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THE DESIGN AND NUMERICAL SIMULATION FOR V-RIBBED BELT FATIGUE TESTER

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ABSTRACT

According to the actual working conditions of the V- ribbed belt, automobile V-ribbed belt fatigue tester machine is designed to test for the automobile engine V- ribbed belt fatigue wear. Finite-element analysis software ANSYS is employed to perform finite-element analysis on fatigue testing machine load shaft, bearing, universal joint key parts of the finite-element analysis, and to analyze the modality of the major structure, which provides the references for the structure optimization, the research and development of fatigue tester. Taking factors of influencing V-ribbed belt fatigue life into consideration, the design is on the standard of actual conditions to make the device meet the needs of V-ribbed belt fatigue test, which offers the reference method for V-ribbed belt quality inspection.

Keywords: *V-ribbed Belts, Fatigue Testing Machine, Numerical Analysis*

1. INTRODUCTION

Automotive v-ribbed belts have an important influence on vehicle driving safety, efficiency and environmental protection [1]. In the running of the automobile, if automotive synchronous v-ribbed belts are destroyed, it will lead to the failure within the gas distribution system of the engine, even will make the cylinder end so that automobile safety is not effectively guaranteed [2]. The serious damage of automobile v-ribbed or slipping will affect the normal working of the compressor, resulting in brake failure and causing traffic accidents[3]. The characteristics of belt's own, transmission system arrangement, the external environment and other factors are the main factors affecting the service life of the belts[4]. The design and finite-element analysis of fatigue testing machine are based on the actual work of automotive v-ribbed belts in this paper.

Many domestic and foreign scholars designed related fatigue tester for many key components of automobiles. Scholar Yin Sumin[5] designs a fatigue tester for the absorber of automobile clutch and discussed in detail MCS8098 single chip measurement and control system to monitor the whole testing process. According to the broken characteristics of torsion spring fatigue and endurance testing, auto torsion spring fatigue testing machine based on theory of crank and rocker mechanism is designed by Scholars heading by Chen Zhitai[6]. With PLC programming, controlling and counting of endurance experiments of the torsion spring are also tested. The bending fatigue tests and torsional fatigue tests of automobile engine crankshaft are studied by scholar Xie Liying[7] with a study emphasis on the equipment, test method and test evaluation. This study will provide technology support for the reliability of crankshaft in the product development and in production inspection. Ju Hao[8]introduces the structure and working principle of the testing machine of bending fatigue for automobile wheel. The single chip computer real-timerly test, control and display the bending moment preset by computer to keep it constant during the course of testing. The testing machine monitors the change of the rotating speed which indicates whether fatigue failure happens or not.

It also has the function of automatic alarm and shut-off before the fatigue failure occurs. Scholars leading by S. R. SIN[9] present a method for determining the fatigue life of multi-lap spot weldment of a high strength steel sheet. In this method, the fatigue life is estimated using the lethargy coefficient, which is the total defect coefficient according to rupture stress and time obtained by the quasi static tensile-shear test. The fatigue life obtained by the fatigue estimate equation, which contains a specific lapping constant was compared and verified with an experimental value. A tensile and tensile-mode-fatigue tester has been developed for testing microscale specimens in high humidity environments in order to investigate the fracture mechanisms of micro-electromechanical materials scholars heading by

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T.Tsuchiya[10]. A reduction in the fatigue strength was observed at high relative humidities. Different fracture origins and fracture behaviors were observed in tensile tests and fatigue tests, which indicates that the water vapor in air affects the fatigue properties of SCS specimens. Scholars heading by Sang-Jae Yoon[11] investigate the Shot-peening effects on the fatigue life behavior of bearing steel. Results of a rotary bending fatigue test showed that shotpeening suppressed not only much of the surface-originated fracture but also the scattering error of the probabilistic stress-life data, and improved the fatigue life by about 6 times through the load levels of the cyclic tests. Yusuke Yamaji[12] reports on a tensile-mode fatigue test in a constant humidity to reveal the mechanism of fatigue fractures of MEMS materials. Using this tester, the fatigue life and strength of single crystal silicon (SCS) thin films and their dependence on the humidity were evaluated.

