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Deflection phenomena on compound synchronizer rings study of the effect of friction temperature and wear

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Abstract: *To address the problem of local wear of composite synchronous rings caused by deflection. This paper proposes a method to optimize the friction performance of the composite synchronous ring by adding brass fibres to carbon fibres. Firstly, the force analysis and working model of the composite synchronizer ring which has been deflected are carried out. Finite element analysis software is used to simulate the position, trajectory and force direction of the composite synchronizer ring in the gearbox by using the previous composite synchronizer ring bias oscillation force analysis and working model. Secondly, the material parameters of the composite synchronizer ring are assigned values and combined with the friction contact mechanism and thermal analysis theory to simulate and analyze the friction temperature and wear of the composite synchronizer ring. The results show that the inner side of the composite synchronizer ring has higher friction temperature and wear compared with other areas. Finally, in order to mitigate the effects of the offset pendulum, the addition of brass fiber to carbon fiber is simulated by changing the material properties, and the conclusion shows that the addition of brass fiber reduces the friction temperature by about 20%; reduces the wear of the composite synchronizer ring by about 5%, so that the composite synchronizer ring is able to provide synchronous torque in a more stable manner.*
Keywords: Composite synchronizer ring, Deflection phenomenon, Friction temperature, Wear, Brass fibers

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I. Introduction

With the vigorous development of the automotive field, the synchronizer, as one of the key components of the vehicle, is being optimized and improved [1-3]. Synchronizer is squeezed by external force during operation, so that the speed difference between bevel gear and intermediate gear gradually decreases, and the synchronization phase ends when the speed between the two gears gradually converges. This synchronization process relies on the direct contact of the synchronizer's friction pair to generate frictional torque to achieve. Therefore, the friction performance of the synchronizer friction pair directly affects the smoothness of the automobile gear shift. At present, in order to meet the demand for high wear resistance of automotive synchronizers, synchronizers consisting of composite synchronizer rings have come into being. Chen Chengying et al [4] described the method of bonding carbon fiber cloth to the friction cone of synchronizer ring by high temperature adhesive under high temperature and high pressure for the technical requirement of high temperature and high pressure bonding curing process of friction material. Hu Qiaoqing et al [5] discussed several types of friction materials for synchronizer rings and their advantages and disadvantages, and introduced the pretreatment process of carbon fiber cloth when composite synchronizer ring friction materials are used. Chandramohan K et al [6] discuss how to replace brass synchronizer rings with composite synchronizer rings to extend the service life of synchronizers. The results show that composite synchronizer rings show greater strength and durability properties compared to brass. Compared with the early copper alloy synchronizer ring and molybdenum spray synchronizer ring, the composite synchronizer ring exhibits excellent characteristics such as high wear resistance and high heat resistance [7-9]. However, small gaps in the synchronizer ring assembly process, uneven shifting force applied to the joint sleeve and unstable friction between the internal components lead to the generation of synchronizer ring deflection [10-13].

Therefore, mitigating the hazards posed by the deflection pendulum phenomenon to composite synchronous rings has become a hot research problem today [14-16].Zhang R., Li Yajuan et al [17-18] demonstrated that the existence of a clearance gap of about 0.5-1.2 mm in the axial direction of the synchronous ring caused the ring to deflect and caused the wear of the tapered surface of the synchronous ring. ph. Sainsot, Bruzzone Fabio et al [19-20] proposed a deflection equation and verified the validity of the deflection equation experimentally by finite element simulation. Markus Grebe et al [21] studied the damage caused by small deflection angle at roller bearing raceway and analyzed the damage type in detail.Liang Y et al [22] found that as the temperature increases, the oil film gradually decreases, bringing a sharp increase in the friction torque, which is very likely to lead to synchronizer failure.Ulrich S, Mohamed A et al [23-24] studied excellent load carrying capacity, heat resistance and tribological wear properties of carbon fibers.Tsybrii Yurii, za Tavangar et al[25-26]studied the effect of the content of copper fibers in friction materials on their tribological properties and proved that low metal friction materials containing 7% copper fibers exhibited better thermal stability.

After the above research, it can be seen that scholars at home and abroad for the offset pendulum phenomenon on the composite synchronizer ring friction temperature and wear performance of less research, in order to explore its influence, to alleviate the hazards of the offset pendulum phenomenon on the synchronizer ring, this paper on the composite synchronizer ring force analysis and the establishment of a working model. Use finite element analysis software to simulate the position, movement trajectory and force direction of the composite synchronizer ring in the gearbox. The friction temperature and wear of the composite synchronizer ring are analyzed under the working conditions of high rotational speed and large torque to solve the problem that it is difficult to measure the friction temperature and wear under the actual working conditions. In order to mitigate the effects of deflection, the addition of brass fibers to carbon fibers is simulated by changing the material properties. From the simulation results, the addition of brass fiber to carbon fiber improves the thermal conductivity and wear resistance of the composite synchronizer ring. It provides a theoretical reference for optimizing the effect of the bias pendulum phenomenon on the performance of synchronizer rings under actual working conditions.

II. Methodology

The structure diagram of inertia synchronizer assembly and deflection structure diagram are shown in Figure 1. Figure 1(a) shows the ideal condition, the composite synchronizer ring completes the action of axial movement, friction sub-pressing and slip friction under the action of shifting force, and then the output shaft of the gearbox keeps at the initial speed due to inertia, and its speed changes as the synchronization phase proceeds[27]. Figure 1(b) shows that in the actual state, in the process of fork pivoting the bonding sleeve, the three fork legs of the fork are not in the same order of force, and there may be a situation that one of the three fork legs is subjected to force first, which leads to the deflection of the bonding sleeve and causes excessive local force on the composite synchronous ring, resulting in a small angular deflection, and then has an impact on the wear of its friction material.

