THE APPLICATION OF THE BLOCK VIBRATION CHARACTERS OF THE IC ENGINES TO THE COMPRESSING RINGS FAULT DIAGNOSING

Y. Zhang Z.P. Zhang

(Changsha Communications Institute, P.R. China)

Y.C. Zhou

(Wuhan Transportation University, P.R. China)

Abstract In this paper, the principle to diagnose the fault compressing ring by the block vibration signal is analyzed by considering of the drift process of the ring and the excitation forces. The equation to calculate the nature frequency of the ring in the cylinder is given. The simulation tests on the diagnosing for fault ring are carried out by the two types of the diesel engines. The method to diagnose the fault compressing ring by the block vibration signal is got: In the domain of the low frequency of the block vibration signal there is a characteristic frequency which is closed to the single ring's nature frequency in the cylinder, the PSD value at the characteristic frequency is grown, in the narrow frequency band including to the characteristic frequency the power value is grown obviously, then we can believe that there are fault compressing rings. (usually it is the first ring)

Key Words vibration, IC engines, compressing ring, fault diagnosing

It is not unusual that the compressing rings are in fault of the gumming, wearing, elasticity lacking and breaking while the engines are in the tendency of large—scale, high rotary speed and huge power[1]. Generally the fault of the compressing ring can be diagnosed by the cylinder gas pressure and the temperature of the exhaust gas[2], but those parameters are not best because of the convenience and accuracy. In this paper some items about to diagnose the fault of the compressing ring by using the block vibration signal, which includes the fault information and the vibration feature of the rings, is discussed.

1. THE VIBRATION PRINCIPLE OF THE COMPRESSING RING

In the cylinder the vibration of the compressing ring depends on the two conditions: ①the compressing rings are in the situation of drifting instead of to be pressed to the groove, ②there is an enough force to excite the ring.

1.1 The drifting of the ring

The pressure $F_{zi}(\alpha)$ (in vertical) doing to the No. i ring is:

$$F_{zi}(\alpha) = p(\alpha) \times (K_i - K_{i-1}) \times S \pm F_{zi}(\alpha) + Q_0(\alpha) \qquad (1)$$

In equation (1): The "±" becoming "+" while the ring running up or becoming "−" while the ring running down; The $p(\alpha)$ is the cylinder gas pressure, the $F_{zi}(\alpha)$ is the friction force between the No. i ring and cylinder, the $Q_0(\alpha)$ is the reciprocating inertia force of the ring, the S is the side area of the ring, the K_i is the pressure declining coefficient of the No. i ring. When the $F_{zi}(\alpha)$ is less than zero, that means the No. i ring is in the situation of drifting. The figure 1 shows the No. 3 ring's drifting of a 4135G diesel engine at the operation condition of 1500r/min, No. 1 and 2 rings fault, 75% capacity[X]. So we can know from figure 1 that There are 2 sections of the drifting in the domain of 0~720°CA.

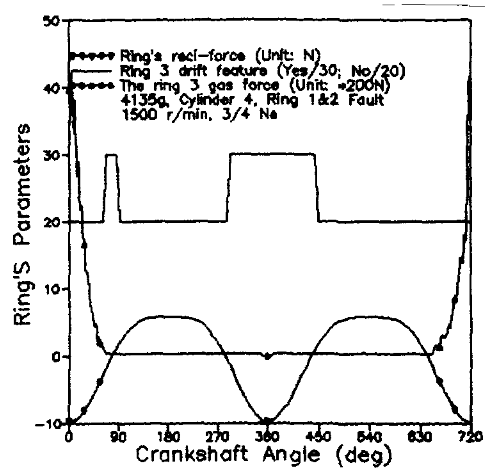

Figure 1 No. 3 ring's drifting of a 4135G diesel engine

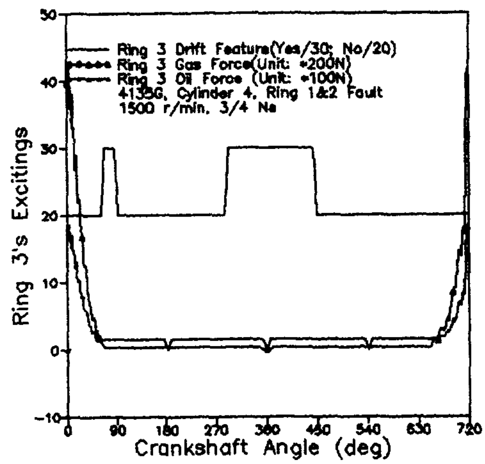

Figure 2 Gas pressure and the oil—film force (in horizon) doing to the No. 3 ring of a 4135G diesel engine