The fatigue life prediction of SCS was performed for the long-term reliability assessment of MEMS devices. A novel micro impact-fatigue tester is developed to overcome such drawbacks of conventional methods by Ilho Kim and Soon-Bok Lee[13]. A newly developed impact fatigue apparatus directly applies impact force to solder joints and measures deformation of the solder joints. The impact fatigue test apparatus consists of an electromagnetic actuator, an impact-pin, a load-cell, a displacement sensor, and a main frame. Electromagnetic actuator produces a repeatable impact force with a changeable amplitude and pulse duration. The report given by Nenadic Nenad G[14] and some others describes fatigue-induced seeded cracks in spur gears and compares them to cracks created using a more traditional seeding method, viz. notching. Finite element analysis (FEA) compares the effective compliance of a cracked tooth to the effective compliance of a notched tooth where the crack and the notch are of the same depth. In this analysis, cracks are propagated to the desired depth using FRANC2D and effective compliances are computed in ANSYS. A compliance-based feature for detecting cracks on the fatigue tester is described. The initiated cracks are examined using both non-destructive and destructive methods. The destructive examination reveals variability in the shape of crack surfaces.

Above all, the domestic and foreign scholars have made large amounts of study on automobile fatigue test, but the related researches on automobile v-ribbed belts fatigue test have not been reported in public yet. Therefore, the device of v-ribbed belts fatigue test is designed in this paper to meet the needs of automobile v-ribbed belts fatigue testing, which provides technology support for practical manufacturing.

2. GENERAL PLAN DESIGN

According to the actual working condition of automobile engines, automotive v-ribbed belts fatigue testing machine design should contain the power input parts, transmission parts, tension and high-temperature control parts.

In this design, considering the engine power, speed and engine operation process of load fluctuation, vibration, etc. , the selection of testing machine power input source should ensure that the speed can be adjusted ; considering the layout of the gear train, pulley diameter, tensioning system, wrap angle, with the cross section and with the wedge number and so on, automotive v-ribbed belts fatigue testing machine design should be based on actual gear train arrangement position to make it reflect the true environment of fatigue test ; considering the wedge changes with temperature in the transmission process, v-ribbed belts will be put in a temperature-adjustable sealed box.

In order to ensure the stable operation of the testing machine, select the AC frequency conversion motor as the power source of testing machine and use the frequency converter to meet the needs of automotive v-ribbed belt fatigue testing machine[15]. For the simulation of the engine in the case of wear condition, according to the calculation of actual load when the engine works, use the load on the pump output to the pump wheel to replace an engine load to simulate the real wear of the wedge belt, reaching the aim of fatigue test.

Belt pre-tensioning force is the first condition to ensure that the whole system works properly. The lack of pre-tensioning force will lead to the belt slipping and let the transmission power down. Slippage can also cause overheating, peeling phenomenon and the early abrasion. Large pre-tensioning force will lead to higher side loads, increasing squeezing pressure and support loads and causing premature fatigue rupture and permanent deformation, in addition, the bearing life will also be affected. Though v-ribbed belts have strong tensile layer and a very low elongation, we should strictly control the belt pre-tensioning force. Taking economic factors into account, weight loaded tension can be used. The automobile ribbed belts fatigue testing machine is designed as shown in Figure 1.

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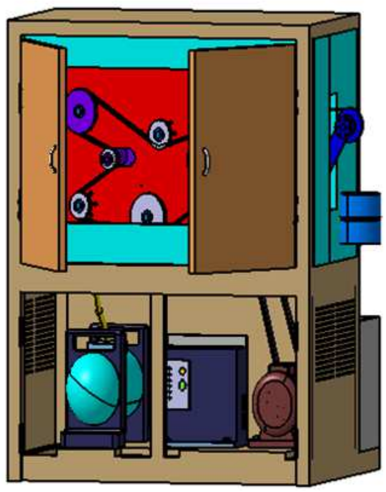
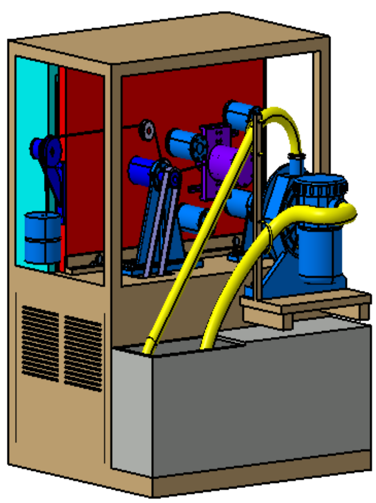


