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TEST AND ANALYSIS OF VIBRATION CHARACTERISTIC ON NEW TYPE DYNAMIC HYDROCYCLONE

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ABSTRACT

Dynamic hydrocyclone is currently used in separating oil and water from the crude oil, in which the fluid rolling motion is drived by the external power. Compared with the static type, the dynamic hydrocylone has higher separating property, while its structure is more complex and its separating property is influenced seriously by all the rotary components. Based on the original model, dynamic hydrocyclone of the new type is designed and manufactured, while applying the vibration signal collection and analysis system of IOtech640 type in the vibration characteristic analysis of the model body. The result shows that, when the rotating speed rises from 600r/min to 2000r/min and the flux from 1 to 3 m^3/h, the level time-domain vibration peak of the monitoring site both the near the electromotor and the faraway is under 3.4×10^{-4}, while the vertical is under 3.2×10^{-4}, with steady frequency components in the vibration signal. It is illustrated that vibration intensity of the dynamic hydrocyclone of the new optimized type is lightened, which may confirm the improvement of the separation property and the operational life.

Key words: Dynamic hydrocyclone, New type, Vibration characteristic, Test and analysis

INTRODUCTION

With requirement of advanced water treatment in oilfield, people gradually begin to pay high attention to a more advanced oil/water separation method Liquid/Liquid Hydrocyclone（Jones, 1993; Belaidi, Thew 2003）. For more than 100 years, two types hydrocyclone are shaped: static hydrocyclone and dynamic hydrocyclone. The former is developed considerably for its advantage of no moving parts, while the disadvantages stand out with the deeper application: the shear failure on the liquid drop by the inlet under high speed; the long moving track of the oil drop to the centerline; the shear failure to the liquid drop by the tangential velocity gradient in the radial direction; the moving speed of the oil drop influenced by the short circuiting or the infliction from the inner wall; the high needed inlet pressure of over 0.6MPa and the high pressure loss of over 0.25MPa between single-stage inlet and outlet, and etc. Therefore, the dynamic hydrocyclone gets people’s attention with the distinct advantages, such as the smaller separated drop, high efficiency, lower needed work pressure, little pressure loss and being more convenient when disposing the production liquid of polymer injection(Wang, Zhao, Li, 1999).

Conventional dynamic hydrocyclone is composed of the fluid inlet cavity, the rotating cylinder, the overflow chamber and underset chamber. The main components concludes transmission wheel, rotating cylinder, rotation barrel, oil collection rod, overflow lip and the conditioning components, while the attachments concludes electromotor, V-belt, pulley, base, brackets, bearings and mechanical seal. The structure sketch is shown in fig.1.

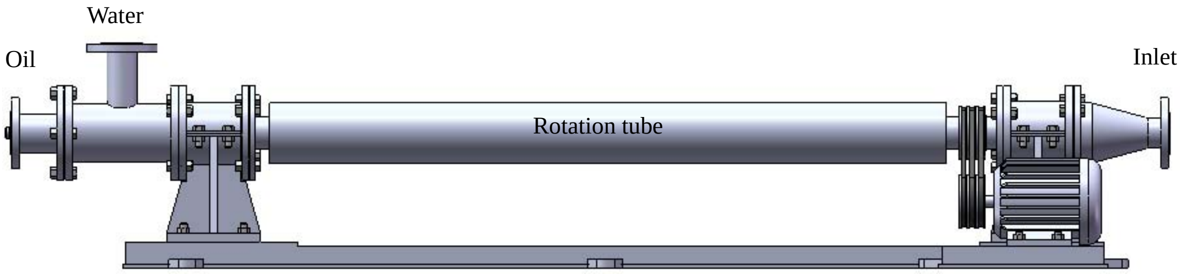

Fig.1 Sketch of hydrocyclone

The separating process of the dynamic hydrocyclone can be described as: the electromotor drives the rotating parts by V-belt, the mixture is transmits to the inlet, then to the rotation barrel and the the orientation of its tail cone. The mixture is processed by the centrifugal force of over 1,000 times the gravity acceleration, as the result, the light-phase oil is transmitted to the drum center migration forming with the formation of oil-core, finally expelled through the overflow lip and the oil collection rod, while the heavy-phase water is transmitted to the tube wall and then expelled through the underset outlet under the longitudinal force, therefore, the oil-water separation is achieved（Jiang, Zhao, Li, Wang, 2000).

