

Research on the effects of geometrical parameter of flexspline on harmonic reducer

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Abstract. The paper obtains the equivalent stress of the two kinds of flexsplines after inserted into the wave generator according to the principle of harmonic gear reducer and using finite element method got different flexspline models with different length and length of the gear tooth to study how these factors influence their equivalent stress.

Introduction

Harmonic gear drive with its advantage of simple structure, less parts, small volume, light weight, large transmission ratio, and high transmission precision has been widely used in aerospace, robotics, optical manufacturing equipment, and other important fields. As a core component of a harmonic gear reducer, flexspline has various kinds of structures, the cup-shaped flexspline and flanging flexspline were used regularly because of their easy making and higher capacity of bearing load. The paper based on these two kinds of flexsplines as the research objects, and established the simulation entity models, compared the two kinds of flexspline's equivalent stress and deformation after inserted the wave generator through the way of finite element analysis, offering the reliable references of the application for using the two kinds of flexsplines.

The model of the two flexsplines

The main part of the above two kinds of flexsplines are similar, but they have different bases. The cup-shaped flexspline has the inward bottom, and the flanging one has outward bottom as shown in Fig. 1.

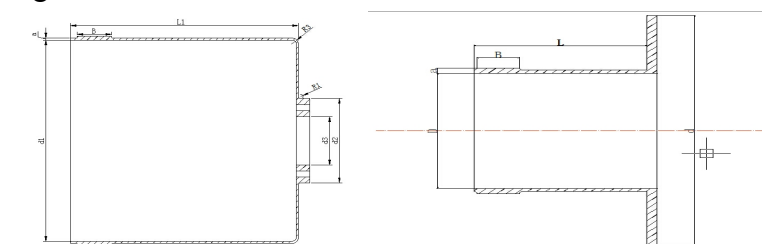


Fig.1 The structure of flexsplines

The involute tooth profile was widely used in the harmonic reducer's flexspline because of its good manufacturing process, so the flexspline's model with the involute gear tools was built in the software Solidworks. Because a flexspline had a lot of tooth the module of the two kinds flexspline

must be smaller $m=0.5$ and the pressure angle $\alpha=20^\circ$, the number of tooth $Z=200$, axial length $L=100\text{mm}$, the thickness of tube part $\delta=1\text{mm}$, deformation coefficient $m^*=0.8$.

The stress analysis of the flexsplines after initial deformation

Setup for the finite element analysis

Before the finite element analysis of the flexspline the model of flexspline must be imported to the software ABAQUS, during the process of simulation the half of a flexspline can be used because of its structure and load were symmetry, so the computational cost be obviously reduced. As for the property of the material the elasticity modulus $E=210000$, and Poisson ration $\nu=0.3$. In order to improve the accuracy of finite element analysis the model was divided into hex shape mesh and the element type chose C3D8R (an 8-node linear brick, reduced integration, hourglass control).

The wave generator was simplified as a oval annulus, the cross-section of a flexspline was circular before the generator inserted it and during the process of initial deformation the internal surface of the flexspline contacted the outside surface of wave generator, the flexspline was squeezed, resulted in forced deformation. The initial step of the finite element analysis was set up as nlgeom process. In the process of the simulation set the initial reference point of the wave generator under the bottom of the flexspline, the bottom of the flexspline was set to completely fixed, the symmetric cross section was set to the symmetry constraint, the wave generator's outside surface and flexspline's inner surface was set as face to face contact, the wave generator's outside surface was the active one.

The result of finite element calculation

The stress distribution of the flexspline affect the reliability and the service life of the harmonic gear reducer, the wave generator extruded the flexpline along the radial direction to simulate the assemble process. The results of equivalent stress distributions are as shown in Fig.2. So we can see that the two kinds of flexsplines' equivalent stresses are all symmetrical distribution alone the round edge, the equivalent stress of the flanging flexspline were significantly greater than the cup-shaped flexspline, the gear tooth part distribute bigger stress, the largest equivalent stress is taken place at the end of the tooth root part. The deformation of other part was small so it got lesser stress, the round angle in the bottom can decrease the initial cylinder stress caused by initial deformation effectively.

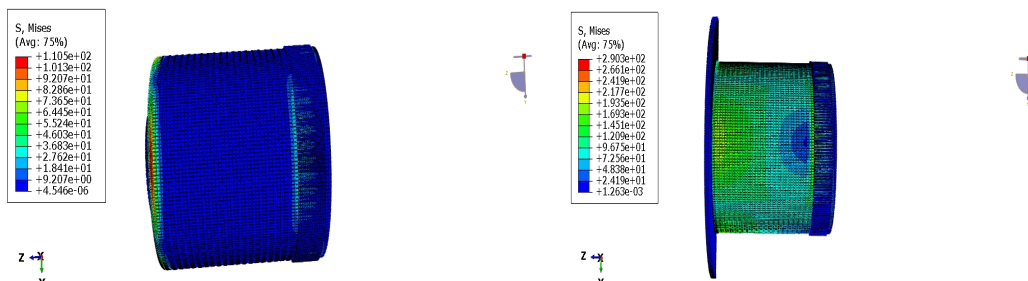


Fig.2 The stress distribution on the two kinds of flexsplines

The equivalent stress distribution along the long axial direction of the two kinds of flexsplines' maximum radial deformation part are as shown in Fig 3. The result show that the cup-shaped flexspline's equivalent stress is less than the flanging one in every part of the structure and the stress along the tube part of the cup-shaped flexspline is stable in a smaller range, however, it would become larger at the bottom of the flexspline gradually, because of the border effect. We can also see that the heel row of teeth part and bottom of the flexspline are parts of stress concentration. The circumferential stress distribution on the two kinds of flexsplines' heel row of