1-Jointing set，2- Jointing gear ring，3- Composite synchronous ring outer ring，
4- Composite synchronous ring inner ring，5- Spline Hub

Figure 1 Structure diagram of inertia synchronizer assembly and deflection structure

2.1 Composite synchronizer ring force analysis and working model

Combined with the working state of the composite synchronous ring at work, analyze the influence of the deflection phenomenon on the composite synchronous ring, on the basis of Figure 1, take a certain domestic composite synchronizer ring as an example, the force analysis of the composite synchronous ring, the force sketch is shown in Figure 2.

(a) Normal force (b) Abnormal force

Figure 2 sketch of compound synchronous ring force

By using the mechanical relationship shown in Figure 2, the synchronizing torque of the composite synchronizing ring is obtained as shown in Equation 1:

$$M_s = \mu FR / \sin\alpha \tag{1}$$

Among them: M_s : Composite synchronizing ring synchronizing torque; α : Composite synchronous ring friction cone angle; μ : Composite synchronous ring friction cone friction coefficient; R : Composite synchronizing ring effective radius β: Composite synchronous ring deflection angle.

Since the vehicle gear system is very complex in the working state, in order to reflect the working state of the composite synchronous ring more reasonably, combined with the characteristics of the vehicle gear process, the working process of the composite synchronous ring is simplified, as shown in Fig. 3

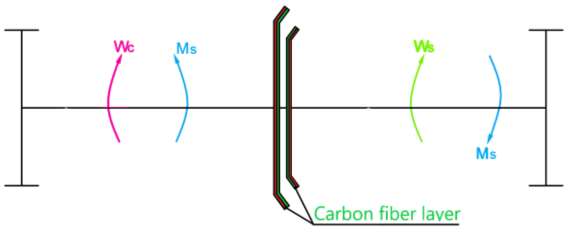


Figure 3 Composite Synchronizer Ring Working Model

From this model, and according to the relationship between the torque and the rotational inertia and the relative angular velocity, another expression of the synchronizing torque is obtained, as shown in Equation 2:

$$M_s = J\frac{\Delta\omega}{t} \tag{2}$$

Among them: $\Delta\omega$: Relative angular velocity at the input ; J : Equivalent rotational inertia at the input. Equations 1 and 2 show that the rotational inertia, rotational speed difference, friction cone angle and shift force have a large influence on the synchronizing torque. In order to simplify the simulation process, the rotational speed difference is selected as the only variable, and the rest of the variables take fixed values. Taking the measured data of the domestic composite synchronizer ring as an example, the relevant parameters are shown in Table 1 [28-29].

Table 1 Composite Synchronizer Ring Related Parameters

Shift process	1st~2nd	2nd~3rd	3rd~4th
Relative speed difference（r/min）	194.303	241.124	296.296
Relative angular velocity（rad/s）	20.347	25.250	31.028
Equivalent rotational inertia at the input（N · mm · s^2）	100		
Friction coefficient	0.25		
Composite synchronizing ring effective radius(mm)	78.5		

Maximum shift displacement(mm)	12
Cone of frictionα(°)	7
Friction cone width（mm）	8
Friction material thickness(mm)	1

2.2 Complex Synchronizer Ring Friction Material

Considering the mechanical properties, friction and wear properties as well as the service life of the composite synchronizer ring, the simulation selects carbon fiber cloth with relatively large thickness as the friction material of the composite synchronizer ring. The parameters are shown in Table 2 and Table 3 [30]

Table 2 Basic material parameters of carbon fiber cloth

Elastic properties					
Young's modulus		Poisson's ratio		Shear modulus	
$E_1 = E_2$	E_3	v_{12}	$v_{13} = v_{23}$	G_{12}	$G_{13} = G_{23}$
68GPa	10GPa	0.22	0.49	5GPa	4.5GPa
Strength attributes					
$X_t = Y_t = X_c = Y_c$	Z_c	Z_r	S_{12}	S_{13}	S_{23}
880MPa	340MPa	96MPa	84MPa	120MPa	120MPa
Maximum strain					
$\varepsilon_1 = \varepsilon_2$		ε_3		$\varepsilon_{12} = \varepsilon_{23} = \varepsilon_{13}$	
0.025		0.05		0.1	

Table 3 Contact setting parameters

E_N	E_T	T	S	G_{IC}	G_{IIC}	M
40GPa	30GPa	11MPa	45MPa	$287J/m^2$	$1830J/m^2$	1.42

2.3 Friction Temperature Calculation Model

The composite synchronizer ring works in the closed gearbox, which is cone-ring shaped, and its heat transfer process is a typical transient axisymmetric process without internal heat source, and the temperature field is distributed in the axisymmetric state, as shown in Fig. 4. The axisymmetric temperature field is only related to r and z, and has nothing to do with θ. Therefore, it is enough to take any plane A of the friction vice to analyze the distribution law of the temperature field, as shown in Fig. 4, which is to transform the three-dimensional temperature field problem into a two-dimensional plane problem [31-32].

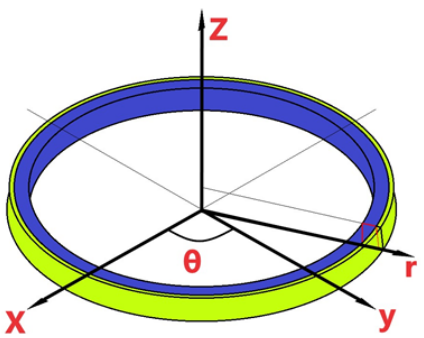


Figure 4. Temperature field of composite synchronous ring

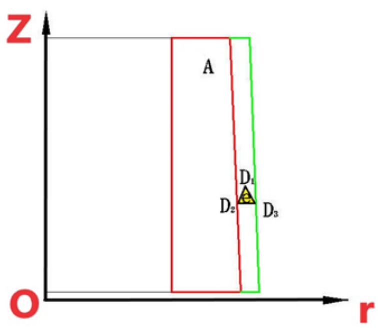


Figure 5. 2D plane of temperature field of composite synchronous ring

Here the finite difference method is used to analyze the heat transfer process of the triangular cell, the coordinates of the vertices of the triangular cell e shown in Fig. 5 are $D_1(r_i,z_i)$, $D_2(r_j,z_j)$, and $D_3(r_k,z_k)$, and the nodal temperatures are T_i , T_j, and T_k.

