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Complex System Models used in the Automobile Clutch Release Bearing Fatigue Life Studies

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Abstract: According to the system engineering point of view, any kind of technical product, regardless of the size and complexity of its structure are how a system should achieve the intended technical process and in this process relies on the input and output into contact with the outside world. Any mechanical system\should be achieved economically task book the required technical capabilities and maintain the safety of people and the environment as part of its general goal to pursue. Regardless of economic feasibility, technical capabilities alone to achieve the target will lose mechanical practical value. In the automotive power transmission process, the role of the clutch release bearing by means of the axial displacement of the bearing to connect or disconnect the power transmission between the transmission and the engine, thus completing the smooth start the car, suspended and transform operations such gear. Automobile clutch release bearings are vital parts clutch parts of the merits of its performance, the car's handling performance vehicle has great influence. Release bearing fatigue life analysis is based on the bearing rings or rolling fatigue spalling began to appear, a phenomenon with exposure to cyclic stress related. Rolling elastic contact between components belong, the contact stress analysis methods used in the past experience or simple analytical method. In this study, bearing materials, lubricants, sealing structure, fatigue life test and simulate working conditions failure data processing methods have raised new research content, by establishing a new release bearing fatigue life model for complex systems, the introduction of the smelting process, the surface defect, roughness, residual stress, EHL oil film, environmental cleanliness, temperature, variable load characteristics And other factors that affect the fatigue life. The results showed that: release bearing new life prediction model is closer to the actual condition clutch for further study a new generation of high- speed heavy automobile clutch release bearings provide a theoretical support.

Key words: Prediction model, fatigue life, clutch, release bearing, commercial vehicle

INTRODUCTION

For one with energy, material and signal conversion technology tasks, will be able to build on this system between the input and output and can only clear the relationship between reproduction and thus its search for a suitable solution. Feature is the system input and output, in order to complete the required tasks require the mutual relations. According to the system engineering point of view, any kind of technical product, regardless of the size and complexity of its structure are how a system should achieve the intended technical process and in this process relies on the input and output into contact with the outside world. the technical system input and output of only the energy, materials and signals are three and only their states and their characteristics and the amount and direction of flow through the system to changes in technology. Engineering is the study of technical product design theory, methods, techniques and tools of a discipline. Application engineering knowledge learned helps to significantly improve the development of new products and improving the efficiency of existing products, thereby enhancing the competitiveness of products in the market. From the methodological point of view, the design is based on a given target and in part conflicting conditions for gifted process. Since the objective requirements at any time change, so a solution can only be designed at the time given the optimal conditions sought, or sought to be achieved. Engineering design research methods: A systematic viewpoint and method, the constraints arising from the thought of technology products to the end of life of the whole process of logical analysis, synthesis and optimization of induction.

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CLUTCH RELEASE BEARINGS

Engine torque-rpm characteristics and requirements of car use is not suited to general vehicle power: Requirements exactly the opposite: low speed requires a greater power for accelerating, climbing; whereas the normal speed (often called for cruising speed) driving, the power consumption required only 10% of maximum. Further, in a case where the output power corresponding to a certain speed range only have lower fuel consumption, by adjusting the transmission ratio of the drive system can achieve the desired speed. Therefore, the design of automotive powertrain of the car's power, fuel economy has a significant impact.

The traditional single disc clutch is driven (driven disc), pressure plate (clutch cover) and the release bearing (release bearing) composition, it was confirmed that a fully mature, economical systems on commercial vehicles in the world, has been wide range of applications. Modern standards clutch design (Fig. 1) structures are as follows: Diaphragm spring clutch flywheel bolts; dribbling two clutch friction surface, the transmission power toward the driven plate can move axially with the input direction; torsional vibration damping is incorporated into the driven plate; transfer clutch release bearing transporting power see (Fig. 2), relying on its power comes from the manipulation of ball bearings on the clutch cover non- rotating part.

