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Influence of Involute Sprocket Tooth Number on Wear Elongation of Chain Drive

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Abstract

The wear elongation of chain drive has a great relationship with the tooth profile of sprocket. But for sprocket with the same pitch of silent chain, the design parameters of involute sprocket change with the number of teeth of sprocket, so the number of teeth of involute sprocket has an inevitable influence on the wear elongation of chain drive. The influence of tooth number on the main parameters of involute sprocket tooth profile has been analyzed, and the influence of sprocket tooth number on the wear elongation of chain drive has been studied by 240 hours bench test. The analysis and results shown that with the increase of sprocket teeth number, the wear elongation of chain decreases obviously, which can effectively prolong the service life of chain.

Keywords

Sprocket teeth number; Wear elongation; Modification coefficient; Circular tooth thickness.

1. INTRODUCTION

Silent chain is an important mechanical foundation which is widely used. Especially under the working conditions of high speed, heavy load, low noise and large center distance, its transmission performance is superior to that of toothed belt transmission, gear transmission and roller chain transmission, and it has become one of the preferred transmission forms in many industries. The wear elongation of silent chain is one of the important indexes to judge its reliability. How to strengthen the wear performance of silent chain, reduce the wear elongation and improve the stability of chain drive has been regarded as one of the technical problems by chain drive researchers at home and abroad for many years.

Researches shown that the factors affecting the wear elongation of silent chain mainly included: material selection, heat treatment process, assembly accuracy and meshing mechanism of silent chain, etc. However, no conclusion has been given about the influence of tooth profile of sprocket on silent chain drive's wear elongation.

About the chain drive design, the determination of sprocket parameters is an important factor affecting the design quality. Among them, the number of sprocket tooth Z has an influence on all the main design parameters of sprocket tooth profile. This paper analyzed the influence of sprocket tooth number on the main design parameters of sprocket tooth profile. Through experiments, the influence of sprocket tooth number Z on wear elongation ε of silent chain drive was studied. The results shown that when the sprocket tooth number $Z<120$, the chain wear elongation decreases obviously with the increase of sprocket tooth number, which could effectively improve the service life of the silent chain.

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2. INFLUENCE OF SPROCKET TOOTH NUMBER ON MAIN DESIGN PARAMETERS OF SPROCKET

About the chain drive design, the determination of sprocket parameters is an important factor affecting the design quality. When the pitch of the silent chain is determined, the sprocket tooth number Z has influence on the main design parameters, such as the modification coefficient χ of the sprocket tooth profile, the diameter of the graduation circle D, the diameter of the addendum circle Dt, the diameter of the base circle Db, the diameter of the bottom circle De, the meshing point K, the pressure angle α_k of the meshing point, and the arc tooth thickness S relative to each diameter.

2.1. Influence of Tooth Number on Modification Coefficient

Involute sprocket can be regarded as involute gear with large negative modification coefficient, and the formula of sprocket displacement coefficient can be obtained as formula (1).

$$\chi = \frac{\pi}{4\tan\alpha_2} - \frac{Z}{2} + \frac{\pi}{2}\cot\frac{\pi}{Z} - \frac{\pi\tau}{p_2\sin\alpha_2} \tag{1}$$

In the formula (1), α_2 is normal pressure angle of sprocket hob, τ is chain plate apothem, p_2 is normal pitch of sprocket hob.

When $\alpha_2 = 30°, \tau = \frac{3}{8}p, p_2 = p$, formula (1) can be simplified to formula (2).

$$\chi = \frac{\sqrt{3}\ (1-\sqrt{3})}{4}\pi - \frac{Z}{2} + \frac{\pi}{2}\cot\frac{\pi}{Z} \tag{2}$$

According to formula (2), the change of sprocket modification coefficient χ was only related to the number of tooth Z, and its change curve with the increase of the tooth number was shown in Figure 1.

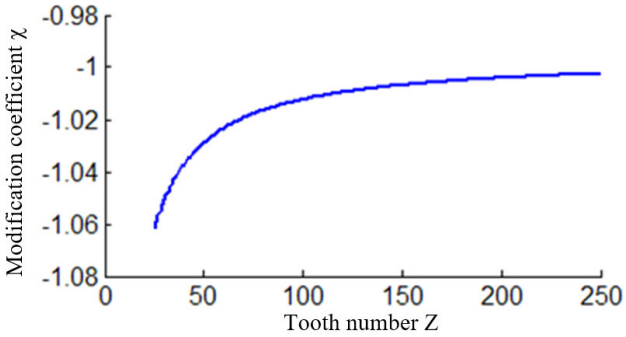

Fig 1. Modification coefficient χ change curve with the increase of the tooth number

It could be seen from Fig. 1 that the absolute value of sprocket modification coefficient χ decreases with the increase of sprocket tooth number Z, and when the tooth number 25<Z<120, the absolute value of modification coefficient χ decreases rapidly with the increase of tooth number Z, When the tooth number Z>120, the decrease of the absolute value of the modification coefficient χ could be neglected. Therefore, when the designed sprocket was less than 120 teeth, its tooth number Z has great influence on its modification coefficient χ.