VIBRATION ANALYSIS FOR THE DYNAMIC HYDROCYCLONE

Compared with the static model, the structure of the dynamic hydrocyclone is more complex due to it driving equipments from the external power, which requires additional transmission device, supporting parts, sealing devices, etc. As the result, the machining precision of the components can not be exactly confirmed, simultaneously, the system reliability is depressed by the possible irrationality of some elements and ultimately affects the separating performance of the hydrocyclone.

For the dynamic hydrocyclone, the vibration is absolutely veil. Since the vibration may make the oil core thicker, even bent it, then affect the oil collection process, in severe cases, it may cause the oil-water separation failure.

By analyzing, the vibration driving source can be found. First of all, it is difficult to ensure the concentricity between the tube and the rotor bearing seat due to the low precision. Since the rotation tube is welded with the inlet pipe and underset pipe, while the rotor length-radius aspect ratio of 12.5 and over15 after the welding connection, although several processes such as reciprocal bases and assistant machining with combination of the tailstock and follow rest, is applied in the machining, the parts deformation can still not be absolutely avoided. With no complete confirmation of the rotor's straightness and roundness, the concentricity can not be ensured, therefore, the sharp vibration may arise by the eccentric force when rotating with high speed. Secondly, for the total structure distribution of the dynamic hydrocyclone, the electromotor locates at the flanking which is linked with the V-belt, the rotation tube is set as simple beam structure, the force diagram can be described as Fig.2.

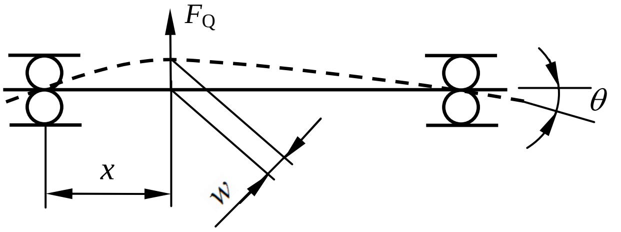

Fig.2 Force diagram of the rotating tube

The force on the rotation tube by the pulley F_Q(Pu, Ji, 2005):

$$F_Q = 2zF_0 \sin\frac{\alpha_2}{2} \tag{1}$$

where F_0 is pulley tensioning force, z is pulley number, α_2 is rotor angle of the pulley。

By F_Q, the rotation tube eccentricity arises which cause the vibration with high-speed rotation. While the rotation accelerates, the vibration gets sharper. In addition, the presence of the force may also generate a certain angle θ and deflection w (Liu Hongwen, 2005):

$$\theta = \int \frac{M}{EI} dx + C \tag{2}$$

$$w = \iint (\frac{M}{EI} dx) dx + Cx + D \tag{3}$$

where M is the moments by F_Q, EI is a constant for the uniform cross-section tube, C、D are constants related with the tube dimensions.

The main driving source and the affect object of the vibration is the seal system. The non-equilibrium spring rotating mechanical sealing mode is applied in the dynamic hydrocyclone which mainly relies on the contact seal between the dynamic ring and the static ring. It can be analyzed that the leakage is mostly caused by the dynamic seal point failure. Because of the rotating angle θ, the assembly accuracy is depressed after working for a certain period, which may generate the swing of the dynamic ring, as the result, the periodic leakage of the attaching surface comes out, seriously cause the seal system failure. The total seal system is shown in Fig.3. When the seal system gets fault, the significant increase of the noise generates mainly in the bearing seats of the dynamic hydrocyclone.

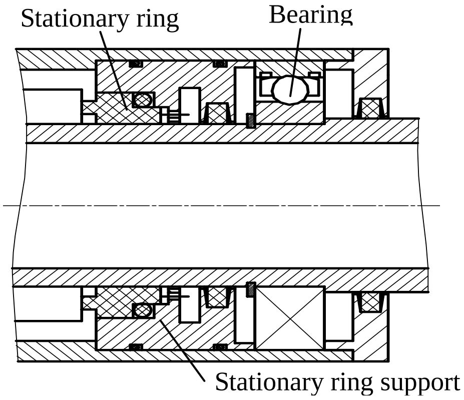

Fig.3 Sealing and bearing structure of the old type

STRUCTURE IMPROVEMENT

Based on the above analysis, several structure improvement is processed for the dynamic hydrocyclone:

Improvement to the power structure distribution

The coaxial-driving approach is used as in Fig.4. The electromotor is installed in the front which is coaxial to the rotation tube, while the tube is linked with the electromotor spindle by flexible coupling. By coaxial-driving approach, the wearing parts is reduce, at the same time, the pulley changing problem is solved. In addition, the coupling demolishes its performance of throwing switch forasmuch gets higher transmission accuracy, less electromotor power loss, and more flexible and accurate control on parameter of rotating speed. However, coaxial-driving approach requires higher concentricity and higher alignment precision of the electromotor and tube, so, the improved structure needs higher machining and installing precision.

Change of the support location

Rotation tube is the main separating section of the hydrocyclone which is affected by the vibration, therefore the vibration damping for it is significant. In the new mode, the support is directly located on the rotation tube in order to shorten the span of the support, which restrict the tube deformation and the veil vibration by the eccentricity. On the other hand, the shortening of the span may be favor of ensuring the concentricity and precision improvement.

Improvement to the static ring support

The improvement to the static ring support makes the bearing away from the mechanical seal to forms several independent units, among which a fluid collection crater and a drain hole are specially designed. The distinct advantage is that even the mechanical seal fails, the testing mixture will flow into the fluid collection crater along with the spindle and hole wall, then output from the drain hole, in stead of flow into the bearing seats. The perfect protection for the bearing is shown in Fig.5.

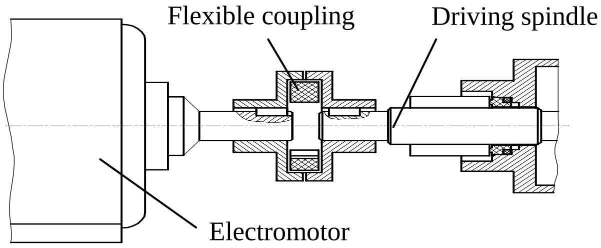

Fig.4 Driving mode of the new structure prototype

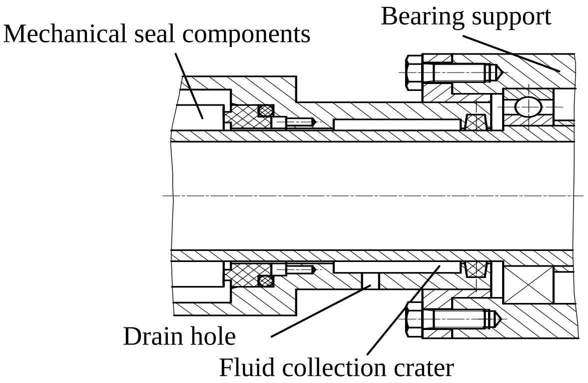

Fig.5 Construction of sealing and bearing sets

Through the above designment, most baneful vibration, leakage and maintenance difficulty are demolished. Based on the project of the improved model, the basis and rotation tube are designed, then the new-type dynamic hydrocyclone is detailed draw out, whose structure is shown in Fig.6.

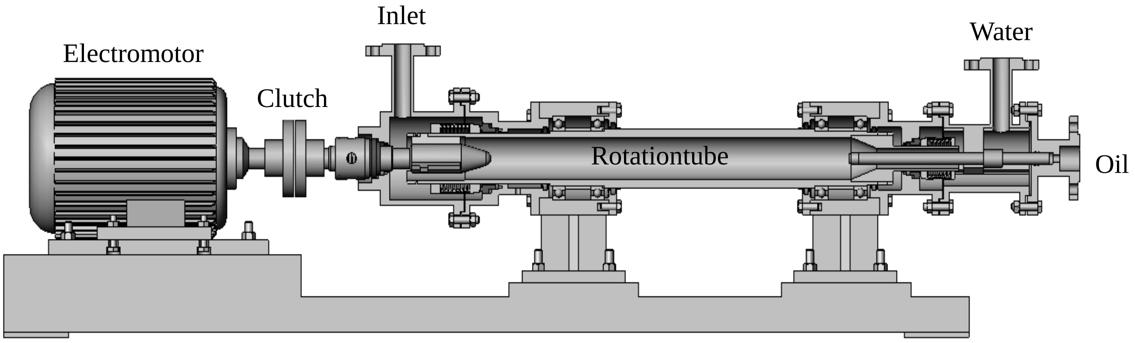

Fig.6 Prototype of new structure

ANALYSIS ON VIBRATION PERFORMANCE OF NEW-TYPE DYNAMIC HYDROCYCLONE

With IOtech640 series handheld dynamic signal analyzer, we got the vibration signal from the hydrocyclone body and analyzed it through the special software of *eZ-analyst Version 5.1.56*.