The generalized function on a typical axisymmetric temperature field cell e without internal heat source is:

$$J^e[T(r,z)] = \iint_e \left\{\frac{Kz}{2}\left[\left(\frac{\partial T}{\partial r}\right)^2 + \left(\frac{\partial T}{\partial z}\right)^2\right] + \rho C_p \frac{\partial T}{\partial t}\right\} drdz + \int_{\mathrm{r}_e} h\left(\frac{T^2}{2} - T_f T\right) zds\#(3)$$

Among them：r: Composite Synchronizer Ring Radius; z: Composite Synchronizer Ring Axis of Symmetry; K:Carbon Fiber Thermal Conductivity;T_f: Medium temperature; ρ: Material density; C_P: Specific heat of material . Heat transfer coefficient h[33]:

$$h = C_p \frac{\lambda_p}{d_{(i,o)}}\left(\frac{v_{(i,o)} d_{(i,o)}}{v_p}\right)^n Pr^{\frac{1}{3}}\#(4)$$

Among them：P_r:Prandtl coefficient for transmission lubricants $v_{(i,o)}$: Carbon Fiber Ring Surface Linear Velocity $d_{(i,o)}$: Carbon Fiber Ring Diameter ; Constants C=0.193，n=0.705.

The partial derivatives of the generalized function of the cell e with respect to the nodal temperatures Ti , Tj , Tk are:

$$\left[\frac{\partial J^e}{\partial T_i}\frac{\partial J^e}{\partial T_j}\frac{\partial J^e}{\partial T_k}\right]^T = [K]^e\{T\}_t^e + [V]^e\left\{\frac{\partial T}{\partial t}\right\}_t^e - \{F\}_t^e\#(5)$$

Among them：$\{F\}_t^e = hT_f s_i \begin{bmatrix}0 & \frac{1}{2} & \frac{1}{2}\end{bmatrix}$; s_i: Boundary length of surface A; $[K]^e$: Unit e temperature stiffness matrix; $[V]^e$: Unit e Temperature Change Matrix; $\{T\}_t^e$: Cell e node temperature matrix at time t. When t takes a fixed value, $\left\{\frac{\partial T}{\partial t}\right\}_t^e$can be regarded as a constant. Let$\{S\}_t^e = [V]^e\left\{\frac{\partial T}{\partial t}\right\}_t^e - \{F\}_t^e$. Equation () can be written as:

$$\left[\frac{\partial J^e}{\partial T_i}\frac{\partial J^e}{\partial T_j}\frac{\partial J^e}{\partial T_k}\right]^T = [K]^e\{T\}_t^e + \{S\}_t^e\#(6)$$

Within the whole face A, it contains N similar cells e. Therefore, the generalized function J of the whole face A is defined to be the sum of the generalized functions J^e of the cells e, ie:

$$J = \sum_{i=1}^{N} J^{e_i}\#(7)$$

Among them：Let there be M nodes in the generalized function J. Then the generalized function J is polarized to the node temperatures T1, ⋯, TM of the nodes to obtain:

$$\frac{\partial J}{\partial T_k} = \frac{\partial \sum_{i=1}^{N} J^{e_i}}{\partial T_k} = \sum_{i=1}^{N}\frac{J^{e_i}}{T_k} = 0(k = 1\ 2\ \cdots M)\#(8)$$

$$\begin{bmatrix}k_{11} & \cdots & k_{1M}\\ \vdots & \ddots & \vdots\\ k_{M1} & \cdots & k_{MM}\end{bmatrix}\cdot\begin{Bmatrix}T_1\\ \vdots\\ T_M\end{Bmatrix} = \begin{Bmatrix}S_1\\ \vdots\\ S_M\end{Bmatrix}\#(9)$$

$$[K]\{T\}_t = \{S\}_t\#(10)$$

Therefore, in the case of a known initial temperature field, the temperature field for the next period of time can be solved for, and so on, the cycle of solving can be repeated to solve for the temperature for the entire t time.

2.4 Friction Temperature Calculation Model

According to the wear calculation model proposed by Archard, it is known that two friction cone surfaces of the composite synchronizer ring slide relative to each other under the action of the shift force[34]. Macroscopically, the two friction cone surfaces are in complete contact, but the friction cone surfaces are uneven from a microscopic point of view. Therefore, the two friction cone surfaces are always in point contact rather than face contact, and the contact actually occurs in the micro-convex body. The process of contact, extrusion deformation and separation between the micro-convex bodies on the friction cone is shown in Fig. 6.

