshyari.com/article/7179256

Daneshyari.com