(A)Gear, Power Supply And High Temperature Control Equipment Layout Diagram



(B)Pre-Tightening Force Loading Device And Load Distribution Map

Figure 1: Ribbed Belts Fatigue Testing Machine Schematic

Because the friction during the rotation process can produce a lot of heat, which make the ribbed belt transmission have always been in the high-temperature environment and the automobile engine's starting and stopping makes ribbed belts in the changing environment of the high and low temperature. To simulate the course of the transmission belt of the wedge wear, we add a high-temperature control device at the bottom of the testing machine. During the testing process, wedge belts are always in a confined environment and the internal temperature within the test machine was controlled by the high and low temperature control equipment of the testing, which can simulate to wedge belt temperature working conditions in a changing environment.

3. FINITE ELEMENT ANALYSIS OF THE KEY COMPOENTS

To analyze and test the performance indicators of the automotive v-ribbed belt fatigue tester and ensure the overall strength and stiffness of the v-ribbed belts fatigue testing machine when testing, the finite-element analysis software ANSYS is used to test on the machine key components such as the load shafts, universal joints and bearings. While it works, if the input power is a torque, size 23000N*mm, and this torque is applied to the finite-element analysis of the force and deformation of the load shaft end surface of the load axis statics. We can get the stress distribution nephogram as shown in Figure 2.

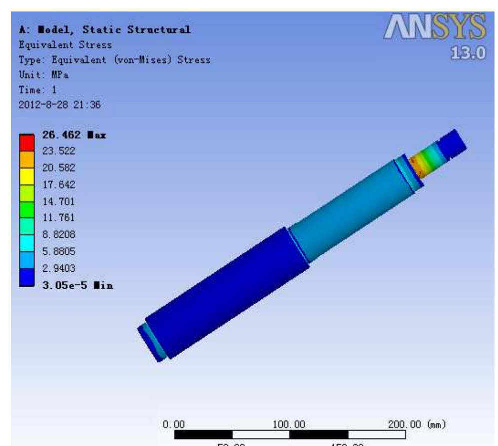


Figure 2: Load Shaft Stress Distribution Nephogram

From the load shaft stress distribution nephogram, we can see the maximum stress of load axial is 26.462Mpa, the material from the load shaft is 45# steel, which requires tempering treatment, and the allowable stress is 60MPa. Its fracture limit is far greater than the load shaft stress. Therefore, the load shaft meets the strength requirements. Under the same conditions, we can get the load axial strain distribution of images as shown in Figure 3.

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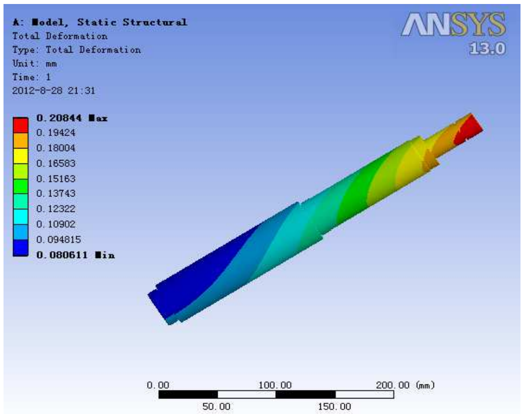

Figure 3: Load Axial Strain Distribution Nephogram

We can see from the load axial strain contours. The maximum strain of the load axis appears at the end of the shaft. Its size is 0.20844mm and this impact of the deformation amount of automotive ribbed belt's fatigue testing machine is so small that it can be neglected, so the load axis design is reasonable and reliable. Under the effect of the torque, we can get the bearing stress distribution nephogram as shown in Figure 4 and the bearing strain distribution nephogram as shown in Figure 5.