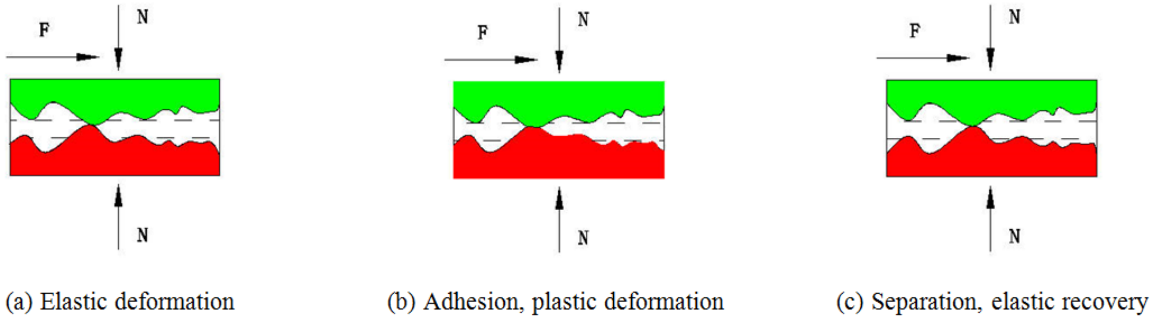


Figure 6. Friction synchronization process diagram of micro-convex body

Figure 6(a) shows the initial stage of friction between the two friction cones, where the two micro-convexes come into contact with each other under the action of the shifting force, and the elastic deformation of the ends of the micro-convexes generates shear stresses at the same time to reduce the speed difference between each other. Figure 6(b) shows the second stage of friction, where the micro-bumps adhere to each other at the contact position due to the high temperature generated by the friction as well as their own deformation, at which time the micro-bumps deform plastically, generating higher shear stresses. Figure 6(c) shows the final stage of friction, as the speed difference becomes smaller and smaller, the shear stress required for synchronization is also decreasing, so the micro-bumps are separated from each other and the elastic deformation is partially restored until the friction synchronization process is completed. In summary, the friction force generated by friction is the sum of the shear stresses generated by all the micro-bumps, i.e. :

$$F = \alpha A_r + \beta N \#(11)$$

Among them： F: Friction; A_r: Actual contact area; N: Shift Force; α and β are coefficients of the friction surface and their magnitude is determined by their own physical and mechanical properties.

Assuming that the micro-convex body is a hemispherical shape and the radius is r, deformation occurs during operation, and the micro-convex body reaches the deformation limit when the sliding distance is 2r. Then the wear rate of the volume at this time is .

$$\frac{d_v}{d_l} = \sum \frac{\frac{2}{3}\pi r^3}{2r} = \frac{1}{3}\sum \pi r^2 \#(12)$$

Among them： v: Friction cone wear volume; l: Relative sliding distance between two friction cones; The compressive yield limit of the composite synchronizer ring friction material is Re, assuming that each microconvex body reaches the compressive yield limit and the wear volume is:

$$V = \frac{N}{3R_e} l \#(13)$$

In fact, the degree of deformation of micro-bumps varies, and not every micro-bump undergoes the complete frictional synchronization process of contact, extrusion deformation, and separation. Introducing a wear probability coefficient k, which represents the number of contacts before the micro-bump is fully plastic deformed, and the value of k is related to the material properties, working conditions, and lubrication status, the wear volume V are:

$$V = k\frac{N}{3R_e} l \#(14)$$

2.5 Simulation analysis

According to the mechanical model of the composite synchronizer ring, a simulation model is established to analyze and investigate the influence of the pendulum phenomenon on the friction temperature and wear amount of the synchronization phase of the composite synchronizer ring. Input the simulation parameters according to the carbon fiber cloth material properties. The simulation grid density is set to 2mm, and the initial oil temperature ambient temperature is set to 22℃. In the established composite synchronizer ring simulation model of the friction interface in the vertical direction, uniformly selected five nodes, point 78 is located in the composite synchronizer ring inner edge, point 79 for the composite synchronizer ring on the outer edge of the point, point 78.5 is located in the composite synchronizer ring on the effective radius, point 78.25, point 78.75 are 78.5 and 78 and 79, respectively, the midpoint of the composite synchronizer ring friction surface reference nodes. The distribution diagram is shown in Figure 4.

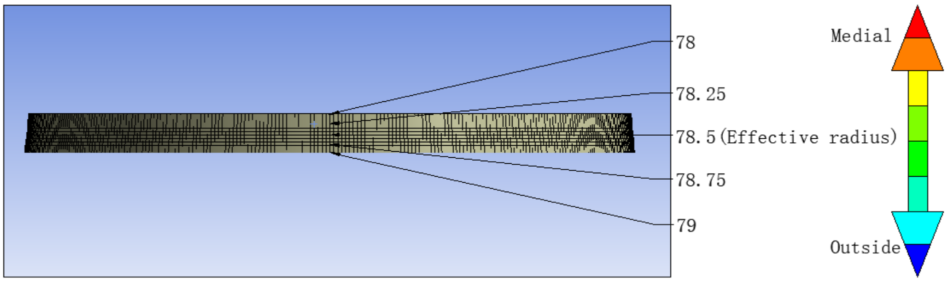


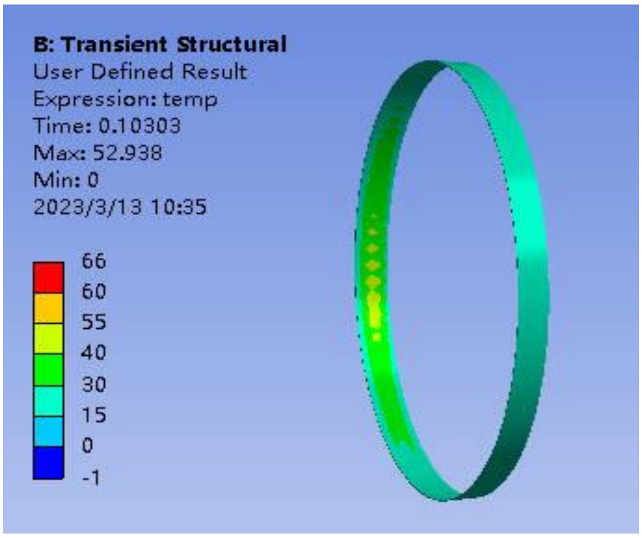
Figure 4 Composite synchronous ring friction surface reference node distribution

