http://ansinet.com/itj

ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 11 (4): 516-519, 2012
ISSN 1812-5638 / DOI: 10.3923/itj.2012.516.519

Research for the Crack Dynamic Monitoring of Crank Shaft of Marine Diesel Engine Based on Magnetic Memory Technology

Liao Jian-bin, Zhou Hai-feng and Sun Di
Marine Engineering College, Jimei University, Xiamen Fujian, 361021, China

Abstract: Diesel engine crankshaft is one of the most important parts and crankshaft fatigue fracture is a major failure. In order to alert fatigue fracture of crankshaft to prevent accidents, diesel engine crankshaft dynamic monitoring based on metal magnetic memory testing technology is given as well as detection technology and the results was studied in this study and the appropriate conclusions was drawn.

Key words: Diesel engine, crankshaft, metal magnetic memory, dynamic monitoring

INTRODUCTION

Diesel engine crankshaft is one of the most important moving parts and fatigue fracture is a major failure of crankshaft. Damage detection for crankshaft current is usually judged by subsequent maintenance or testing of oil, which is significant lag. Metal magnetic memory detection knowledge was studied in this paper and with which engine crankshaft was monitored on line, therefore early warning before crankshaft damage occurs can be given to prevent failure occurrence.

INTRODUCTION OF METAL MAGNETIC MEMORY TESTING TECHNIQUE

Metal Magnetic Memory Technique (MMMT) is a new discipline in non-destructive testing areas (Doubov, 1997, 2002) which is a new type of metal non-destructive testing techniques occurred in the late 1990s (Jun and Biao, 2008). With the role of natural geomagnetic field, the various micro-defects and local stress concentration particularly responding on magnetic field within metal, the technique is capable for early diagnosis and life assessment of ferromagnetic metal components (Chechko, 2002).

Magnetic memory testing principle can be stated as: the internal of iron workpiece with work load under magnetic environment will occur magnetic domain of directional with magnetostrictive properties and irreversible re-orientation and can form maximum leakage magnetic field Hp changes in concentration area of deformation and stress. That is the tangential component of the magnetic field Hp (x) has a maximum value, while the normal component of Hp (y) changes sign and has a zero point (Fig. 1) and the irreversible changes of magnetic state even retain after work load is removed. We can accurately infer the parts of stress concentration zone by determination leakage magnetic field normal component Hp (y) and taking the value of K (K = dHp (y) / dx).

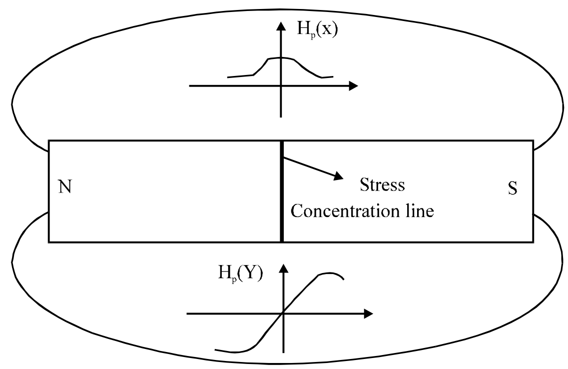

Fig. 1: The elementary diagram of magnetic memory test

Metal magnetic memory for in-service components of equipment is shown on a cumulative way because of its genetic structure and the load in operation (Doubov, 1999). The size and direction of load force in running components will cause magnetization changes of metal in magnitude and direction.

The relationship between variation of leakage magnetic field Hp and mechanical stress $\Delta\sigma$ anisotropy on Δ Z segment of component detected is shown as:

$$H_p = \frac{\lambda^H}{\mu_0}\Delta\sigma \quad (1)$$

where, λ^H is-piezomagnetic coefficient; $\Delta\sigma$ is-external force changes and μ_0 is vacuum permeability.

Corresponding Author: L. Jian-Bin, Marine Engineering College, Jimei University, 361021, China

Stress level on ΔZ section can be determined by detecting leakage magnetic field according to Eq. 1 (Hui and Wanli, 2004).

In short, metal magnetic memory diagnostic techniques is used to indirectly determine the existence of defect or stress concentration area in ferromagnetic component by micro-changes sending information initiatively in the Earth's magnetic field when defect exist or to be form.