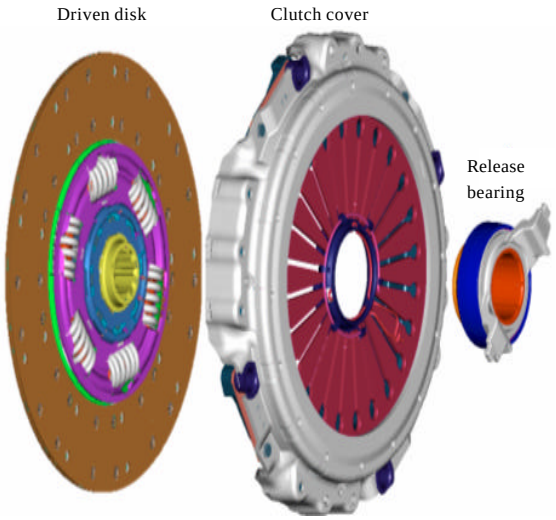

Fig. 1: Schematic diagram 3 piece clutch parts

Automobile clutch release bearings are the important automotive driveline components. In the automotive power transmission process, the role of the clutch release bearing by means of the axial displacement of the bearing to connect or disconnect the power transmission between the transmission and the engine, thus completing the smooth start the car, suspended and transform operations such gear. Automobile clutch release bearings in high speed, strong vibration, temperature, humidity and easy to work under conditions of pollution, requiring release bearing has good strength and toughness, impact resistance, abrasion resistance and excellent contact fatigue performance.

RELEASE BEARING FATIGUE LIFE

The release bearing fatigue life analysis is based on bearing rings or rolling body began to appear fatigue spalling, in which this kind of phenomenonis under cyclic stress. Usually, spalling occurred early in the maximum shear stress of contact surface area and phenomenon of fatigue theory is different from the material of bending fatigue test of the observed. The general fatigue and rolling bodies between fatigue failure model and stress conditions are different, the material constants of determined for specific bearing cannot be used for other bearing type Therefore, the contact fatigue failure mechanism is more complex than ordinary materials bending fatigue. Experiments show that, under the same load, the same number of bearing life with the two parameter Weibull distribution function (Vlcek *et al*., 2003), namely the service life of the bearing is less than or equal to L and the failure probability can be expressed as:

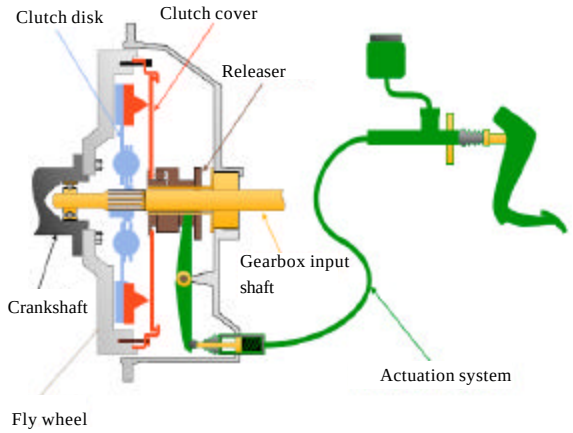

Fig. 2: Clutch system design structure diagram

$$F(L) = 1 - \exp\left[-\left(\frac{L}{\beta}\right)^{e}\right] \quad (1)$$

Where:

F (L) = Damage probability of the bearing life is less than or equal to L

L = The bearing life, are treated as random variables. Refers to the bearing rolling body or raceway operated total revolutions before fatigue spalling (with one million speed calculation), or at a certain speed work hours

e = The slope parameter, . side discreteness for a number of bearing life. The e value is big, show that the discrete smaller

β = Characteristic life parameters, said bearing life failure probability corresponding to 0.632, also known as the scale parameter