III. Discussion of Results

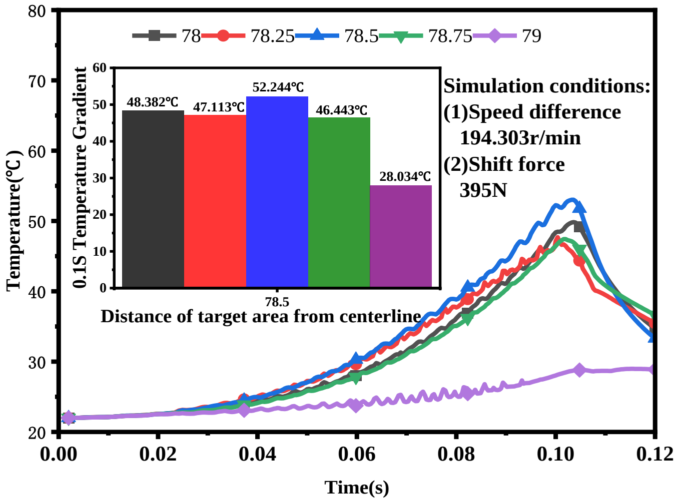
3.1 Simulation analysis of friction temperature of composite synchronous ring

The friction temperature simulation of the composite synchronous ring is carried out to obtain the friction temperature variation curves and friction temperature clouds at each node of the composite synchronous ring under different speed differences, as shown in Fig. 5, Fig. 6 and Fig. 7. The comparison shows that the friction temperature appears from high to low at point 78.5, point 78, point 78.25, point 78.75, point 79. The high temperature zone appears at the inner position of the effective radius, and increases with the accumulation of time, and reaches the peak at t=0.1s.

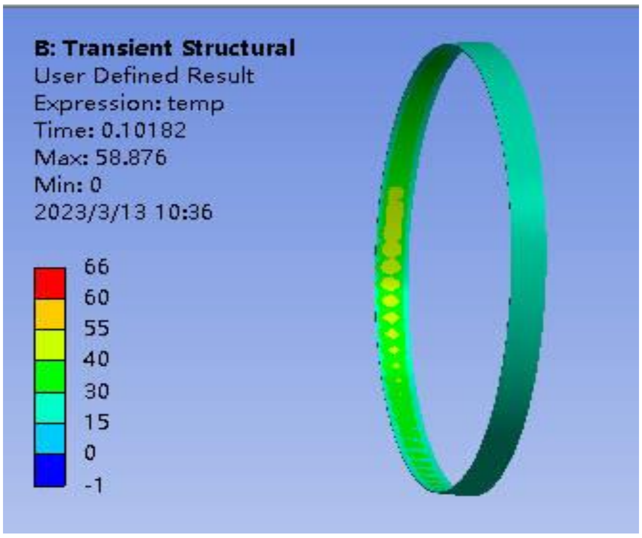
The analysis shows that the main reason for this phenomenon is that when synchronization begins, there is a small gap between the friction pair, so that the outer ring of the composite synchronous ring deflection, resulting in the inner side of the outer ring first contact with the inner ring, resulting in extrusion slip friction. Slip friction makes the heat flow density rise obviously, the heat surge, but because the effective radius relative to other positions of heat dissipation is poor, so the highest friction temperature, the influence of the thermal conductivity of the material other positions also rise in temperature. Due to centrifugal force, the cooling oil inflow rate is lower than the outflow rate, making the effective radius of the friction surface outside the convective heat exchange is greater than the inner side, the effective radius of the outer side of the heat dissipation conditions better than the inner side, so the effective radius of the inner side of the friction temperature is higher. This uneven temperature distribution leads to uneven thermal deformation of the friction surface, resulting in an increase in local contact pressure. The interaction of thermal deformation and frictional heat further increases the temperature difference between the inner and outer sides and intensifies the frictional temperature build-up on the inner side of the effective radius. In the late synchronous period the relative speed difference keeps decreasing, and although the friction surface still generates heat, it dissipates more quickly and the friction temperature begins to drop.



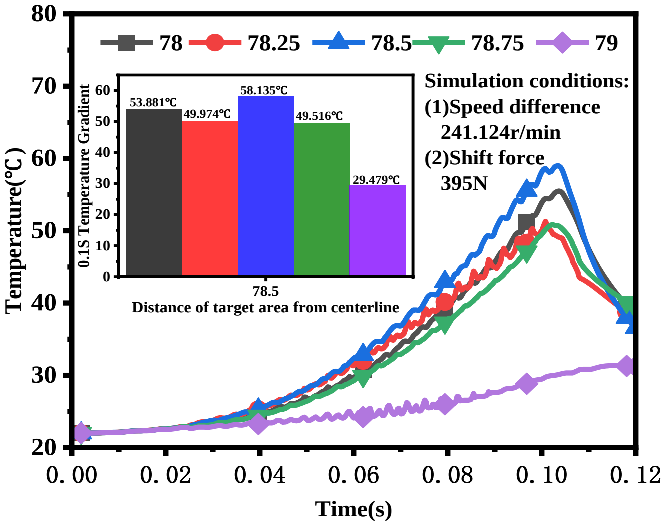
(b) Friction temperature cloud map



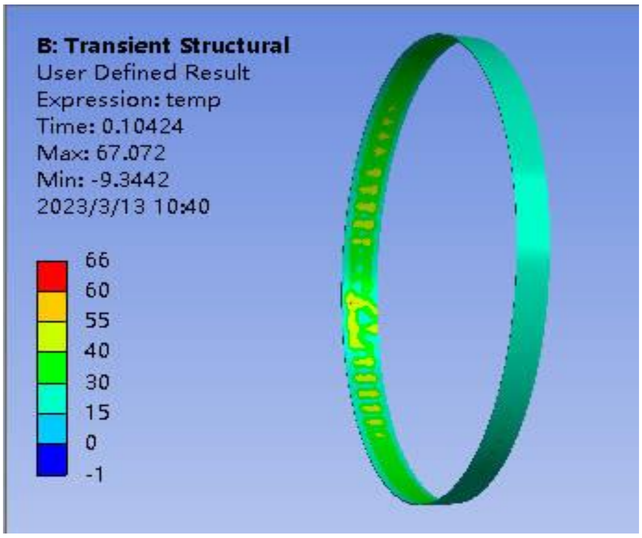
(a) Friction temperature variation curve at each node of friction material surface
Figure 5 speed difference 194.303r/min friction temperature graph