CRANKSHAFT FRACTURE MECHANICS ANALYSIS

Crankshaft is one of the most important parts in diesel engine which in general is forged with carbon steel or medium carbon alloy steel. Diesel engine crankshaft weight is about 10% of the engine and the cost is about 20% of the whole (Yunjun and Jialong, 2009). Marine diesel engine crankshaft prone to fatigue fracture due to complex shape, poor working conditions and complex stress.

Fatigue fracture is sudden without apparent plastic deformation, often causing serious accidents. Diesel crankshaft fracture is also part of the fatigue fracture. Seen by the linear elastic fracture mechanics, stress intensity factor Kf and crack body stress σ, crack length and crack geometry factor f (y) have the relationship (Zili *et al*., 1995):

$$K_f = f(y)\sigma\sqrt{a} \qquad (2)$$

According to Paris formula, the fatigue crack growth rate is da /dN = C $(\Delta K)^n$ .Here a is crack length for calculation, N is the number of cycles and ΔK is stress intensity factor amplitude which is proportional to the stress amplitude $\Delta\sigma$, C and n is Paris parameters mainly related to nature of material (Yuhang and Jianguo, 2009).

According to fracture mechanics, after taking the structure of geometry, crack size and load factors into account, equivalent stress intensity factor can be expressed as:

$$K_{Ieq} = \sigma_a f\left(\frac{a}{\Delta}\right)\sqrt{\pi a} \qquad (3)$$

where, σ_a is the maximum principal stress in "local" of crack for the crack-free structure. f (a/ Δ) is geometry of structure factor, where Δ is crankshaft overlap degree, because geometric factor has nothing to do with the loading and the stress intensity factor is mainly affected by the maximum stress σ_a. After calculation, junction between the crank pin and crank arm by the side of the corner is the maximum stress. The crack initiated in this area with expansion along the axis about 45° direction , which is good agreement with broken shaft measured on-site (Guangqin *et al*., 2002). After analysis, we can see that the main stress concentration and fatigue area of engine crankshaft is around the corner near main journal on crankshaft, which is at the crank fillet and facilitate to determine the measuring point when simulation experiments occurred.

CRANKSHAFT CRACK ONLINE DIAGNOSTIC WITH MAGNETIC MEMORY

In this study, we use 295 G diesel engine produced by Fuzhou Qi Deli Power Machinery Co., Ltd, with a hydraulic dynamometer which can achieve different working conditions with variable speed and variable load.

Magnetic memory testing apparatus: In this study, we use SMART-2004 intelligent multi-functional electromagnetic detector produced by Xiamen Autosun, which can give fast early diagnosis for stress concentration of in-service equipment due to material discontinuities (defects), surface, subsurface defects and represented by means of a variety of graphically.

Dynamic monitoring of diesel engine crankshaft: According to fracture mechanics analysis to the diesel engine crankshaft, two fillets on a crank of crankshaft is the major key areas to test. Two holes should opened with similar to magnetic memory tester probe holes in diameter on diesel engine crankcase doors, which is aligned with left and right fillet of the crank pin respectively meanwhile the nearest distance from crankshaft to probe is about 3-4 mm to prevent probe to be hit by crankshaft as well as ensure the effectiveness of measurement distance. Measuring point layout is shown in Fig. 2.

Firstly, operate diesel engine in various of load condition in the meantime observe and record magnetic memory tester signal changes and then stress