Testing points location

Based on the above analysis and detail design, the testing points locates at the bearing seat of both ends as Fig.7 and Fig.8, which individually includes two inspecting points: the horizontal and the vertical.

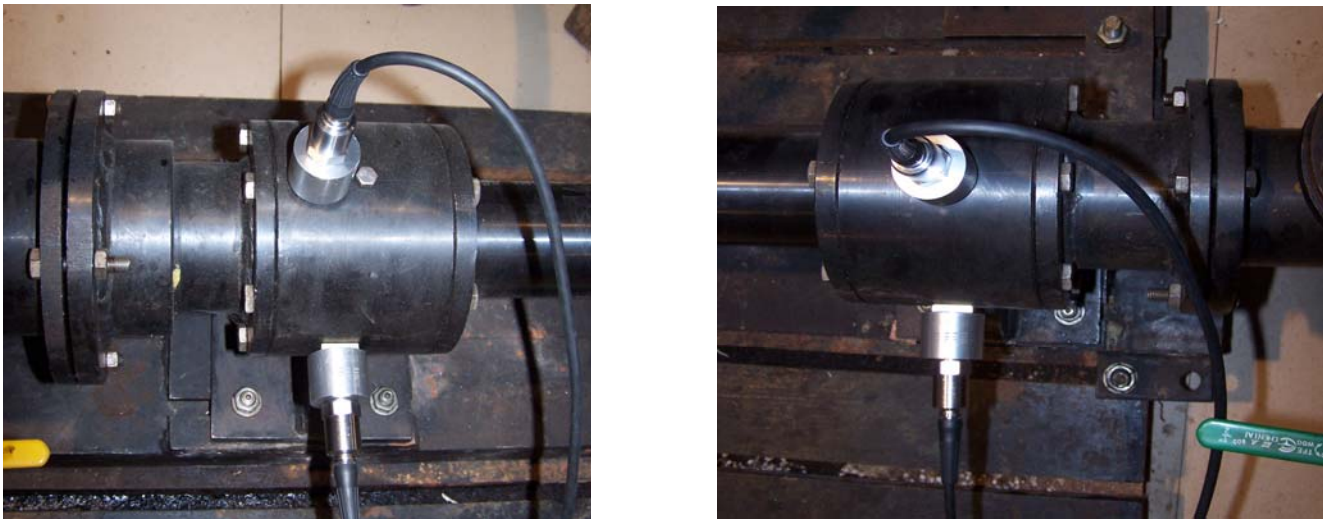

Fig.7 Local testing pictures

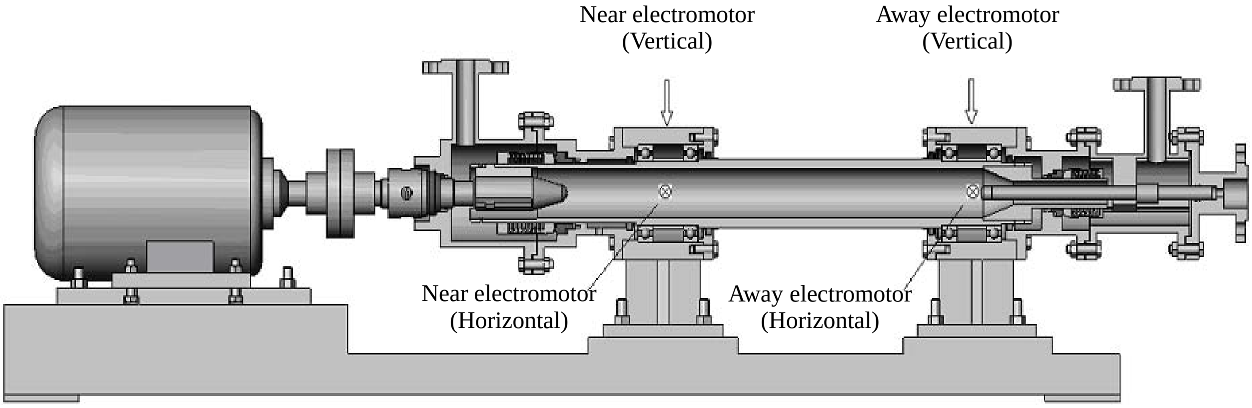

Fig.8 Checking points distribution sketch

Result analysis

Near-electromotor vibration

Tab.1 Near-electromotor vibration information

Signal Number	Speed (r/min)	Flux (m^3/h)	Horizontal Time-domain Peak（$\times 10^{-4}$）	Vertical Time-domain Peak($\times 10^{-4}$)	Signal Number	Speed (r/min)	Flux (m^3/h)	Horizontal Time-domain Peak($\times 10^{-4}$)	Vertical Time-domain Peak($\times 10^{-4}$)