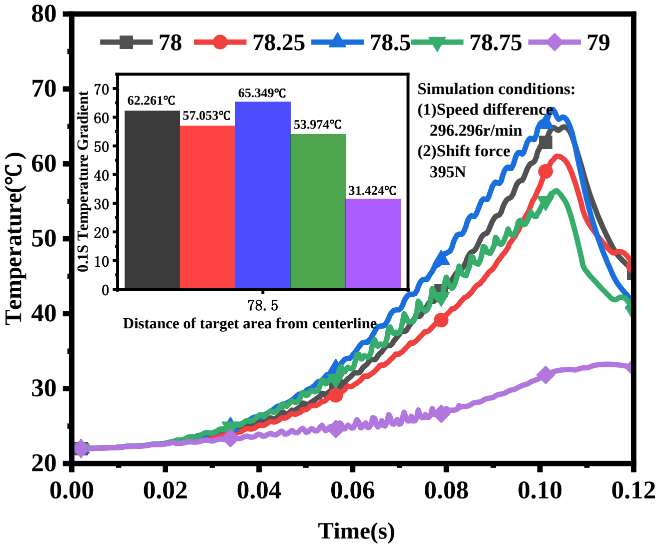
(b)Friction temperature cloud map



(a) Friction temperature variation curve at each node of friction material surface
Figure 6 speed difference 241.124r/min friction temperature graph



(b)Friction temperature cloud map

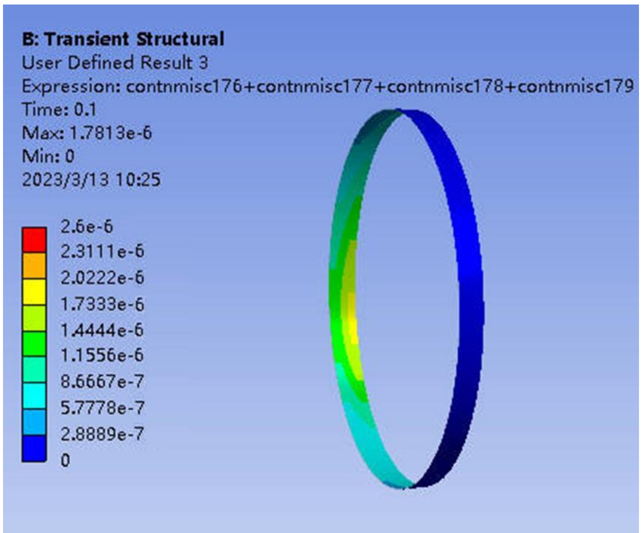


(a) Friction temperature variation curve at each node of friction material surface
Figure 7 speed difference 296.296r/min friction temperature graph

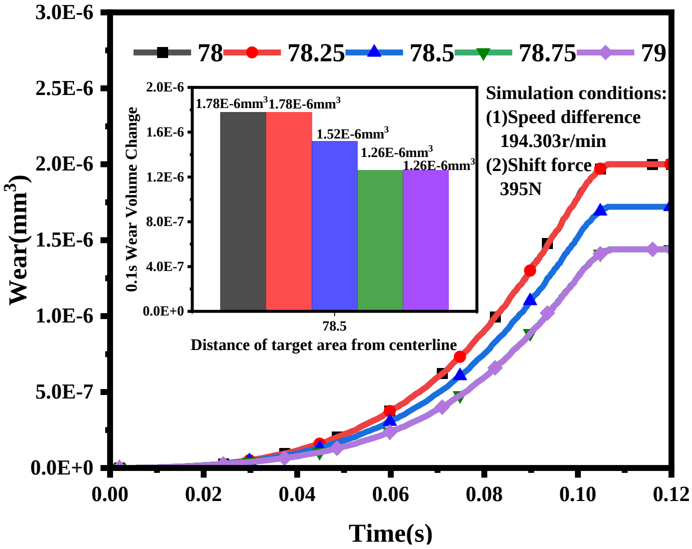
3.2 Composite synchronous ring wear simulation analysis

Figures 8, 9 and 10 show the wear curves and wear clouds at each node of the friction surface for three sets of velocity differences. The analysis results show that the high wear location is concentrated in the inner part of point 78.5 on the effective radius, and the wear amounts of the outer edge point 79 and point 78.75, and the inner edge point 78 and point 78.25 are basically the same, and the wear amount is increasing with the accumulation of time, and it reaches the peak value starting from t=0.11s, and then tends to be stabilized.

From the wear map, it can be clearly seen that the high wear area is concentrated in the inner side of the outer ring of the composite synchronizer ring. This is due to the phenomenon of deflection pendulum that makes this region firstly in the state of slippage, which firstly generates shear stress and wear. Since the lubricant between the two friction surfaces is not completely extruded, there is still some lubrication, so the wear at the beginning of the joint is small. However, as the synchronization phase advances, the lubricant in the region affected by the offset phenomenon will be extruded preferentially, resulting in intense local wear. The graph shows that the wear is mainly concentrated in the time period of 0.05-0.09s. Along with the lubricant is completely extruded, the two friction surfaces are in full contact, the shear stress generated at this time is sufficient to make the rotation of the two sides of the composite synchronizer ring to maintain the same, so the wear at this time does not change significantly until the end of the synchronization stage.

