**An example of finite element analysis of PNLG and involute non-circular gear**

This document introduces an example of FEA of pure-rolling non-circular line gear andinvolute non-circular gear. All simulation operations were completed in Ansys software. The specific steps were shown in the following three steps.

The first step was to establish the three-dimensional solid model. The model of PNLG as established by sweeping method, while the model of non-circular involute gear was generated by Gearify software. Moreover, non-circular involute gear could also be generated according to the method in Ref. [1]. The involute non-circular gear and the PNLG had the same pitch curve, namely, the transmission ratio curves of two gear pairs were the same. Furthermore, the center distance and the maximum outer diameter of two gear pairs were consistent.

The second step was to set material properties, mesh and set boundary conditions. After the 3D solid model was established, it was import into Ansys. In order to shorten the calculation time, few teeth FEA model was established, as shown in Fig. 1. Two pairs of rigid surfaces corresponding to the driving gear and driven gear were built to apply rotation velocity and torque respectively. Rigid surfaces of gears were connected to the reference node located on the axis of rotation. The frictional contact model was applied to the contact pair. Tetrahedron elements were used to mesh the line teeth, and contact tooth surfaces were meshed by the local mesh refinement. In addition, the material was stainless steel whose Young’s modulus was 180GPa and Poisson’s ratio was 0.3. Finally, a rotation velocity of 20 degrees per second was applied on rigid surfaces of the driving gear and a torque of 0.1Nm was applied on the driven gear, and the velocity and torque were applied by using of a slope function. The total simulation time was 4s, and the time step was 1×10-3s. It was worth noting that the involute non-circular gear and the PNLG had the same pitch curve, namely, the transmission ratio curves of two gear pairs were the same. Moreover, the center distance and the maximum outer diameter of two gear pairs were consistent.

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Fig. 1 The finite element analysis model of PNLG (a) and involute non-circular gears (b).

The third step was to output and process the results. The rotation angle of driving gear, the rotation angle of driven gear, the speed of driving gear, the speed of driven gear, the bending stress, the contact stress and the position of maximum contact stress could be directly output. And then based on these data, the error of the rotation angle, the transmission ratio and sliding rate could be calculated. When the transmission ratio of PNLG and that of involute gear pair changed from 1.5 to 1, the FEA results of contact stress, teeth root bending stress and sliding rate of two non-circular gears were shown in Fig. 2. Furthermore, Table 2 showed the comparison results of average error of transmission ratio (), standard deviation of transmission ratio error (), maximum contact stress (), maximum root bending stress () and maximum sliding rate ().

From the comparison results of the FEA in Fig. 2 and Table 1, the contact stress of involute non-circular gear with line contact is less than that of PNLG, while the root bending stress of involute non-circular gear is greater than that of PNLG. This is because the involute gear has more teeth and smaller tooth thickness. From the standard deviation of transmission ratio error in Table 1, the involute gear has a larger value, which is mainly due to the change of meshing stiffness when odd and even teeth alternating meshing. From the results of sliding rate, the sliding rate of involute gear pair is 0 at the pitch curve, and the maximum sliding rate is -0.489, while the sliding rate of PNLG is very small in the whole process.

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Fig. 2 The FEA results of contact stress (a), teeth root bending stress (b) and sliding rate (c) of two non-circular gears.

Table 1 The comparisons of FEA results of PNLG and involute non-circular gears.

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| Terms |  |  | [Mpa] | [Mpa] |  |
| PNLG | 0.008 | 0.013 | 442.96 | 40.04 | 0.013 |
| Involute gear | 0.011 | 0.065 | 138.92 | 76.89 | -0.489 |

[1] Vasie, M., Laurentia, A., Design and generation of noncircular gears with convex-concave pitch curves. The Annals of ”Dunarea de Jos” University of Galati, Fascicle V, Technologies in machine building, Vol. 30, No.2 (2012), pp. 55-60.