1	600	1	3.4	3	7	1350	3.33	3.2	3
2	600	2.5	3.4	3.2	8	1500	3.22	3.2	3
3	750	2.5	3.2	3	9	1650	3.1	3.0	2.9
4	900	2.5	3.2	3	10	1800	3.03	3.0	3
5	1050	2.5	3.1	3	11	2000	2.9	3.1	3
6	1200	2.5	3.2	3					

Tab.1 includes the vibration information of the near-electromotor testing points with changing parameters (flux and rotation speed), on which four cure is drawn out:

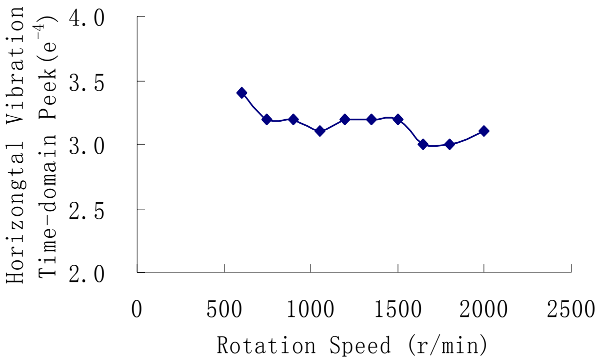

Fig.9 Relationship between rotation speed and horizontal vibration peak of near-electromotor

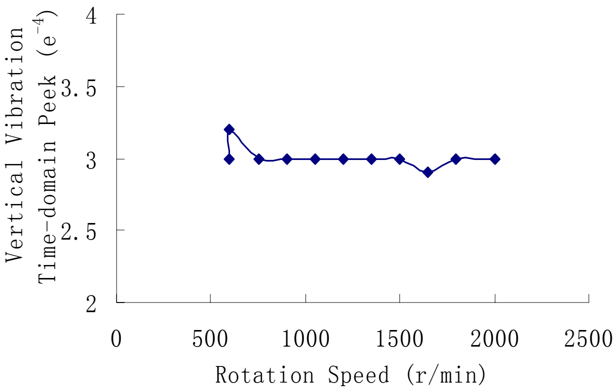

Fig.10 Relationship between rotation speed and vertical vibration time-domain peak of near-electromotor

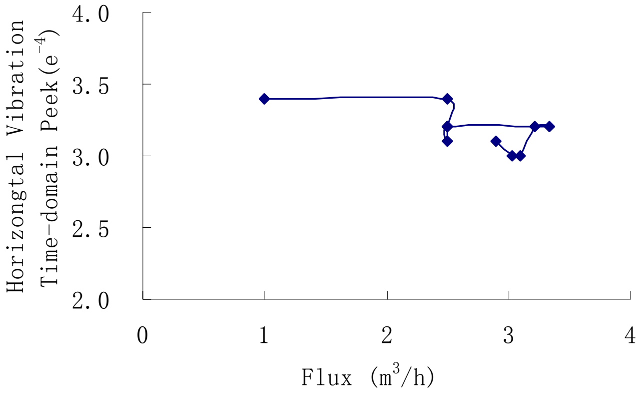

Fig.11 Relationship between flux and horizontal vibration peak of near-electromotor