Typically, flaking earliest withstand the maximum shear stress in the contact area under the surface and then expanded into a mesh cracks. However, do not form a fluid Elastic Dynamic (EHD) Tandon *et al*. (2007) lubrication of the working conditions, the rolling elements will occur in the near surface fatigue and then exposed to the maximum shear stress along the regional expansion fatigue spalling. Contact fatigue bending fatigue with materials having similar points (Liao and Lin, 2002), such as a large dispersion of fatigue life, fatigue life and the stress related to the size. However, the contact fatigue bending fatigue is different from ordinary materials, mainly: the contact stress distribution is very uneven, contact stress is mainly concentrated near the surface; affected by the surface geometry and physical properties and lubricating and other factors more apparent. Landes Berg (Lundberg and Palmgren, 1947) and Pamgreen (Lundberg and Palmgren, 1947) presents the maximum dynamic shear stress theory (hereinafter referred to as PL theory). PL theory that the contact surface parallel to the rolling direction of the maximum shear stress determined alternating occurrence of fatigue cracks and then extends to the surface, resulting in contact fatigue spalling. And the maximum dynamic shear stress affects the depth where the probability of material failure, the greater the number of stress cycles and the greater the volume by stress, both the probability of failure of the contact material increases:

$$\lg\frac{1}{S} \propto \frac{\tau_0^{c} N^{e} a l}{z_0^{h-1}} \quad (2)$$

Where:

S = Probability of survival

τ_0 = Maximum dynamic

l = Length of the raceway

e = Times

V = A stressed volume

a = Hertzian contact ellipse long axis

l = Rings running Weibull (Weibull) distribution slope parameter

c, h = Material constant, regardless of the state of contact

FATIGUE CRACKS UNDER THE SURFACE

Depends on fatigue crack propagation under the surface defects local plastic strain and toughness of the steel usually present within the non- metallic inclusions and other defects, each defect may cause the generation and propagation of fatigue cracks and defects within the material of any size and position randomly distributed, contact fatigue life of parts from these random distribution of material defects combined effects of the decision. Manson- Coffin (Seng, 1985) Equation indicates the contact surface under the plastic strain and fatigue life of the contact:

$$N_{se} = C_p\left(\frac{D}{\gamma_p}\right)^{\phi} \quad (3)$$

Where:

Nse = Subsurface defects originated in contact fatigue life (number of stress cycles to count)

γp = Single defect at the plastic strain

D = Local toughness characterization of materials resistant plastic strain capacity

φ = Material constants

Cp = Related with shear stress and the amount of relevant material properties

Cp = cA p

Ap = Crack size can be customized extensions, also known as the critical crack size

C = Material constants

SURFACE CRACKS CAUSED BY PRE- DEFECT

Surface pre- cracks caused by defects, such as surface pre- crack, formed during machining grinding cracks, slight dents and surface defects such as inclusions adjacent the contact under repeated stress due to the stress concentration arising from the impact surface crack and to extend deep, leading to fatigue spalling.

Single defect identified contact fatigue life:

$$N_{se} = C_p[f_2(\sigma_s)]^{-\xi} p_0^{-3.0\xi} t_R^{-\xi} \rho^{-0.2\xi} [(K_t)_\infty - 1]^{-1.2\xi} \chi^{-1.2\xi} \quad (4)$$

Where:

Cp = And shear stress and the amount of relevant material properties
f_2 ( ) = Function symbols
σ_S = Material yield strength
ζ = Material constants
Cp = And shear stress and the amount of relevant material properties
Cp = cA p
p0 = Hertzian contact ellipse center pressure
tR = Dimensionless shear stress, see formula (8)
ρ = The size of defects
$(K_t)_8$ = This single defect in the stress field of an infinite theoretical stress concentration factor
χ = Stress concentration factor correction coefficient

Tallian (1996) the LP based on the theory put forward new data fitting bearing life prediction model (T model) (Tallian, 1996), this model introduces a smelting process, the surface defects, roughness, residual stress, EHL oil film, environmental cleanliness, the factors that affect the fatigue life. The prediction model is:

$$-\ln S(N) = \left[\Phi_0^{-1/\beta\varsigma} N^{-1/\varsigma} + \tau_0\right]^{-\beta\varsigma} \Phi_T \quad (5)$$