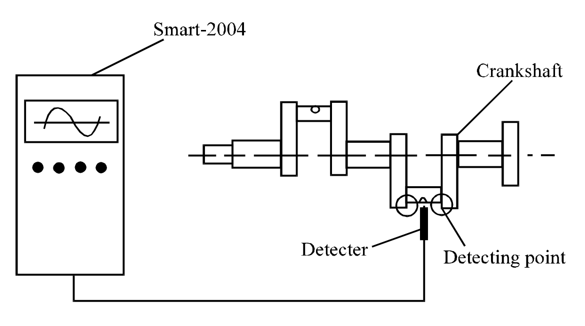

Fig. 2: The layout plan of measuring point

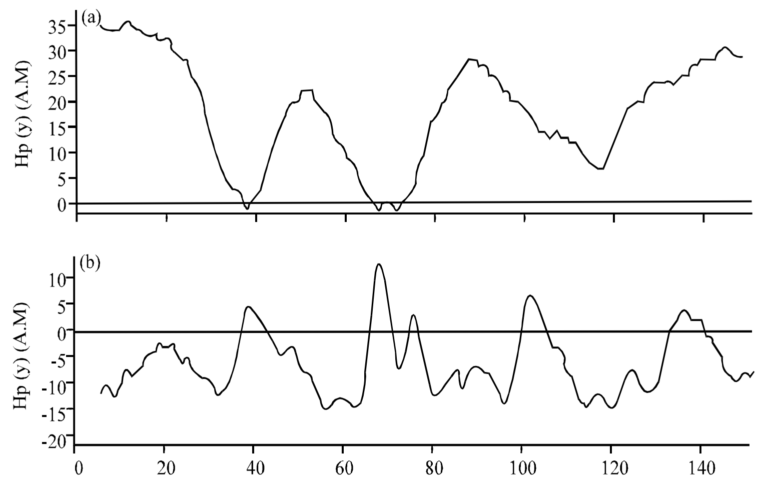

Fig. 3(a-b): Graph of magnetic memory signal in different position of crank pin. (a) Magnetic memory signal of the left excessive rounded corners of crank pin. (b) Magnetic memory signal of the right excessive rounded corners of crank pin

concentration creation or change at crank fillet of crankshaft can be seen in different diesel engine loads; Secondly, run the diesel engine with different speed and test the crank fillet of crankshaft with magnetic memory tester to observe the changes in magnetic memory signals; In addition, since crankcase oil temperature is not always the same in different load and speed, magnetic memory signal changes to crank fillet of crankshaft can also be given in different temperature of crankcase. Diesel engine operated under load applied by a hydraulic dynamometer and the main operating parameters including speed, cooling water temperature, oil temperature and exhaust gas temperature at different loads can be records collected by computer.

Experiments of monitoring a crank fillet at a single moment show that stress concentration with different degrees exists at left and right side of the fillet of crank pin, respectively, as is shown in Fig. 3.

Monitoring results analysis: After testing, magnetic memory signal value is not affected by engine speed but only the collection density of magnetic memory tester changed correspondingly with different related graphics intensiveness, therefore the change of speed will not affect the signal magnetic memory tester signal as long as acquisition speed of the instrument is fast enough. Similarly, the surface magnetic field value in stress concentration area does not change much as the temperature is below 500°C in workpiece (Jilin *et al*., 2006); as a result the signal value of magnetic memory is not much affected by crankcase temperature (can be regarded as the crankshaft change in temperature) change and magnetic memory testing signal strength does not change with temperature, In addition, magnetic memory probe lift-off distance impacts the magnetic field strength and gradient, however peak-peak position on the curve has not changed, namely the judgments of stress concentration area is not effected by the fact that the normal component of leakage magnetic field Hp (y) change sign and has a zero point position unchanged. Therefore, according to the point of Doubov "through zero-crossing magnetic field strength to determine the location of stress concentration," it can infer that the changes in lift-off do not affect discriminate stress concentration area (Yun *et al*., 2006). However, with the load applied to the diesel engine increases, the maximum signal value of magnetic memory testing also increases and Hp (Y) may have trend to pass zero Point. It is shown that how the maximum value of magnetic memory testing signal of the crankshaft change with the load and temperature respectively in Fig. 4. In the curve, the left side is crank crankshaft near the free end part and the right side is the crank crankshaft near the flywheel side part.

With the load suffered by engine increases, peak value in magnetic field on magnetic field measurement points of the crankshaft increases. According to ferromagnetic theory, the stress anisotropy generated within the specimen made the magnetic domain magnetic moment deflection since local stress applied on it is the same direction but different sizes. The greater the area of local stress is, the greater the stress anisotropy is and the more magnetic moment with deflection is which is manifested the larger magnetic field values on the surface of specimen.