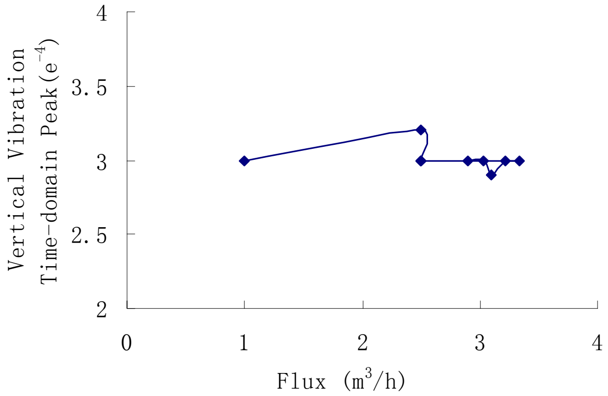

Fig.12 Relationship between flux and vertical vibration peak of near-electromotor

It is known from the above curves that the vibration is stable when the working parameters change rapidly, whether the horizontal or vertical of the near-electromotor testing points.

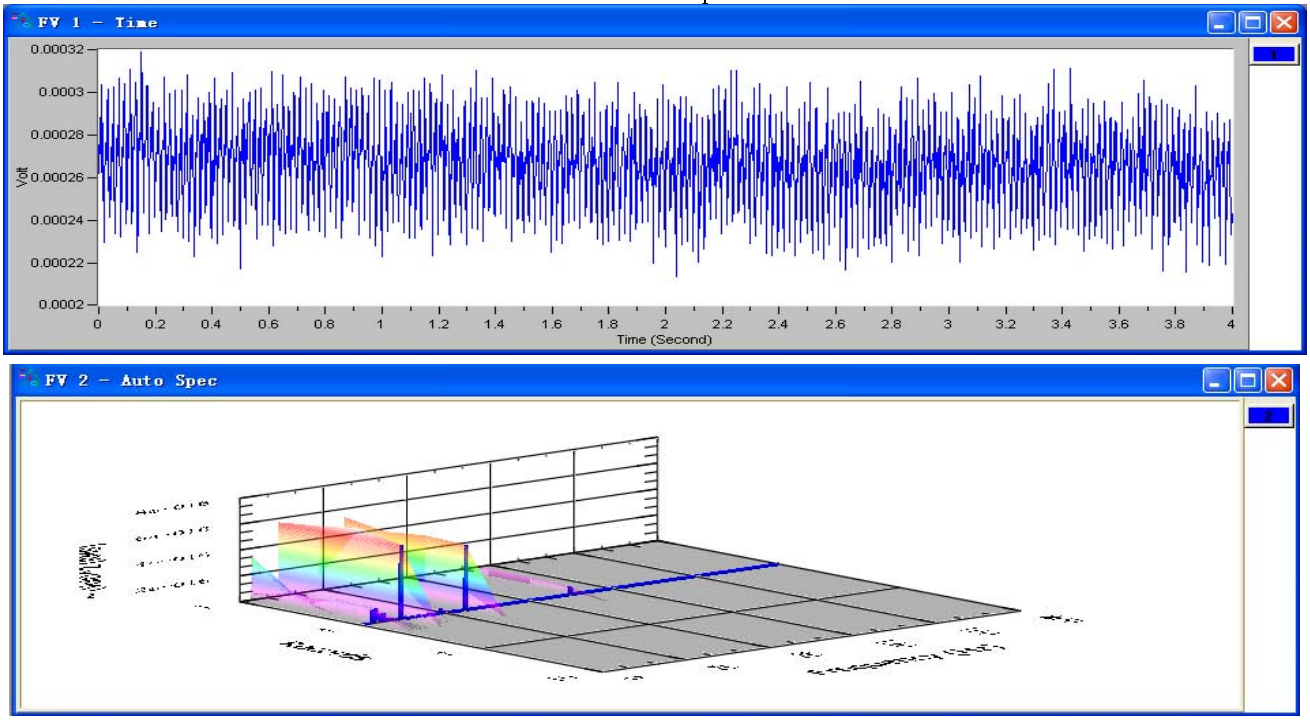

Fig.13 Vibration signal of time-domain and frequency-domain analysis of near-electromotor

Fig.13 shows the vibration signal of time-domain and frequency-domain that illustrates that the main vibration frequency components locate at lower section and the basic frequency components are not in evidence.