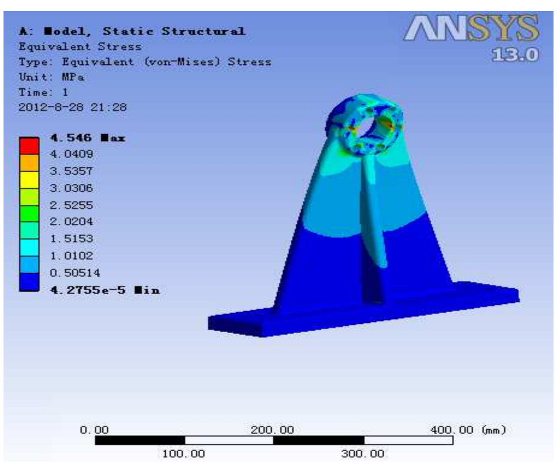

Figure 4: The Bearing Stress Distribution Nephogram

From the bearing stress contours, the maximum bearing stress is 4.546MPa. The selection of materials is HT200. The allowable stress is 20MPa, through theoretical calculations. Therefore, the bearing meets the strength requirements. From the bearing strain contours, the maximum deformation of the bearing is 0.0025262mm and this impact of the deformation amount of automotive ribbed belt's fatigue testing machine is so small that it can be neglected. Therefore, the bearing meets the strength requirements.

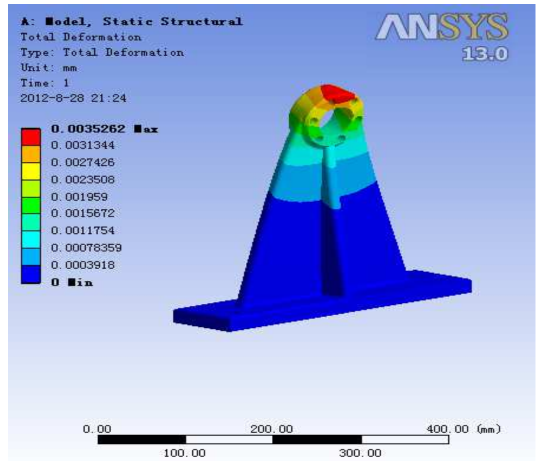

Figure 5: Bearing Strain Distribution Nephogram

Universal joint parts are introduced to realize the power transmission of the variable angle between the load axis and the pump load. Universal joint and axial load constitute the transmission device. Under the same torque conditions, we can get the universal joint stress contours as shown in Figure 6. And the universal joint strain contours as shown in Figure 7.

