Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2013, 5(9):428-433

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

The test analysis of transmission gears' fatigue pitting

Zhifei Wu, Tie Wang and Ruiliang Zhang

College of Mechanical Engineering, Taiyuan University of Technology, Taiyuan, China

ABSTRACT

There were severe pitting corrosions on the surface of transmission gears in diesels. The cause of metal fatigue pitting of gear surface is analyzed in the paper, which based on the contact fatigue experiment of 18Cr2Ni4WA carburizing and quenching gears used in the diesel engine. Causes of pitting on harden tooth surface are studied from three aspects: gear surface residual stress field, oil film pressure and carburizing thickness, which according to the morphology of test gear fatigue fracture and the surface hardening properties of carburizing and quenching gears. The reasons of experimental gears' contact fatigue pitting were analyzed and conclusions were as follows: The depth of the diffusion layer, surface carbon concentration and the carbon concentration gradient of layer were the key to improve the ability to resist wear surface fatigue pitting.

Keywords: Fatigue Pitting, Gear, Carburizing, Quenching

INTRODUCTION

18Cr2Ni4WA alloy steel with excellent strength and toughness, and high hardenability, gear of this material is widely applied in heavy-duty diesel engine, gearboxes and other special conditions vehicles transmission mechanism, but such material gears fatigue properties and other basic test data were few[1-3]. According to the literature reviews, only the bending fatigue characteristic experiments were conducted by some colleges and research institute, and nobody has yet studied their contact fatigue properties[4-7]. Tooth broken is one of the most common modes of fatigue failure in 18Cr2Ni4WA carburizing and quenching gear, and many of the broken places are not on the tooth root which generally considered as the most dangerous section, but in the vicinity of pitting occurred, where tooth broken is caused by tooth surface damage growth. Therefore, there is a great significance to study such material gear contact fatigue characteristics of anti-fatigue design. In this paper, contact fatigue characteristics of 18Cr2Ni4WA gear are studied by carrying on contact fatigue bench test with the limited experimental points' method.

I. GEAR CONTACT FATIGUE BENCH TEST

A. Carburizing and quenching gear contact fatigue source

Although literatures have explored a certain origin of soft surface gear pitting, however, the contact fatigue characteristics of carburized hardened gear tooth surface gears are quite different from the soft surface ones. The soft tooth face gear surface crystal grain lateral is free, therefore, the weary source occurs on the surface, but the carburizing and quenching process can change the metal lattice orientation, and the metallic bond will increase. In addition the hardened layer will be formed through the gear grinding process and other processing technology, the hardened layer exists the residual stress field which is caused by the effect of heat treatment and work hardening, as a result , this stress field could resist external force, therefore, tooth surface contact strength increased greatly. Nonetheless, under the hardened layer, fatigue sources are formed because of the residual stress and low strength.

B. Residual stress fields

Studies have shown that, gear residual tensile stress accelerates the crack and urges the extension[8,9], and the residual compressive stress can partially offset the working load, the expansion of fatigue crack and enhance the fatigue strength[10]. After carburizing and quenching process, compressive stress formed on the surface, tensile stress formed internally. The residual stresses superimpose shear stress while teeth contact, so the thorough stress condition will change greatly.

C. Test gears

The material of test gear is 18Cr2Ni4WA, heat treatment process is carburizing and quenching, the design and manufacture of test gears in accordance with GB/T14229-1993, test gear is an inviolate helical gear with addendum modification.

Parameters: b=22mm, m=4mm, z_1=36, z_2=37, α =20°, x_1=0. 09403, x_2=0. 09403.

D. Installation of experimental machine

The experiment was carried on the closed power flow gear test bench which is shown in Figure 1, the center distance of testing machine is 150mm with mechanical lever loading, motor output torque and closed torque were measured through the torque-speed measurement instrument, the rotation is recorded by the counter. At the same time, noise, oil temperature and vibration of the gearbox were monitored.

E. Installation of test gear

The width of test gear is 22mm, in order to guarantee the experiment is succeed and more data could be obtained, the positive and negative staggered meshing form is applied in the test gear pair installation. So the actual tooth contact width is 11mm, one counter gear test sample may constitute four experiment gear pairs, and obtain four test point data. High contact stress can be got by small torque in this engagement system.

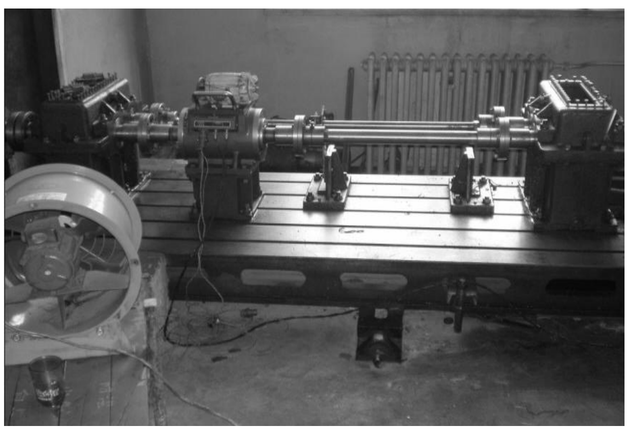

Fig.1 Closed power flow experimental bench

F. Determination of stress level

Four stress levels are applied in this experiment, taking into account the influences of unloading in the testing, we should load once more, and this causes the torque to change. Therefore the torque was given in the form of interval, the loading error controls in M×(1±4%) scope, the four levels of stresses are determined respectively as follows:

Tab.1 The torques corresponding to stress levels

Stress level	Load torque (T/ N*m)
I	1085～1175
II	984～1066
III	893～967
IV	806～877

G. Contact fatigue failure criterion

When the single tooth pitting area rate achieves 4% or the gear pair pitting area rate achieves 0.5% pitting damage limit, which determined that the tooth surface failure, and the gear rotating cycles is the failure life, tooth shown in Figure 2 could determine the tooth surface failure.

When the test gear base cycles $N_0 \geqslant 5 \times 10^7$, and the tooth surface pitting did not appear, the test should be stopped and we can determine the test points beyond, and judge the life is infinite.

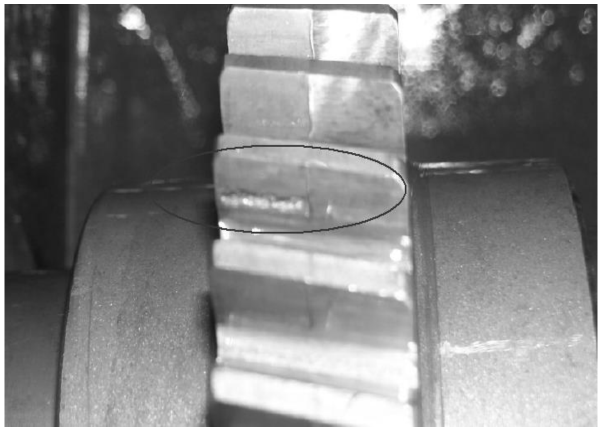

Fig.2 The pitting of test gear

II. DISTRIBUTION OF RESIDUAL STRESS FIELD

A. The fatigue source of harden tooth surface

After carburizing and quenching process, compressive stress formed on the surface, tensile stress formed internally. Some recent research showed that, the residual tensile stress of gear may accelerate crack and urge the extension, and the residual compressive stress could partially offset the load, delay the expansion of fatigue cracks, thus the fatigue strength was enhanced. The residual stress could superimpose the shear stress while gear meshing, therefore the entire stress condition was changed greatly. The layer of residual compressive stress could decrease the shear stress, while the transition region remaining tensile stress could magnify the shear stress, therefore the transition region would be the weakest area. The friction shear stress would be superimposed to the shear stress while the gear pair meshing, which magnified the peak value of stress.

B. Distribution of residual stress

In the precise depth of the tooth surface area, the Hertz shear stress surpassed the gear material shearing strength leaded to pitting and peeling on the harden gear tooth therefore shear stress and shear strength ratio are the key to tooth contact strength. In the literature mentioned[11], if the residual stress was not considered, the shear strength and shear stress distribution along the cross-section shown in Figure 3, A, B curve, gear after cementation quenching the surface forms the prominent remaining compressed stress. At the same time, there was a transition region in the layer under tensile stress with a balanced. The synthesis load curve of pressure and resistance was C, from curve C, the intensity curve A, curve of pressure and resistance B could be seen. Although the surface layer degree of security further increased, but the original transition region actually becomes unsafe, the ratio of shear stress and the shearing strength was higher, because the shear stress was combined with the load stress and the remaining tensile stress, there was likely to exceed the safety limit.

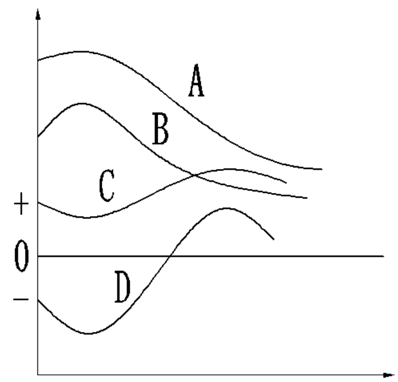

Fig.3 Schematic diagram for the effect of residual stress on case cracking

This phenomenon could be interpreted in accordance with Figure 4, when the gears mesh layer of residual compressive stress to shear stress smaller, but the transition region remaining tensile stress caused the shear stress to increase, such transition region became the weakest region, moreover in the transmission process tooth surface relative sliding had the friction force. Frictional shear stress would also be added to the shear stress, caused the peak value to increase and present the position on the surface layer migratory. This allows maximum shear stress occurred in the sub-surface. Thus the germination and expansion of fatigue crack were under the surface.

