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Analysis method of tooth meshing condition and motion of gears

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1. Introduction

The fluctuation in rotational motion of gears is a critical issue for gear designers. Effective methods of analyzing motion error are needed. Based on the author's developed method [1], this study proposes a new function of stiffness considering actual contact ratio (c.f. Fig. 1). By comparing the obtained results of motion error from the new method and the previous method, the effectiveness is validated.

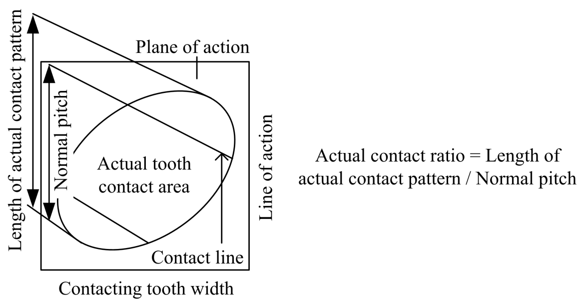

Fig. 1 Definition of actual contact ratio

2. Novel general model of tooth meshing condition

2.1 Tooth flank form deviation

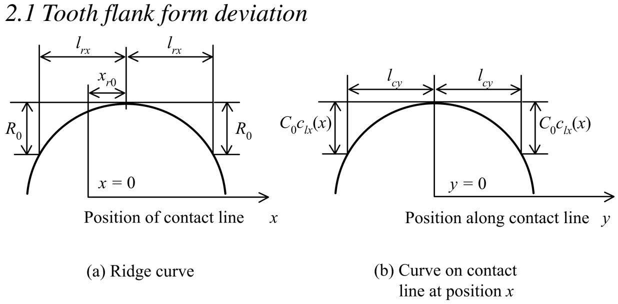

Fig. 2 Definition of ridge curve of tooth flank form and its curve on contact line

Figure 2(a) shows a schematic diagram of the infinitely expanded ridge curve on tooth flank [1]. The ridge curve $R(x)$ is represented as:

$$R(x) = R_0\left(\frac{|x - x_{r0}|}{l_{rx}}\right)^s \tag{1}$$

Figure 2(b) shows a schematic diagram of the deviation form on the contact line at position x. The form of the curve on the contact line is expressed:

$$C(x, y) = C_0 c_{lx}(x) c_{ly}(y) \tag{2}$$

$$c_{lx}(x) = 1 + (c_x - 1)\left(\frac{|x - x_{c0}|}{l_{cx}}\right)^u \tag{3}$$

$$c_{ly}(y) = \left(\frac{|y|}{l_{cy}}\right)^v \tag{4}$$

2.2 Tooth meshing stiffness

The non-linear change of stiffness against the variations in the actual contact ratio is represented as follows:

$$K(x, h_1, \varepsilon) = K_0 s_{tx}(x) s_{tc2}(x, h_1, \varepsilon) \tag{5}$$

$$s_{tx}(x) = 1 - (1 - k_x)\left(\frac{|x - x_{k0}|}{l_{kx}}\right)^i \tag{6}$$

$$s_{tc2}(x, h_1, \varepsilon) = 1 - (1 - k_2)\left(\frac{\left|x - \frac{2h_1 - \varepsilon}{2}\right|}{\frac{\varepsilon}{2}}\right)^{ii} \tag{7}$$

where K_0 controls the magnitude of the unit stiffness and ε is actual contact ratio. Figure 3 shows the definitions of the proposed function of unit stiffness.

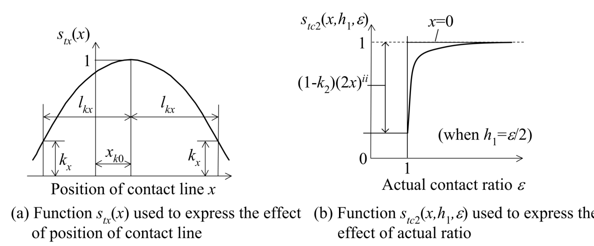

Fig. 3 Functions to define stiffness

2.3 Formulation of motion error

From the expressions mentioned, the absolute amount of motion error T_e is represented as:

$$T_e = R_0\left\{r_{id}(x) + \zeta\left(\frac{r}{s_{tx}(x) s_{tc2}(x, h_1, \varepsilon) t_r(x)^2}\right)^{\frac{v}{v+1}} c_{lx}(x)^{\frac{1}{v+1}}\right\} \tag{8}$$

$$\zeta = \frac{C_0}{R_0}\left(\frac{l_{cl}}{2l_{cy}}\right)^v \left(\frac{c_{lx}(x) s_{tx}(x) s_{tc2}(x, h_1, \varepsilon) t_r(x)^2}{r}\right)^{\frac{v}{v+1}} \tag{9}$$

The normalized motion error T_{e0} is defined:

$$T_e = R_0 T_{e0} \tag{10}$$

3. Effect of changes of parameters in distribution function of unit stiffness

Figure 4 shows the distribution function of unit stiffness on x-direction under each value of parameter k_x. The conditions that, compared with the stiffest contact line (at the center of tooth flank), the stiffness of other contact lines are lower can be expressed by parameter k_x.