Away-electromotor vibration

Tab.2 Away-electromotor vibration information

Signal number	Speed (r/min)	Flux (m^3/h)	Horizontal time-domain peak（×10^{-4})	Vertical time-domain peak(×10^{-4})
1	600	1	3.4	3
2	600	2.5	3.2	3.2
3	750	2.5	3.1	3
4	900	2.5	3.1	3
5	1050	2.5	3.2	3
6	1200	2.5	3.2	3.2
7	1350	3.33	3.2	3
8	1500	3.22	3.1	3.1
9	1650	3.1	3.1	2.9
10	1800	3.03	3	2.9
11	2000	2.9	3	3

Tab.2 includes the vibration information of the away-electromotor testing points with changing parameters (flux and rotation speed), on which four cure is drawn out:

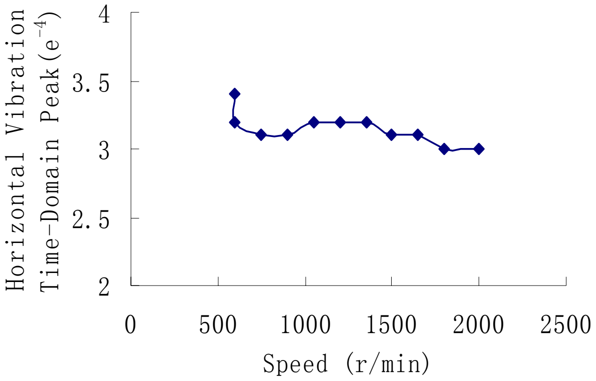

Fig.14 Relationship between rotation speed and horizontal vibration peak of away-electromotor

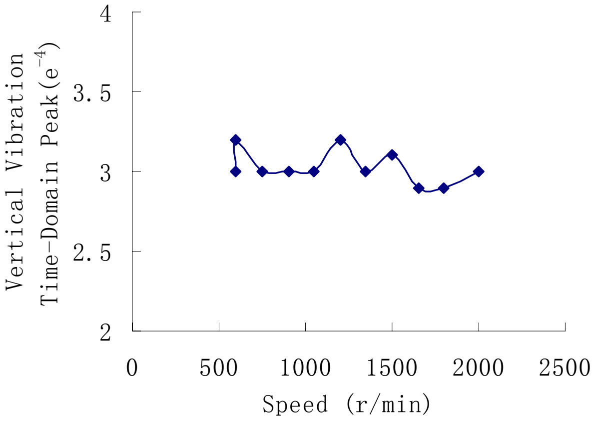

Fig.15 Relationship between rotation speed and vertical vibration peak of away-electromotor

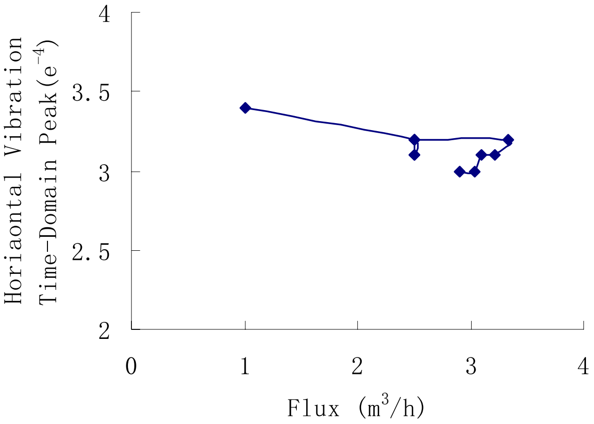

Fig.16 Relationship between flux and horizontal vibration peak of away-electromotor

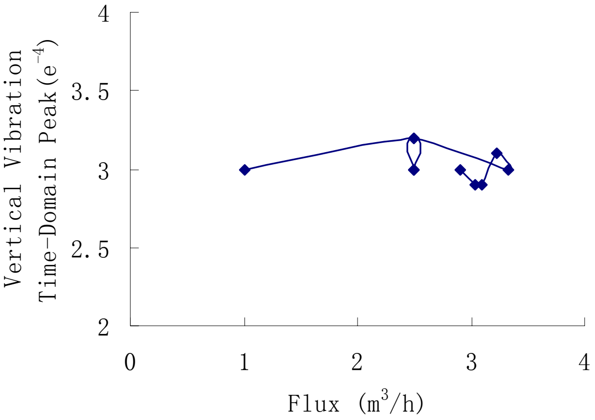

Fig.17 Relationship between flux and vertical vibration peak of away-electromotor

The four curves(Figs.14-17) illustrates that the vibration of the away-electromotor testing points is faint and stable when the working parameters change rapidly, whether the horizontal or vertical of the near-electromotor testing points.