1.2 The force to excite the ring

The force F_i (in horizon) doing to the No. i ring is:

$$\left.\begin{array}{l} F_i - W_{pi} + W_{ri} + W_i = 0 \\ W_{pi} = \pi \cdot B \cdot D_k \cdot p(\alpha) \cdot (-2 \cdot K_i' + K_{i+1}) \quad \text{ring running up} \\ W_{pi} = \pi \cdot B \cdot D_k \cdot p(\alpha) \cdot (-2 \cdot K_i' + K_i) \quad \text{ring running down} \end{array}\right\} \quad (2)$$

In equation (2), the W_{pi} is the gas pressure doing to the No. i ring in horizon, the W_{ri} is the force resulted in the elasticity of the ring, the W_i is the oil—film force doing to the No. i ring in horizon; The B is half of the ring's high, the D_k is the ring's diameter, the K_i' is the back pressure coefficient of the No. i ring. Figure 2 shows the gas pressure and the oil—film force (in horizon) doing to the No. 3 ring at the condition of 1500r/min, No. 1 and 2 rings fault, 75% capacity; It should be noticed that in the first drifting section there aren't any changing of the gas pressure and the oil—film force; but in the 360°CA TDC of the second drifting section, the oil—film force is decreased suddenly to zero because of the changing of the piston moving direction, also the gas pressure is decreased suddenly to zero because of the opening of the intake and exhaust value. At this moment the force F_i is becomed suddenly to the force F_{ei} to excite the ring:

$$F_{ei} = F_i = W_{ri} \quad (3)$$

If there were some fault rings, the gas pressure W_{pi} and the oil—film force W_i would be more different than the normal operation condition, so the exciting force F_{ei} to excite the rings would be also more different than the one. The vibration of the ring will result in the vibration of the cylinder, therefore the block vibration signal, which includes the vibration information of the ring, now is more different than the normal operation condition, too. The key feature of the block vibration signal can be just used to diagnose the fault of ring.

1.3 The calculation of the ring nature frequency

Considering the compressing rings with elasticity, also Considering the rings' vibration in the space formed by cylinder and groove, the equation to calculate the rings' nature frequency is[3]:

$$f = (0.0822 \cdot K_\xi \cdot t_0/D^2) \cdot \sqrt{E \cdot g/\gamma}, \ Hz \quad (4)$$

in equation (4): The K_ξ is a coefficient from 1 to 6.25 for frequency domain; The t (cm) is the thickness of the ring in diameter; The D (cm) is the middle diameter of the ring; The E (dyn/cm^2) is the modulus of elasticity; The γ (dyn/cm^3) is the specific gravity of the ring. According to the equation (4), we could know that the domain of the ring nature frequency of the 4135G diesel engine is from 125 to 501 Hz, and the one of the 175F diesel engine is from 431 to 1727 Hz. Those 2 kinds of diesel engine are used in the simulating tests to disgnose the fault ring.

2. THE SIMULATING TESTS TO DISGNOSE THE FAULT RING

While the compressing rings are in fault condition, the essences of the influence to the diesel engine are that the function closing gas pressure and decreasing piston crashing is lost because of the lacking elasticity of ring meanwhile the friction power expended by rings group is decreased obviously. Usually the first compressing ring is easist to be fault (such as gumming) since it is most closed to the combustion home with high temperature, So the simulating method about the ring fault is to cancel the No. 1 compressing ring directlt.

The simulating tests are carried out at a 4 cylinders diesel engine with type of 4135G and a single cylinder diesel engine with type of 175F. The vibration responses detected from the blocks of the 2 diesel engines are investigated and analysed by the power spectrum density (PSD) of the FFT, shown as figure 3 and figure 4; Some fault characters about the 2 figures are shown in table 1.