The changes of the actual contact ratio at peak and valley and also the amplitude of motion error at peak against parameter k_x is shown in Fig. 5. It can be concluded that parameter k_x has an influence on the actual contact ratio at peak and valley and also the amplitude of motion error at peak position. Figure 6 shows the distribution function of unit stiffness on x-direction under each value of parameter i.

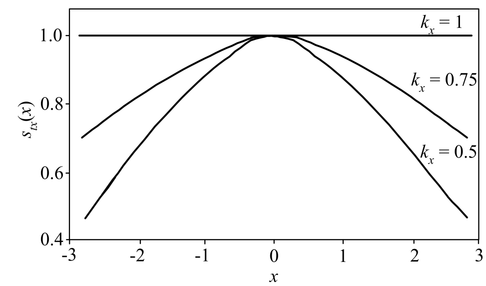

Fig. 4 Relationship between parameter k_x and position of contact line, x

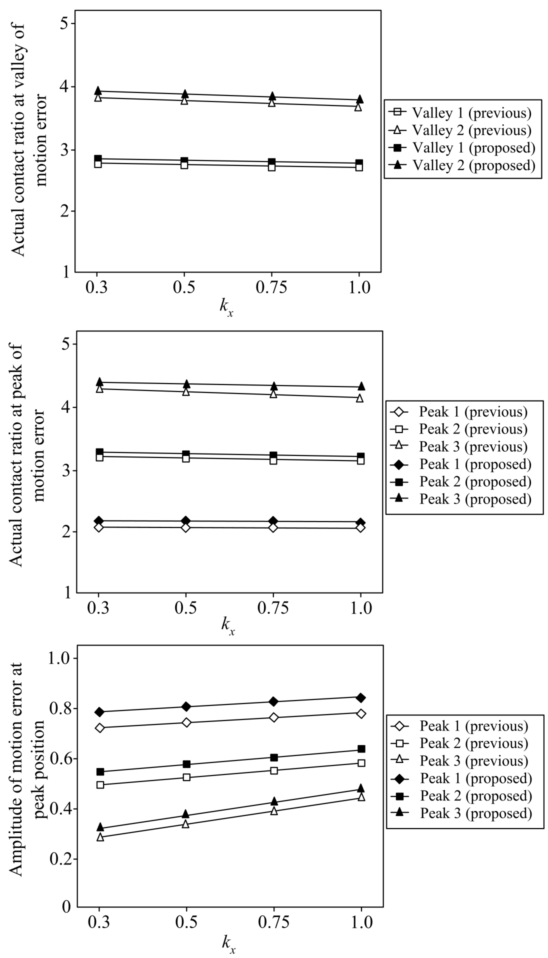

Fig. 5 Relationship between parameter k_x and motion error at peak and valley positions

Figure 7 shows the changes of against the amplitude of motion error at peak position against parameter i. Overall, the effect of parameter i is very small. Based on these results, previous method and the newly proposed method show the identical trend.

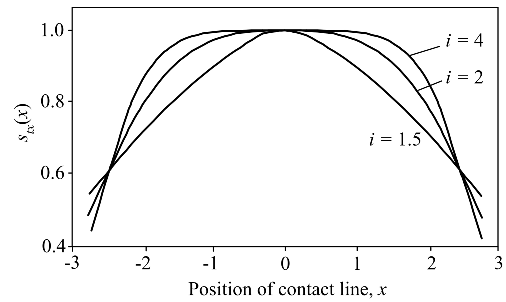

Fig. 6 Relationship between parameter i and position of contact line, x

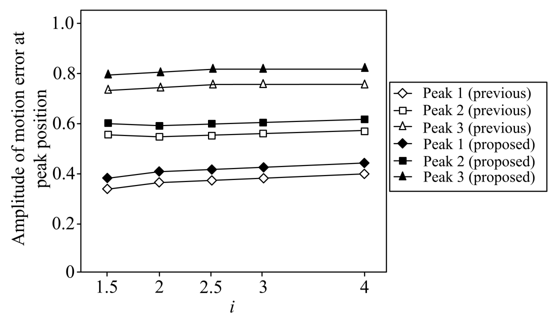

Fig. 7 Relationship between parameter i and motion error at peak and valley positions

4. Conclusions

In this report, by using a formulation for gear motion error based on a general model for meshing condition, the effectiveness of the newly proposed method to represent the stiffness was analyzed. The results obtained by both methods show that the analyzed characteristic of the motion error were in a good correspondence between the proposed method and the previous one.

Acknowledgment

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References

[1] E. Niza Mohamad, M. Komori, Hiroaki Murakami, A. Kubo, and Suping Fang (2009), Analysis of General Characteristics of Transmission Error of Gears With Convex Modification of Tooth Flank Form Considering Elastic Deformation Under Load, Journal of Mechanical Design, Vol. 131, No. 6