Fig.18 shows the vibration signal of time-domain and frequency-domain that illustrates that the main vibration frequency components locate at lower section and the basic frequency components appear, but the amplitude is weak.

The analysis on the vibration signal of the hydrocyclone testifies that when the working parameters (rotation speed and flux) change continuously, the vibration almost does not vary, whether the near-electromotor or the away, the total vibration amplitude and the frequency components are stable.

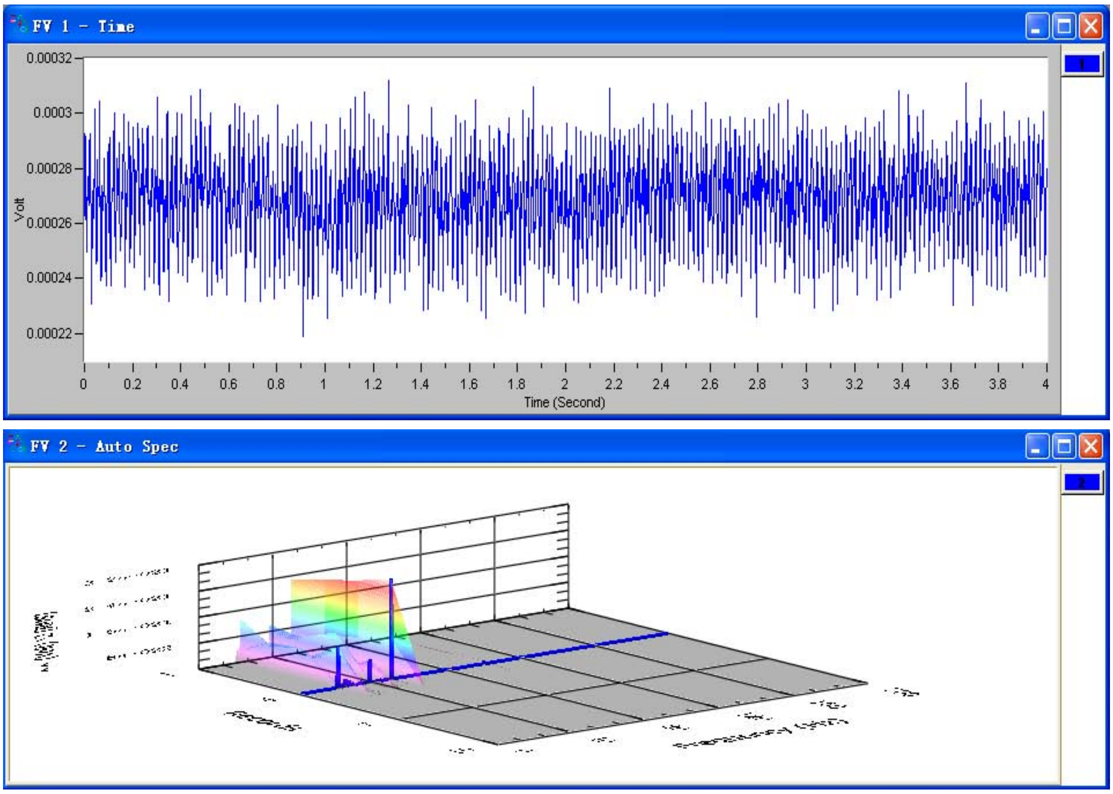

Fig.18 Vibration signal of time-domain and frequency-domain analysis of away-electromotor

CONCLUSION

Based on the working vibration of the traditional hydrocyclone and the limit of the vibration on the separation efficiency, the improving project of changing power-driving mode, support location, independent design of bearing and mechanical seal is proposed and manufactured. Through the vibration analysis on the new-type hydrocyclone, the conclusion can be drawn that when the rotation speed varies from 600r/min to 2000r/min，the flux from 1 m^3/h to 3 m^3/h, the vibration is totally stable, the signal amplitude is 3.4×10^{-4} at most.

The vibration analysis on the new-type dynamic hydrocyclone testifies the stability of the structure, which may provides a novel idea for the hydrocyclone structure towards smart designing, and may play a positive role for the promotion of dynamic hydrocyclone separation technology.

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