Where:

S = The probability of survival life of N
N = Rotation frequency, means of operating cycles
τ_0 = Limit fatigue stress, (Mpa)
ζ = Stress/life exponent
ζ = 11.73/β
β = Life discrete exponential
β = 1.6
$\beta\zeta$ = Survival probability index, 11. 73
φ_0 = Sensitivity coefficient matrix
φ_T = Pobability coefficient multiplied

APPLICATION OF THE NEW MODEL

In order to verify the prediction accuracy of two fatigue life, the corresponding rolling contact test. Testing machine for three rolling fatigue testing machine, the subjects ball diameter 12.7 mm, precision grade G10. Two models for predicting the values in Table 1: Two models: Prediction value and error.

Table 1: New and L-P model for prediction value and error

	New model		L-P model	
P0 (GPa)	Prediction value (million)	Error	Prediction value (million)	Error
5.67	4.537	2.30	5.803	30.80
6.07	2.115	10.30	3.142	33.30
4.5	6.039	4.65	4.645	19.90

RELEASE BEARING CHARACTERISTICS

Clutch release bearings and angular contact bearings Universal has the following differences: clutch release bearing contact angle; clutch release bearing radial clearance than deep groove ball bearing clearance groups corresponding high 2- 3 groups, clutch release bearings vibration values higher than deep groove ball bearing vibration values. Clutch release bearing operating state is divided into stationary state, excessive state and the rotation state. Status of their work with the clutch release bearing clutch changes occur alternately. Clutch Release Bearing in excessive state dynamics is not deep groove ball bearings with special problems. Self-aligning release bearing mounted eccentrically to a certain range, the automatic adjustment of the axial position of release bearing, so that the center of rotation of the clutch diaphragm spring coaxially rotatable, which can overcome the engine crankshaft and the gearbox input shaft mounted between eccentric clutch release bearing systems and ignore the impact can ensure separation of the clutch release bearing can be evenly compress the inner ends of the diaphragm spring, significantly improve the separation of the bearing life.

Clutch release bearing structure, parameters and working conditions with the general deep groove ball bearings have a greater difference. Clutch release bearing suppliers and OEMs that type of bearing vibration feature requests lack of uniform grading. At present, the measurement method of the clutch release bearing vibration deep groove ball bearings with the samemeasurement (Bogard *et al*., 2002) and the assumption of uniform rotation of the bearing was measured under conditions (Yang and Chen 2002), characterized by the clutch release bearing can only approximate the ideal conditions few vibrations. Therefore, the need to study the suitable clutch release bearing dynamic characteristics test methods and specifications. On the pressure plate load and subsequent load shedding process, acting on the pressure plate and pressure plate load F λ the relationship between the displacement curve shown in Fig. 3. Map code points defined as follows:

Where:

Fm = Pressing force for the average working
Fu = Pressing force for the unloading, which
Fm = (Fu + Fo)/2
F_λ = Pressure plate load