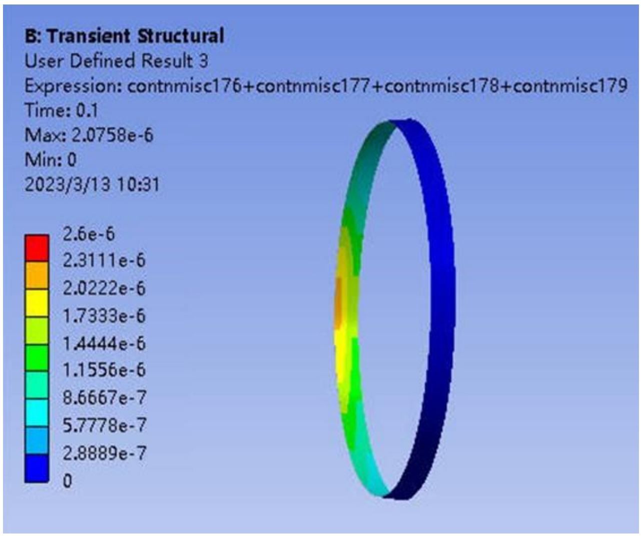


(b) Wear and tear cloud map

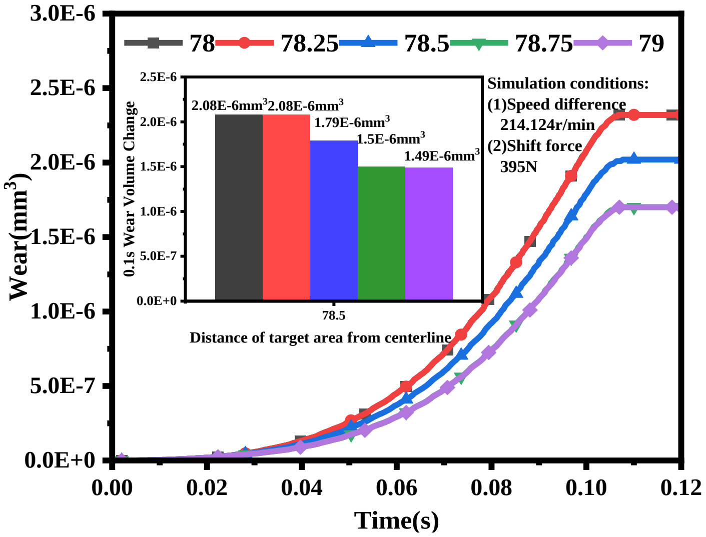


(a) Wear curve of each node with time

Figure 8 Speed difference 194.303r/min wear diagram

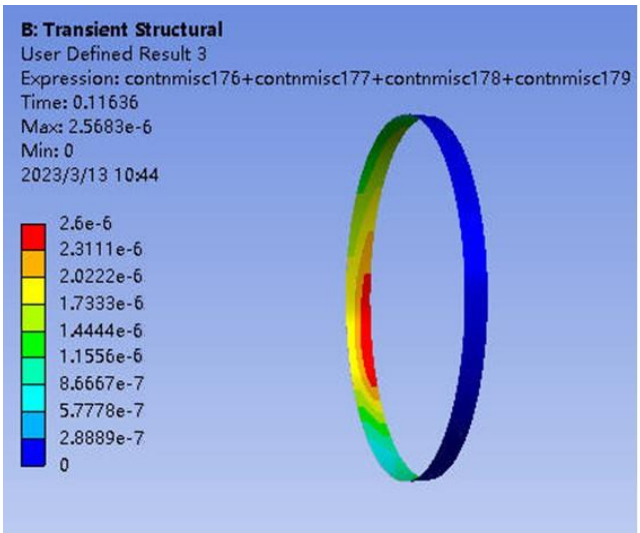


(b) Wear and tear cloud map

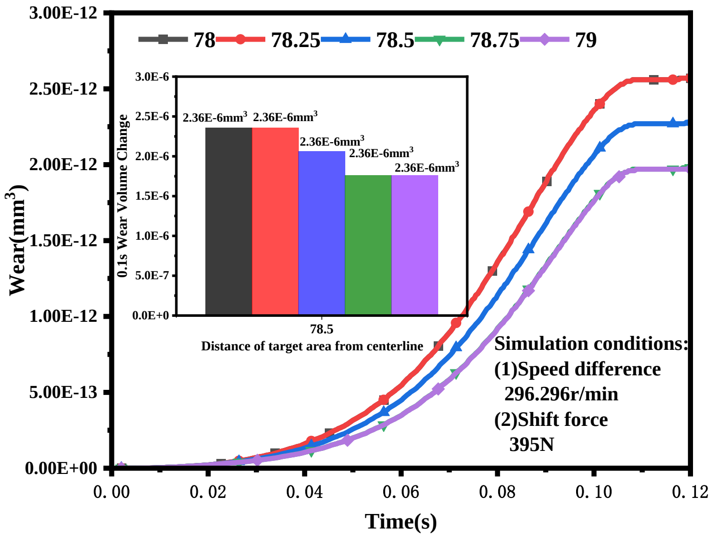


(a) Wear curve of each node with time

Figure 9 Speed difference 241.124r/min wear diagram



(b) Wear and tear cloud map



(a) Wear curve of each node with time

Figure 10 Speed difference 296.296r/min wear diagram

Comparing the simulation results, it can be found that the high temperature region and the high wear region affected by the deflection phenomenon during the synchronization of the composite synchronous ring in the three sets of simulations are found in the inner side of the effective radius under the same other conditions such as shift force and initial temperature. And the effect of the deflection phenomenon will be more obvious with the increase of the speed difference, higher friction temperature and more intense wear.

IV. Optimization and Analysis

In order to alleviate the effects of high local friction temperature and wear caused by the deflection phenomenon, improve shift quality and smoothness, and increase the service life of the composite synchronizer ring, the existing composite synchronizer ring friction material is optimized by adding brass fibers.