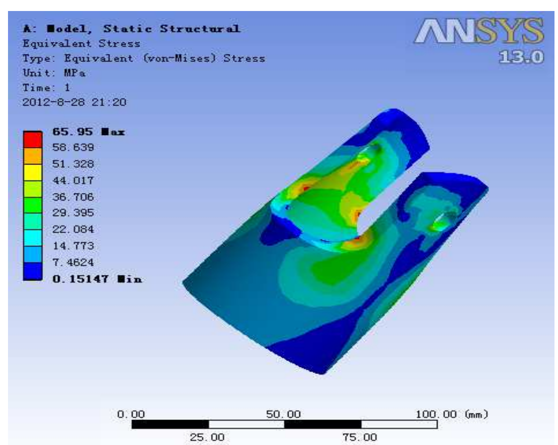

Figure 6: The Universal Joint Stress Distribution Nephogram

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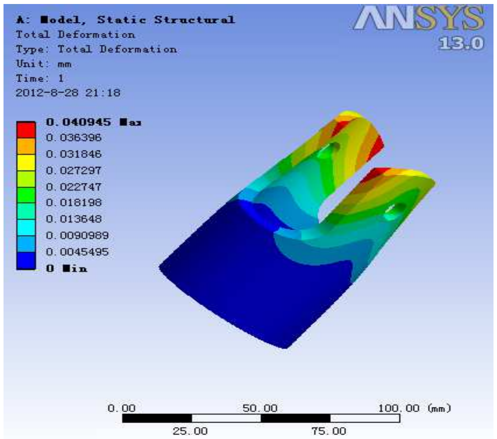
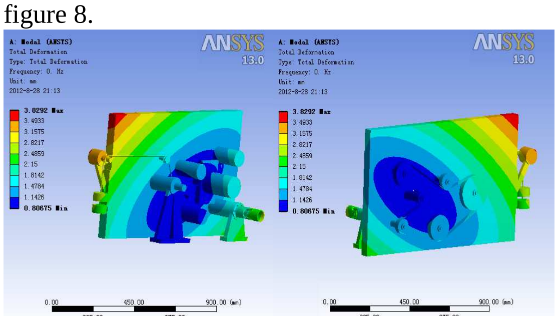


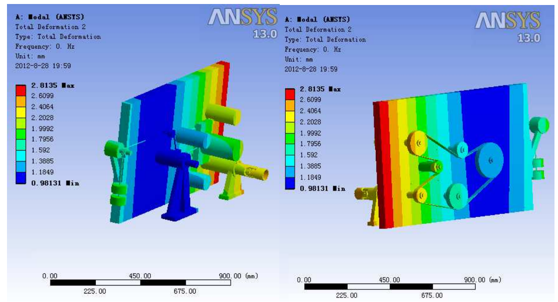
Figure 7: The Universal Joint Strain Distribution Nephogram

The material of the universal joint is 20Cr with allowable stress 85MPa, as we see from Fig.6, the maximum stress on the universal joint is 65. 95Mpa, less than the allowable stress of the material, therefore, the universal joint meets the strength requirements. From Figure 7, the maximum deformation of the universal joint is 0.040945mm, the effect of the deformation amount on the fatigue testing machine still can be neglected. Therefore, the design of the universal joint is also reasonable and reliable.

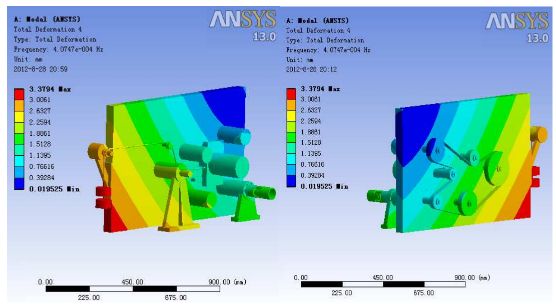
In order to test the rationality of structure design of v-ribbed belt tester, the modality analysis is done on the major structure. Through the modality analysis, the vibration feature can be made sure, the obtained free frequency and shape of vibration can be applied to the structure optimization of v-ribbed belt fatigue tester. The analyzed results of modality vibration shape of major structure are shown in figure 8.



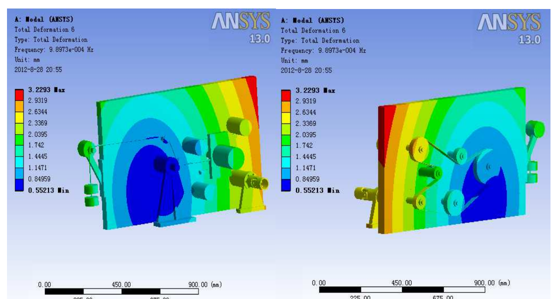
(a) One Order Modality Vibration Shape



(b) Two Order Modality Vibration Shape



(c) *Four Order Modality Vibration Shape*



(D)Six Order Modality Vibration Shape

Figure 8: Major Modality Vibration Analysis

The first order modality vibration shape drawn from major modality analysis usually can be seen as the shape when the structure is in buckling instability. The modality analysis of each order can be used to get the linear buckling critical value of the structure. In order to avoid vibration and noise, loading frequency should be avoided to be same or close to the inherent frequency.

4. CONCLUSION

It is drawn that through the finite-element analysis of the key components of v-ribbed belts fatigue tester by finite-element analysis software

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ANSYS, the key components -load shaft, bearing, universal joint key parts- can satisfy the intensity and the rigidity demand and strain is within reasonable range , so it can be used for automotive v-ribbed belt fatigue test.

