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Effects of misalignment error, tooth modifications and transmitted torque on tooth engagements of a pair of spur gears

Shuting Li *

Department of Mechanical, Electrical and Electronic Engineering, Interdisciplinary Faculty of Science and Engineering, Shimane University, Matsue 690-8504, Japan

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ABSTRACT

In the last research [S. Li, Effects of machining errors, assembly errors and tooth modifications on load-carrying capacity, load-sharing rate and transmission error of a pair of spur gear, Mech. Mach. Theory 42 (2007) 698–726], effects of machining errors, assembly errors and lead crowning on tooth surface contact stresses (CS), root bending stresses, load-sharing ratios (LSR) and transmission errors of a pair of spur gears were investigated through performing loaded tooth contact analysis (LTCA) with developed finite element method (FEM) programs. But this research couldn't investigate the effects of tooth profile modification and lead relieving on tooth engagements. Also, the effects of machining errors, assembly errors and tooth modifications on tooth mesh stiffness (MS) couldn't be investigated. So, as a continuous study of the last research, this paper investigates the effects of tooth profile modification and lead relieving on tooth engagements of a pair of spur gears and the effects of misalignment error of gear shafts on the plane of action, tooth lead crowing and transmitted torque on tooth MS. An arc curve is used to modify tooth profiles of a pair of spur gears in this paper. This is because this method is used very popularly for the spur gears. Methods used in the last research are also used here to investigate the effects of the tooth profile modification, lead relieving and transmitted torque on tooth engagements. Based on the results, it is found that the tooth profile modification and lead relieving have significant effects on tooth CS, LSR and MS. It is also found that transmitted torque has a little effect on tooth MS, but has no effect on LSR of the gears. For the lead-relieved gears, calculation results show that edge-loads happened at the joint parts of the relieved part and the non-relieved part of tooth lead when the lead is relieved with straight lines. Since the edge-loads resulted in greater contact stresses at the joint parts and weakened tooth contact strength, attention must be paid to the lead relieving. It is necessary to reduce the edge-loads as small as possible through making the joint part smooth when the lead relieving is made.

1. Introduction

It is well-known that machining errors, assembly errors and tooth modifications of a pair of gears have significant effects on vibration, noise and strength of the pair of gears. Though this problem has been well investigated by many researchers [1–20], many problems, such as how to estimate vibration, noise and strength levels of a pair of gears with the machining errors, assembly errors and tooth modifications exactly in theory, have not been solved completely.

Umezawa et al. [3–6] conducted researches on tooth MS calculations of a pair of gears with tooth surface deviations using an analytical method. In Umezawa's research, tooth deformation was divided into tooth deflection and tooth approach (resulted from

* Tel./fax: +81 0852 328908.
E-mail address: shutingli@ecs.shimane-u.ac.jp.

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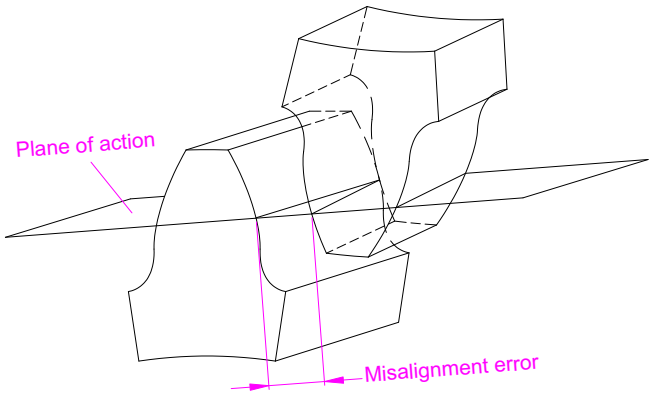

Fig. 1. Image of contact teeth with misalignment error on the plane of action.

the Hertzian contact of contact teeth). The tooth deflection was calculated by a cantilever theory and the tooth approach was calculated by the *Sneddon* equation. Effect of the tooth surface deviations on rotational vibration of a pair of helical gears was also investigated [7].

Since it is a difficult thing to use *Umezawa*'s method to solve tooth contact problems of a pair of gears with complicated machining errors, assembly errors, tooth profile modifications and thin rims, *Li* [11,12] developed FEM software to do LTCA of a pair of gears with machining errors, assembly errors and tooth modifications based on the principle of the mathematical programming method presented by *Conry* and *Seireg* [13,14]. In the last research of the author [12], effects of machining errors, assembly errors and lead crowning on tooth surface CS, root bending stresses, LSR and transmission errors of a pair of spur gears were investigated using the developed FEM software. But this research couldn't investigate the effects of tooth profile modification and lead relieving on tooth engagements. Also, the effects of the machining errors, assembly errors and tooth modifications on tooth MS of a pair of spur gears couldn't be investigated. So, as a continuous study of the last research, this paper investigates the problems that have not been solved in the last research. The same methods and FEM programs are used to do LTCA of a pair of spur gears with tooth profile modification and lead relieving. The effects of misalignment error on the plane of action, tooth lead crowing and transmitted torque on tooth MS of the pair of spur gears are also investigated.

Based on calculation results, it is found that tooth profile modification and lead relieving have significant effects on tooth CS, LSR and MS. It is also found that transmitted torque has a little effect on tooth MS, but has no effect on LSR of the gears. For the lead-relieved gears, edge-loads happened at the joint parts of the relieved part and the non-relieved part of the tooth lead when the lead is relieved with straight lines. Since the edge-loads resulted in greater contact stresses at the joint parts and weakened the tooth contact strength, it is necessary to reduce the edge-loads as small as possible through making the joint part smooth when the lead relieving is made.

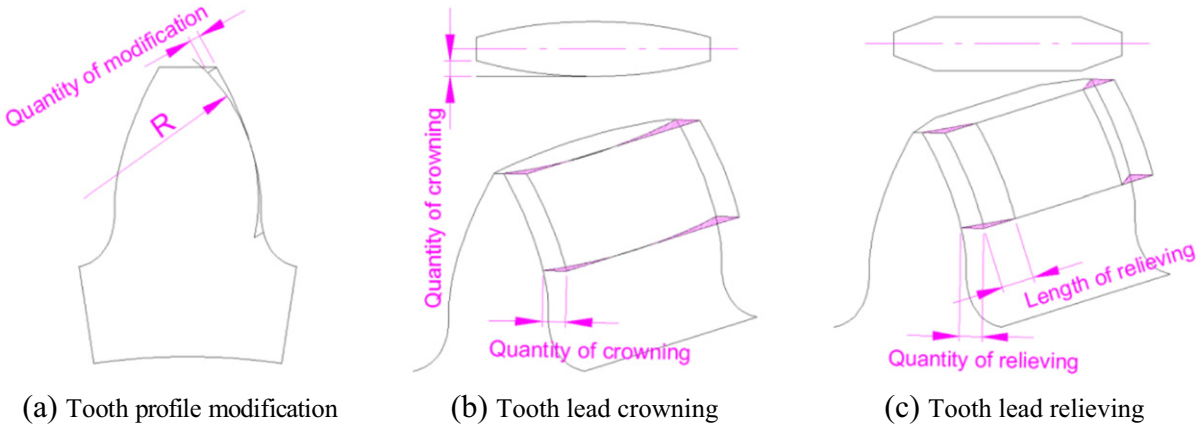

Fig. 2. Image of tooth profile modification, tooth lead crowning and tooth lead relieving.