teeth part are shown in Fig 4, the result shows that the maximum equivalent stress of the flanging flexspline is about 5 times larger than the cup-shaped one and the equivalent stress in cylinder part presents linear increasing, so the design of round angle can reduce the stress of gear ring and cylinder part effectively. The equivalent stress on the heel row of teeth part of the two kinds of flexspline is symmetrical. The maximum equivalent stress of the tooth root part of flanging flexspline is 4.5 times larger than the cup-shaped one. By contrast we can conclude that the cup-shaped flexspline generates smaller equivalent stress than the flanging flexspline at the initial deformation stage so the cup-shaped flexspline should be used when a harmonic gear reducer bears the larger load.

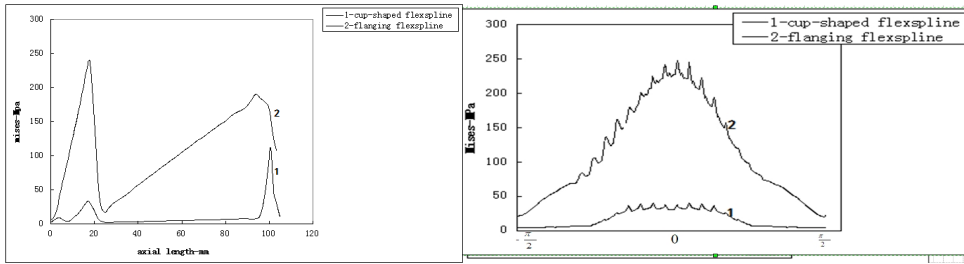


Fig.3 The axial equivalent stress Fig.4 Circumferential stress

The influence of the geometric parameters of two kinds of flexsplines on their equivalent stress

When the length of the flexspline was changed without changing other geometrical parameters, the models with a different length to diameter ratio (from 0.5 to 1.1). From these different models' finite element analysis we get the maximum equivalent stress as shown in Fig 5, the result show that the maximum equivalent stress became smaller gradually as the length to diameter ratio increased, the equivalent stress caused by initial deformation of flanging flexspline reduced obviously. When the length to diameter ratio reached 0.8 the equivalent stress changed in a small range. So the way by decreasing the length of flexspline the volume of harmonic gear reducer can be reduced, but the flexspline's equivalent stress would be increased significantly. So for a smaller harmonic gear reducer a cup-shaped flexspline is more suitable than a flanging flexspline.

The length of the gear tooth effects the bearing ability of a harmonic gear reducer, besides the longer tooth can improve the rigidity of the flexspline. So the length of the gear tooth must be in a certain range in order to get the better bearing ability. In order to study which factors affect the equivalent stress of the flexspline we can change the length of the gear tooth and so get some different models. As shown in the Fig.6, the curves describe the maximum equivalent stresses in the models with different length of gear tooth, the maximum equivalent stress increases as the length of gear tooth elongating. The two kinds of curves of the maximum equivalent stress parallel to each other, the maximum equivalent stress on flanging flexspline is about 2.6 times large than the cup-shaped one. So the length of the gear tooth was not the main factor that affects the equivalent stress of the two kinds of flexsplines. The flexspline is under the effect of cyclic stress when it works, in order to improve the service life, the length of the gear tooth should be designed as short as possible on the premise of satisfying its application.

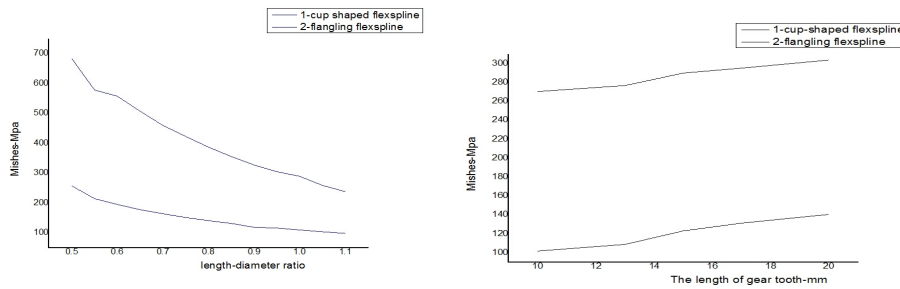


Fig.5 Flexspline with different axial length Fig.6 Flexspline with different length of gear

Conclusions

In this paper, we use the software ABAQUS to simulate the process of flexspline's initial deformation and study the distribution of equivalent stress, then study how the length to diameter ratio and the length of gear tooth affect the stress on the flexspline, the following conclusions can be gotten.

- (1) The maximum equivalent stress of the flanging flexspline is at the heel row of tooth part, and the equivalent stress on the tube increases linearly on the axial direction, the absolute value of the equivalent stress of a cup-shaped flexspline are smaller, and their maximum is at the round part.
- (2) The length of the gear tooth is not the main factor that affects the equivalent stress of two kinds of flexsplines, but the length to diameter ratio is, and the flanging one is affected obviously.

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