2.2. Influence of Tooth Number on Meshing Point

According to reference [2], in the Fig.2, the coordinates (xA, yA) of the meshing point A between the silent chain and the involute sprocket is:

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$$A((r_b \sin\alpha - r_b \emptyset_A \cos\alpha),\ (r_b \cos\alpha + r_b \emptyset_A \sin\alpha)) \tag{3}$$

And in the formula (3)

$$\alpha = \emptyset_A + \beta \tag{4}$$

$$\beta = \frac{3\pi}{2Z} - \frac{2\chi \tan\alpha}{Z} - \mathrm{inv}\alpha \tag{5}$$

By calculating formula 3 to formula 5, the meshing circle radius can be obtained:

$$r_n = \sqrt{{x_A}^2 + {y_A}^2} \tag{6}$$

$$\text{Ordered}\ \ \Delta r = r_t - r_n \tag{7}$$

When $\alpha = 30°$,it could be obtained:

$$\Delta r = r\left(1 - \frac{\sqrt{3}}{2}\sqrt{1 + \emptyset_A^2}\right) + \frac{(1+\chi)p}{\pi} \tag{8}$$

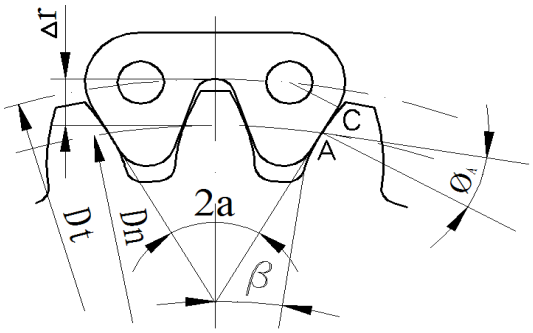

Fig 2. Schematic diagram of meshing and positioning of chain plate and sprocket

When the silent chain's pitch is a constant value, taking p=12.7mm as an example, Curve of the distance Δr from meshing circle to addendum circle with the change of teeth number Z can be obtained, as shown in Fig. 3.

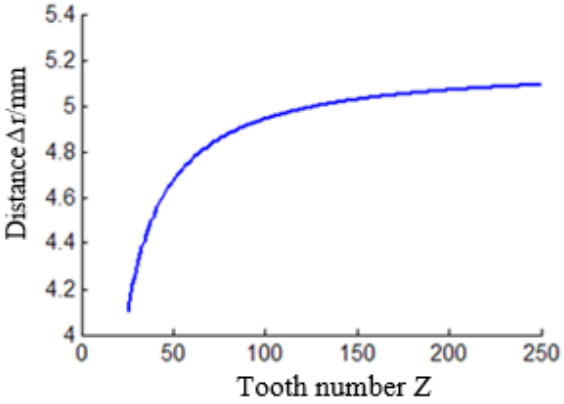

Fig 3. Curve of the distance Δr from meshing circle to addendum circle with the change of teeth number Z

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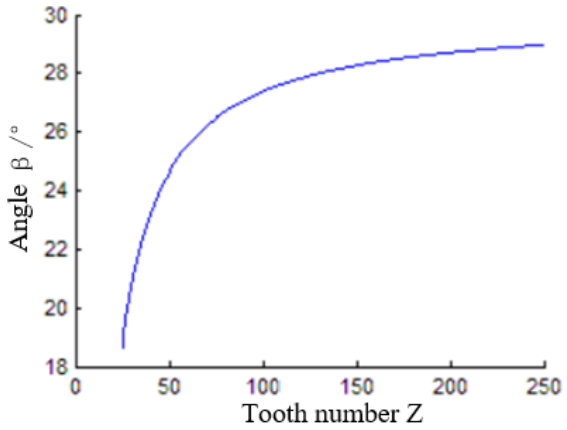

Fig 4. Angle change curve with the change of teeth number Z

It can be seen from Fig. 3 and Fig. 4 that with the increase of sprocket tooth number Z, the involute part of tooth profile used for tooth chain meshing gradually moved up, and the meshing angle β gradually increase, and so the polygon effect, the meshing impact and wear in the transmission process would be reduced.