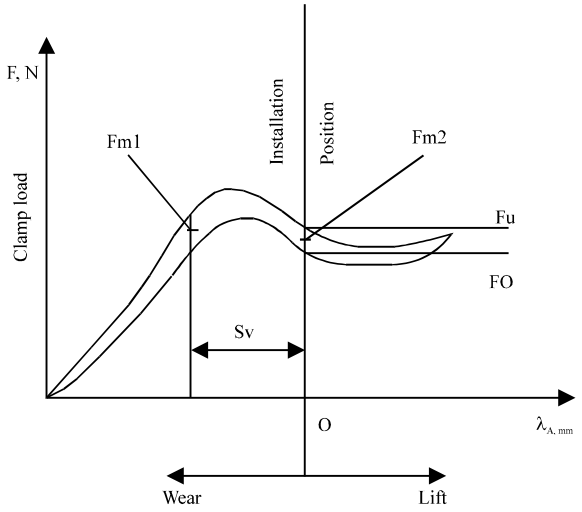

Fig. 3: Clutch load characteristics

Sv = Friction disc wear limit,
S_v = 3 mm

NUMERICAL SOLUTION METHODS

Rolling elastic contact between components belong, the contact stress analysis methods used in the past experience or simple analytical method (Holm- Hansen and Gao 2000). In 1895, Hertz established between the ideal elastomer frictionless formulas and was found by the contact boundary (normal and tangential forces are zero) moving the sliding contact state. Thereafter, contact problem began gradually in-depth study, involving contact with surface friction sliding and rolling contact analysis and other fields. Therefore, seeking a relatively precisely meet practical engineering problems numerical method is very necessary.

The application of numerical methods and computer technology are closely related, where the Finite Element Method (FEM) the advent of promoting the progress of contact problems. With the rapid spread of computer technology numerical solution methods and mechanical knowledge to improve the continuous improvement of the finite element method has been widely used. With elastic contact theory and development of computer technology, using the Finite Element Method (FEM) to solve the problem of rolling bearing contact stress as possible, thus bearing load and contact stress analysis can be a more accurate description. However, due to rolling contact state can not be determined in advance, so the contact model is a local nonlinear contact; analysis showed that: The bearing stress distribution in the contact area depends on the load bearing suffered size, fitting size of the gap and the stiffness of the bearing system. Since three- dimensional mechanical model for the contact boundary space quadric stiffness equation for ultra- high linear equations, iterative algorithm, the computation, storage and computing time, very demanding on computer performance (Hwang and Gahr 2003). Because of the rolling contact surface geometry description and contact force calculation accuracy requirements are high, causing the system simulation workload is growing, with a stand- alone system simulation is not competent, with the development of computer technology for parallel computing, so that Rolling dynamic simulation possible.

CONCLUSION

Tallian model have the influence factors of fatigue life is introduced on the smelting process, surface defect, surface roughness, residual stress, elastohydrodynamic lubrication oil film, environmental cleanliness, temperature, the effect of varying load characteristics and other factors of fatigue life. The results show that: the clutch release bearing life prediction model of new and more close to the real conditions of automobile clutch, provide the theory basis for the development of a new generation high- speed heavy-duty clutch release bearing of the commercial vehicle.

REFERENCES

Bogard, F., K. Debray and Y.Q. Guo, 2002. Determination of sensor position for predictive maintenance of revolving machines. Int. J. Solid Struct., 39: 3159-3173.

Holm-Hansen, B.T. and R.X. Gao, 2000. Structural design and analysis for a sensor-integrated ball bearing. Finite Elements Anal. Design, 34: 257-270.

Hwang, D.H. and K.H.Z. Gahr, 2003. Transition from static to kinetic friction of unlubricated or oil lubricated steel/steel, steel/ceramic and ceramic/ceramic pairs. Wear, 225: 365-375.

Liao, N.T. and J.F. Lin, 2002. Ball bearing skidding under radial and axial loads. Mechanism Machine Theory, 37: 91-113.

Lundberg, G. and A. Palmgren, 1947. Dynamic capacity of rolling bearings. Acta Polytechnica Mechanical Engineering Series. Vol. 1, Royal Swedish Academy Engineering, Generalstabens Litografiska Anstalts Forlag, Stockholm, Sweden, Pages: 50.

Tallian, T.E., 1996. A data-fitted rolling bearing life prediction model-Part II: Model fit to the historical experimental database. Tribol. Trans., 39: 259-268.

Tandon, N., K.M. Ramakrishna and G.S. Yadava, 2007. Condition monitoring of electric motor ball for the detection of grease contaiminants. Tribol. Int., 40: 29-36.

Vlcek, B.L., R.C. Hendricks and E.V. Zaretsky, 2003. Determination of rolling-element fatigue life from computer generated bearing tests. Tribol. Trans., 46: 479-493.

Yang, J.P. and S.X. Chen, 2002. Vibration predictions and veri?cations of disk drive spindle system with ball bearings. J. Comput. Struct., 80: 1409-1418.