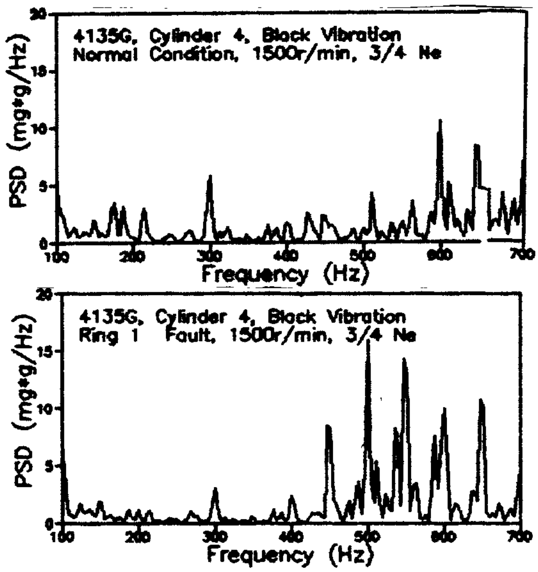

Figure 3 The PSD of 4135G block vibration, 1500r/min, 75% capacity (Zoom of 100~700Hz)

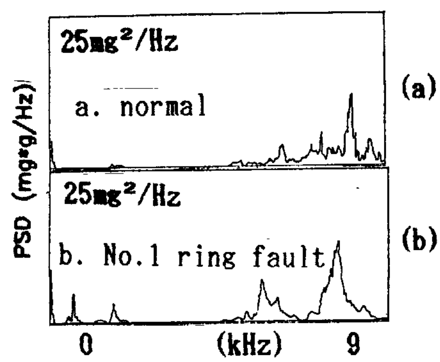

Figure 4 The PSD of 175F block vibration 1470r/min, 0% capacity

Table 1 Fault characters about the block vibration of 4135G or 175F diesel engine

Some fault characters	4135G diesel engine normal condition	4135G diesel engine No. 1 ring fault	175F diesel engine normal condition	175F diesel engine No. 1 ring fault
cha. frequency(Hz)	500	500	—	580
cha. PSD value(mg^2/Hz)	4.36	16	0.6	6
narrow band power (g^2) (400~600Hz)	0.27	0.65	—	—
total power(g^2)	23.3	27.5	9.19	11.9
acc. mean—square(g)	6.55	6.93	3.50	3.79
max. gas pressure(MPa)	7.43	7.08	2.05	1.87

* The "cha." means "characteristic"; the "acc." means "acceleration"; The "max" means "maximum".

So we can know from figure 3,4 and table 1 that there are some characteristics when the compressing ring of 4135G or 175F diesel engine is in fault condition:

①The cha. frequency, which is 500Hz or 580Hz and in the domain of the frequency calculated by equation (4), is the ring's nature frequency in cylinder.

②In the condition of the No. 1 ring fault, the cha. PSD value and the narrow band power are larger than the one in the normal condition.

③. The cha. frequency, the cha. PSD value and the narrow band power are all the parameters related to the fault condition of the ring.

④. The variety of the parameters of the "total power" and the "acc. mean—square" are not very obvious because those parameters are all the general paremeters which express the model information of the system formed by piston—rings—cylinder—block.

3. CONCLUSION

Summing up, the block vibration characteristics of the diesel engine with ring fault are: ①There is a characteristic frequency which is closed to the nature frequency in cylinder; ②The cha. PSD value and the narrow band power are larger obviously than the one in the normal condition.

4. INFORMATION ABOUT THE FIRST AUTHER

Y. Zhang, Ph. Doctor with the Position of Associate Professor; working in the Automobile Engineering Department, Changsha Communications Institute, Changsha 410076, P. R. China; The major research direction is the condition monitoring and fault diagnosing for mechanical equipment. Having published about the 30 papers on fault diagnosing and automobile engineering. The major paper is " The Research on The Fuzzy & Dynamic Monitoring of The IC Diesel's Operation Condition", Journal of Automobile Engineering, Proceeding of the Institute of Mechanical Engineers Part D, UK. The major work is" The Research On Construction Response And Operation Condition For IC Engine's Main Moving Assembly", Railway Press, 1th edition, Beijing, P. R. China, 1997.

5. REFERENCES

[1]W. Muller. Service Experience From Sulzer RTA—series Engines. May. 1991

[2]Y. Zhang. The Research on The Construction Response And Operationb Condition for IC Engine's Main Moving Assembly. Ph. D Thesis, Wuhan Transportation University, Wuhan, P. R. China. 1996

[3]B. Q. Wu. The Rings of IC Engine. Railway Press. 1th edition. Beijing, P. R. China. 1987. 20—40