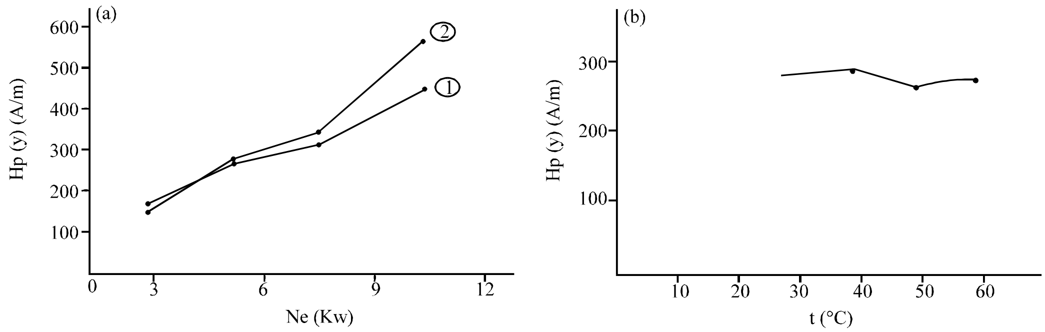

Fig. 4(a-b): Graph of magnetic memory signal in variable load and temperature; 1: Curve for left transition round corners of crank pin, 2: Curve for right transition round corners of crank pin

It is coincident with the principle of magnetic memory testing, as well as also satisfies the relationship of leakage magnetic field and mechanical stress as is shown in formula (1), i.e., that with load suffered in diesel engine increases, the mechanical stress $\Delta\sigma$ imposed on the crankshaft will increase and leakage magnetic field Hp in the measured component will inevitable increases.

CONCLUSION AND PROSPECT

Static and dynamic experiments and studies have shown that the two fillets on crank of crankshaft is the main area of stress concentration which is also a high incidence breakage region of crankshaft, meanwhile the engine load increase will lead to increased mechanical stress also with increased magnetic Memory signal value. Thus, analysis and studies above have shown that metal magnetic memory testing technique can be applied to ferromagnetic components such as diesel engine crankshaft in daily routine to dynamic monitor crack failure of crankshaft, also monitor and early warn early fatigue and stress concentration of the crankshaft, which can timely detect problems and provide solutions to prevent serious accidents. In addition, multi-point simultaneous acquisition and the alarm threshold value is still lack of quantitative analysis, hence these areas still needs further study.

ACKNOWLEDGMENT

Authors thanks to National Natural Science Foundation funding (51179074); Pan Jin long subject of Jimei University Construction Fund (C5 10068).

REFERENCES

Chechko, I.I., 2002. Using the method of magnetic memory of metal to evaluate the service life of the items of power equipment at the konakovo district power station. Thermal Eng., 49: 12-14.

Doubov, A.A., 1997. A study of metal properties using the method of magnetic memory. Metal Sci. Heat Treatment, 39: 401-402.

Doubov, A.A., 1999. Diagnostics of metal items and equipment by means of metal magnetic memory. Proceedings of the CHSNDT 7th Conference on NDT and International Research Symposium, October 1999, China, pp: 181-187.

Doubov, A.A., 2002. Express method of quality control of a spot resistance welding with usage of metal magnetic memory. Weld. World, 46: 317-320.

Guangqin, W., L. Xingren and G. Qing, 2002. Calculation of stress intensity factors for cracked diesel engine crankshafts. J. Southwest Jiao Tong Univ., 37: 655-658.

Hui, J. and Z. Wanli, 2004. Check on the metal magnetic mnemonic of ferromagnetic constructional part in power plant. Water Conservancy Electric Power Mach., 26: 11-13.

Jilin, R., C. Xi and S. Kai, 2006. Study on the influencing factors of metal magnetic effect of metallic structures. NDT, 28: 292-295.

Jun, Z. and W. Biao, 2008. Recognition of signals for stress concentration zone in metal magnetic memory tests. Proc. CSEE, 28: 144-148.

Yuhang, W. and N. Jianguo, 2009. Fatigue behavior of studs in a composite beam based on fracturemechanics. J. Tsinghua Univ. Sci.Tech., 49: 1467-1470.

Yun, Y.F., Z.C. Xu and W. Miao, 2006. The study of the effect of placement direction and lift-off on the magnetic memory testing signals. Mach. Design Manuf., 5: 118-120.

Yunjun, Z. and R. Jialong, 2009. Study on the remanufacture restoring of diesel engine crankshaft. Mach. Design Manufacture, 8: 176-178.

Zili, D., K. Jian and X. Yucai, 1995. A fracture mechanics analysis and experimental investigation on crankshaft of model 8nvd48a-2u marine diesel engine. Nei Ran Ji Gong Cheng, 16: 1-8.