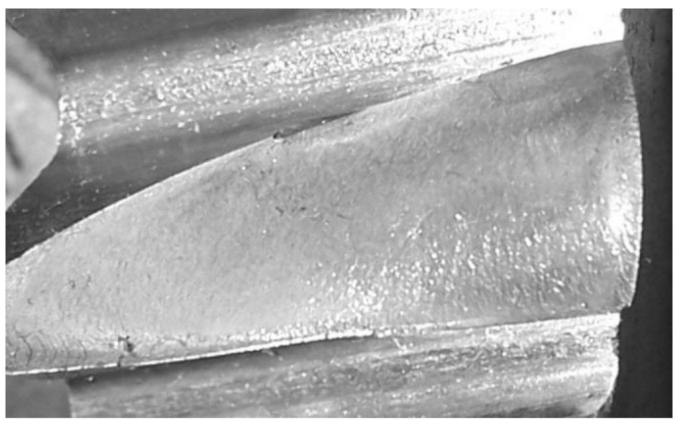

Fig.4 The morphology of test gear fatigue fracture

C. Influence of oil film pressure

The growth of surface fatigue was influenced by complex factors, such as stress distribution, growth of generally thinks the surface fatigue crack initiation the macroscopic stress distribution, the fine texture and the environment. There were many pitting and fatigue cracking area on the experimental gear tooth surface shown in Figure 5, but only a few cracks could expand to pitting corrosion shown as Figure 2 which near the pitch line.

The lubricant film pressure was considered as the critical factor of pitting growth in some research, however, the oil wedge function forms the lubricant film pressure peak value did not as large as literature [12] predicted values, which due to the plastic deformation of tooth surfaces, therefore the peak value of pressure was not the key aspect which formed the hard tooth surface gear pitting shown in Figure 6, however, the contact on section line accelerated the section near the fatigue crack growth.

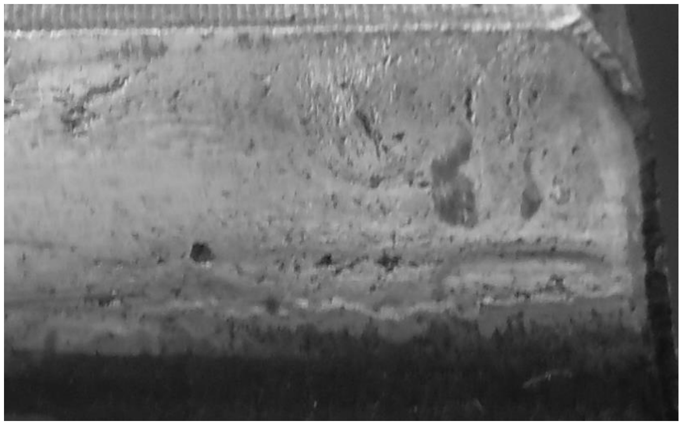

Fig.5 The morphology of gear surface fatigue crack

Fig.6 The morphology of gear addendum fatigue crack

D. Influence of carburized depth

When the depth of carburizing was tiny, the contact fatigue crack stemmed from the tooth surface frequently showed in Figure 7, while the running-in just begun, the tooth surface has not had the plastic deformation, and the flaking formed in no time. It was due to the depth of carburized layer was not enough, and the fatigue crack initiation appeared in the transition region.

The gear operating conditions, heat treatment factors and energy consumption were comprehensively considered, the carburizing depth should be suitable, and the decisive factor was the nice gradient distribution, therefore the ideal cementation region requested high hardness and smooth transitive on sub-surface.

Fig.7 The morphology of surface fatigue during running-in

CONCLUSION

In this article, the gear contact fatigue experiment was carried on through few test points, installation method of test gear and load the stress level had been studied. Causes of pitting on harden tooth surface were studied, the depth of diffusion layer, surface carbon concentration and the carbon concentration gradient of the layer was the critical factors in the ability of resisting gear surface fatigue pitting.

REFERENCES

[1] P.J.L. Fernandes, C. McDuling, **1997**. *Engineering Failure Analysis* , 4: 99–107.
[2] Li S, Kahraman A. **2013**. *Int J Fatigue*, 47:205–15.
[3] Li S, Kahraman A. **2011**. *Int J Fatigue* , 33:427–36.
[4] Li S, Kahraman A, Klein M. **2012**. *ASME J Mech Des* , 134:11.
[5] Laine E, Olver AV, Lekstrom MF, Shollock BA, Beveridge TA, Hua DY. **2009**. *Tribal Trans*, 52 : 526–33.
[6] Cardoso NFR, Martins RC, Seabra JHO. **2009**. *J Eng Tribol* 223: 481–95.
[7] Li S, Kahraman A. **2009**. *Tribal Int* , 42: 1163–72.
[8] Chen Guo-min, **2008**. *Heat Treatment of Metals*, 33: 25～33.
[9] Osman T, Velex Ph. **2012**. *Tribal Int*, 46: 84–96.
[10] Glodez S, Potocnik R, Flasker J, Zafosnik B. **2008**. *Eng Fract Mech*, 75:880–91.
[11] Martins R, Seabra J, Brito A, Seyfert Ch, Luther R, Igartua A. **2006**. *Tribal Int* , 39:512–21.
[12] Dong WB, Xing YH, Moan T. **2012**, *Energies*, 5: 4350–71.