4.1 Effect of coated micro-textured tools on cutting temperature

The results of the friction temperature simulation analysis of the composite synchronous ring optimized by adding brass fiber are shown in Figure 11. From the figure, it can be seen that the friction temperature of the composite synchronous ring under different speed difference has significantly decreased after adding brass fiber. When the speed difference is 194.303r/min, the friction temperature decreases by 9.8℃, when the speed difference is 241.124r/min, the friction temperature decreases by 11℃, and when the speed difference is 296.296r/min, the friction temperature decreases by 16℃, which further shows that when the speed difference is larger, the friction temperature is higher, and the brass fiber thermal conductivity is more obvious. In addition, compared with no brass fiber, the friction temperature rise of the brass fiber composite synchronous ring is lower and smoother, which can effectively alleviate the local high temperature caused by the deflection phenomenon. Brass fiber as a metal material with small specific heat capacity, high thermal conductivity and excellent heat dissipation performance, in high speed, high load and other harsh conditions, brass fiber can quickly absorb and transfer the frictional heat generated, reduce the high temperature caused by the composite synchronous ring thermal recession phenomenon, improve the service life of the composite synchronous ring.

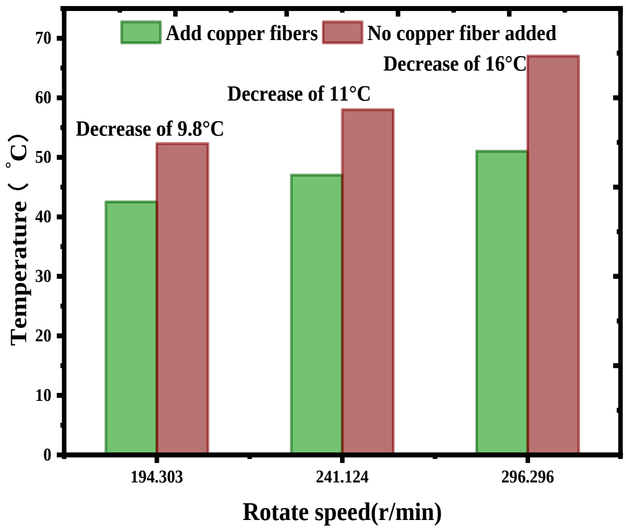


Figure 11 Before and after optimization of composite synchronous ring friction temperature comparison chart

4.2 Composite synchronizer ring optimized for wear resistance

The wear resistance simulation analysis of the composite synchronous ring after adding brass fiber was carried out, and the comparison of wear before and after optimization was obtained, as shown in Figure 12. It can be seen from Fig. 12 that when the speed difference is 194.303r/min, the wear decreases by 2.18E-6mm, when the speed difference is 241.124r/min, the wear decreases by 1.32E-6mm, and when the speed difference is 296.296r/min, the wear decreases by 1.11E-6mm. It can be seen that the inclusion of brass fibers can, to a certain extent, alleviate the high wear caused by the phenomenon of bias pendulum, and the lower the rotational speed difference, the more obvious this alleviation effect.

As a kind of metal fiber, brass fiber has the characteristics of low hardness and good electrical conductivity, so brass fiber can be used as the filler material of the friction material. In the synchronization process of the composite synchronizer ring, brass fibers are easy to transfer and gradually form a protective layer in the form of a thin film on the surface of the composite synchronizer ring friction material [37], and the formation of the protective layer can increase the contact area of the composite synchronizer ring, and play a protective role on the surface of the friction sub-surface of the composite synchronizer ring, so as to increase the hardness and abrasion resistance of the friction material of the composite synchronizer ring and to improve the friction characteristics.

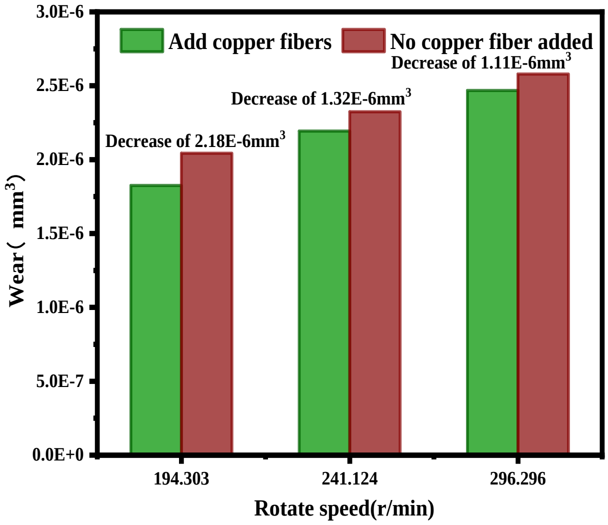


Figure 12 Composite synchronizer ring before and after optimization wear comparison chart

From the analysis, it can be seen that the composite synchronous ring after adding brass fiber can play a positive regulating role on the uneven force and vibration of the synchronous system caused by the deflection phenomenon, as well as the friction temperature and wear rise of the composite synchronous ring, which can effectively reduce the wear and friction temperature of the synchronous ring, and can effectively avoid the failure, burning, cracking and other faults of the composite synchronous ring. It makes the compound synchronous ring maintain a relatively stable state for a long time, increases the service life, and improves the stability of gear shifting and driving safety.

V. Concluding Remarks

The friction temperature and wear of the composite synchronous ring under different speed differences were studied through finite element simulation tests, and the addition of brass fibers to the carbon fibers of the composite synchronous ring was studied in the tests:

1、The inner side of the compound synchronous ring is more seriously affected by the deflection phenomenon compared with other positions, and the friction temperature in this area is high, the wear is intense. And the effect of the deflection phenomenon will be more obvious. Therefore, in the normal conditions of the vehicle speed change process, the speed difference should not be too large, try to maintain a smooth, in order to reduce the impact of the main swing phenomenon, caused by the composite synchronizer ring early failure;

2、The addition of brass fiber in the carbon fiber of the composite synchronous ring obviously alleviates the influence of the phenomenon of deflection for the friction temperature of the composite synchronous ring, so that the friction temperature of the composite synchronous ring is reduced by about 1/5, which reduces the burn of the composite synchronous ring due to high local temperature.

3、The addition of brass fiber improves the friction and wear performance of the composite synchronous ring, reduces the wear of the composite synchronous ring by about 5%, so that the composite synchronous ring can provide synchronous torque more stably.

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