Through the modality analysis to major structure, the inherent frequency of each order vibration shape is achieved, which can be applied to optimize major structure of v-ribbed belt fatigue tester and help to make sure the design plan of v-ribbed fatigue tester proposed in this paper. The design of this device is reasonable and feasible, and can provide technical support for the v-ribbed belt fatigue life test, and for the design, research and development of the v-ribbed belt fatigue tester. It is of cert

REFRENCES:

[1] Zhaoping Lü, "The design basis of ploy V-Belt Gear Train", Enterprise Science and Technology & Development, No. 18, 2008, pp. 84-86.

[2] Li Liu, "Research on Optimizing Design of Poly-rib Belt Driving Wheel System and Development of Test-bed", Ph.D.Thesis, Dept. Wuhan University of Technology, China, 2005.

[3] Zhi Zhang, "Wenbin ShangGuan and Qiuhai Xu, Measurement and optimization control of slip rate between driven pulley and belt in serpentine belt drive system", Journal of Vibration Engineering, Vol. 23, No. 6, 2010, pp. 616-619.

[4] Jun Liao, "The fatigue test and simulate analysis for the vice-frame of an electric car", Manufacturing automation, No. 14, 2010, pp. 139-143.

[5] Sumin Yin, "New type of car torsional damper fatigue testing machine development", Journal of Jiangsu University of Science and Technology, Vol. 18, No. 1, 1997, pp. 56-60.

[6] Chen Zhitai and Hua Muju, "Design of Auto Torsion Spring Fatigue Testing Machine", Value Engineering, No. 14, 2012 pp. 51-52.

[7] Liying Xie, "Study on Bending Fatigue Test of Automotive Engine Crankshaft", Automobile Technology & Material, No. 3, 2006, pp. 9-12.

[8] Hao Ju and Junlin Zhang, "Car wheel bending fatigue testing machine research and development", Industrial control computer, Vol. 18, No. 2, 2005, pp. 12-13.

[9] S. R. Sin, S. M. Yang, H. S. Yu, C. W. Kim and H. Y. Kang, "Fatigue analysis for a multi-lap spot welded joint of high strength steel using quasi static tensile-shear tes", International Journal of Automotive Technology, Vol. 9, No. 1, 2008, pp. 81-86.

[10] T. Tsuchiya, Y. Yamajin, K. Sugano and O. Tabata, "Tensile and Tensile-Mode Fatigue Testing of Microscale Specimens in Constant Humidity Environment", Experimental Mechanics, No. 50, 2010, pp. 509-516.

[11] Sang-Jae Yoon, Jung-Hoon Park and Nak-Sam Choi, "Fatigue life analysis of shot-peened bearing steel", Journal of Mechanical Science and Technology, Vol. 26, No. 6, 2012, pp. 1747-1752.

[12] Yusuke Yamaji, Koji Sugano, Osamu Tabata, and Toshiyuki Tsuchiya, "Tensile-mode fatigue tests and fatigue life predictions of single crystal silicon in humidity controlled environmentst", MEMS 2007, (Page: 21 Year of Publication: 2007 ISBN: 1-4244-0951-9)

[13] Ilho Kim and Soon-Bok Lee, "Development of a Novel Microimpact-Fatigue Tester and Its Application to Impact Reliability of Lead-Free Solder Joints", IEEE Transactions on Components and Packaging Technologies, Vol. 32, No. 3, 2009, pp. 542-549.

[14] Nenad G. Nenadic, Joseph A. Wodenscheck, Michael G. Thurston and David G. Lewicki, "Seeding Cracks Using a Fatigue Tester for Accelerated Gear Tooth Breaking, Rotating Machinery", Structural Health Monitoring, Shock and Vibration, No.5, 2011, pp.349-357.

[15] Chengzhi Su, Dong Chen, Kailiang Li, Demin Wang and Guohua Cao, "Wheel bending fatigue test machine based on hammer directly driven by hollow shaft motor", Manufacturing automation， No. 18, 2011, pp.152-156.