2.3. Influence of Tooth Number on Arc Tooth Thickness

It can be obtained from Fig. 5 that the center angle γ corresponding to the arc tooth thickness S_r corresponding to the arbitrarily determined diameter $D_r(D_e < D_r < D_t)$ is:

$$\gamma = \frac{\pi+4\chi\tan\alpha}{z} + 2(\text{inv}\alpha - \text{inv}\alpha_r) \tag{9}$$

$$\alpha_r = \arccos(\frac{D\cos\alpha}{D_r}) \tag{10}$$

$$S_r = \frac{D_r}{2}\gamma \tag{11}$$

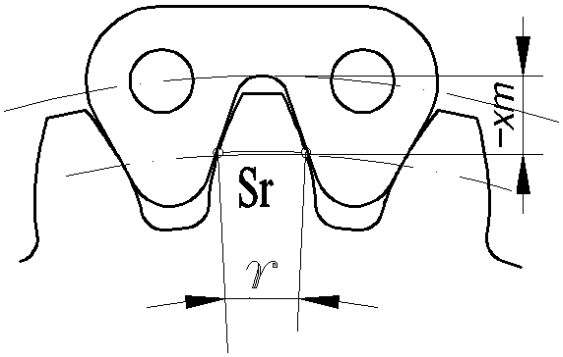

Fig 5. Schematic diagram of arc tooth thickness

When the pitch is a constant value, taking p=12.7 mm as an example, when $D_r = D_t$, $D_r = D_n$, the tooth thickness S_t and S_n changing with the number of tooth Z were shown in Fig. 6 and Fig. 7

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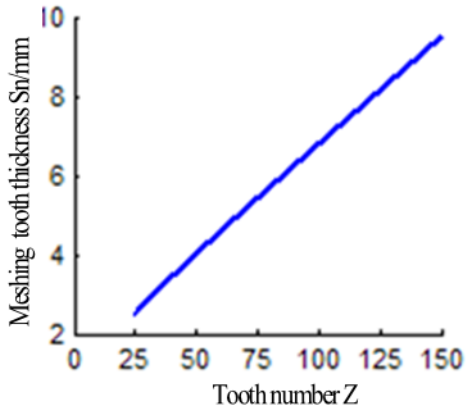

Fig 6. Meshing tooth thickness change curve with the change of teeth number Z

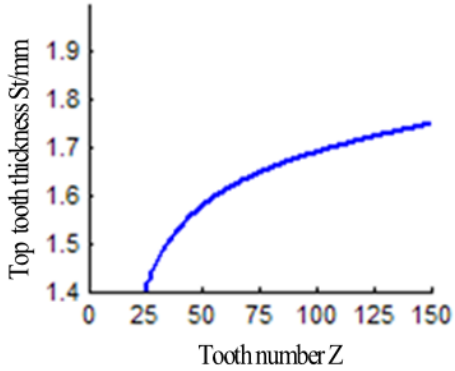

Fig 7. Top circular arc tooth thickness change curve with the change of teeth number Z

3. WEAR TEST

Under the same working conditions, the wear test of 250 hours was carried out by using a closed force-flow test-bed. The test chain adopted standard silent chain with pitch p=12.7 mm and the test sprocket teeth number was 25,35,45 and 60. The test chain was removed from the test-bed every 24 hours, and the length of 30 chain links after wear was measured by Lcc-1500 chain length measuring instrument, and the wear elongation could be calculated. Closed force-flow test-bed was shown in Fig.8, and the Lcc-1500 chain length measuring instrument was shown in Fig.9.

Fig 8. Closed force-flow test-bed

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Fig 9. Lcc-1500 chain length measuring instrument

As shown in Fig.10, the change curve of wear elongation obtained by analysis and calculation shown that when the sprocket tooth number Z was the same, the wear elongation increases with test time, and when the wear test time was the same, the wear elongation decreases obviously with the increase of the sprocket tooth number Z.

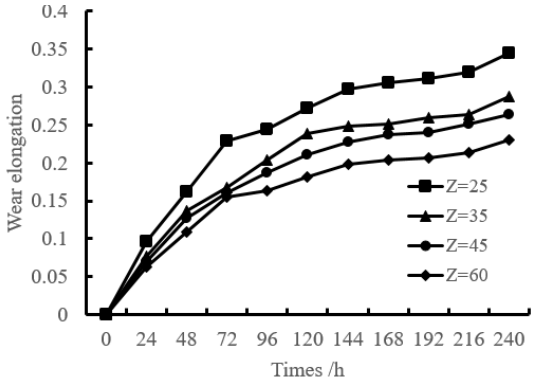

Fig 10. Change curves of wear elongation

4. CONCLUSION

Chain wear elongation is an important factor affecting its service life. This paper analyzed the influence of sprocket tooth number on the main design parameters of sprocket tooth profile. Through experiments, the influence of sprocket tooth number Z on wear elongation of silent chain drive was studied. The results shown that the chain wear elongation decreases obviously with the increase of sprocket tooth number, which could effectively improve the service life of the silent chain.

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