Water Source Heat Pump’s Stuck Problems and Solutions

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Abstract. This paper analyses the water source heat pump’s normal stuck reasons, and test each of them. Identify the main reasons of the stuck pump is pump mechanical seal dynamic ring and static ring binding problems. (Poor water quality, water calcium carbonate, magnesium carbonate grind through the dynamic and static ring, after a long time stop, static ring long force extrusion contact, static ring binding surface molecular diffusion migration adhesion), due to the two rings’ binding, rotating torque beyond the motor starting torque, make the motor can’t start normally. This paper aims to find the real cause of the dynamic ring absorption, and put forward subsequent rectification measures to prevent recurrent stuck.

1. Introduction
The working principle of the water source heat pump unit is to transfer the heat from the building to the water source in summer; in winter, the energy is extracted from the water source with a relatively constant temperature, and the heat pump principle is used to raise the temperature through air or water to the building. Usually, the water source heat pump consumes 1kw of energy, and the user can get more than 4kw of heat or cold volume. Water source heat pump has overcome the shortage of outdoor heat exchanger frost in winter, and high operation reliability and heat production efficiency, widely used in China in recent years.[1]

Breakdown occurs frequently in certain area of northeast of China, the major failure is the stuck of the heat pump. Manual stirring the blades by tools is still out of work. This paper means to find a real cause of the stuck, and put forward subsequent rectification measures to prevent recurrent stuck. And from the structure and material to control that happening probability.

2. Problem Introduction
There are four units running for a whole winter last year without any problems, the machine halted for three seasons, then this winter, all the units can’t start. The mail situation is as follows:
Table 1. Formatting sections, subsections and subsubsections.

| Unit | Failure Description | Recheck |
|------|---------------------|---------|
| 1    | Pump stuck          | Switched on, low frequency sound of the pump occurs, stuck. Stirred the blade, pump is slightly blocked and stuck, and after a while, the power-on pump operates normally. |
| 2    | Pump stuck          | Switched on, low frequency sound of the pump occurs, stuck. Stirred the blade, pump is blocked and stuck, and after turning, the power-on pump can’t operate normally. |
| 3    | Pump stuck          | Switched on, low frequency sound of the pump occurs, stuck. Stirred the blade, pump is blocked and stuck, and after turning by hand, the power-on pump can’t operate normally. |
| 4    | Pump stuck          | After stirring the blades, it works |

Fig. 1: Aftermarket water pump disassembly

After-sales review of the fault parts, the power pump returns to normal, and the fault after some adjustment still exists. The invalid adjustment stuck the pump is dismantled, the internal cavity of the pump is seriously dirty, the water quality is black or yellow, the black stain water quality is similar to a smell of coal and oil gas. Disassemble the pump head, impeller and shaft sleeve of the water pump one by one, resulting lock the mechanical seal dynamic ring and static ring adhesion, confirm the static ring and dynamic ring binding surface attached with glue, impurities foreign body, oil pollution and black scale.

3. Cause Analysis

Combined with the actual customer service conditions and the locale research results, the main factors leading to the dynamic and static ring adhesion are analysed from the failure mechanism are considered as followings: The rings material selections problems, the Friction bonding for the rigidity. Mechanical seal spring pressure, the vacuum suction exits in the mechanical sealing binding surface, Water pump start torque reductions, the impurities.

3.1. Mechanical seal test comparison

A vender’s pump: sealing type: PB20-15/L01, diameter of axle 15mm. Material: dynamic ring-solvent impregnated resin graphite, static ring- RB-Sic, rubber- Chemigum, spring- SS304, mechanism-SS304;

B vender’s pump: type:MG12-14/G6, diameter of axle 14mm. material: dynamic ring - Thermal pressure graphite, static ring-no pressure RB-SiC, rubber- EPDM, spring -SS316, mechanism -SS316

(a) : A vender  (b) : B vender

Fig. 2: mechanical seals
The two mechanical seals static ring material is SiC, test is SiC. Dynamic ring material required is graphite, test is graphite. The material is qualified. Comparison of static ring rigidity, roughness, flatness, pore parameters.

Table 2. the testing items of the mechanical seals

| Testing items              | B mechanical seal | A mechanical seal | Note                                      |
|----------------------------|-------------------|-------------------|-------------------------------------------|
| dynamic ring roughness Ra  | new:1.29μm       | new:2.40μm       |                                           |
|                            | old:4.04μm       | old:1.89μm       |                                           |
| static ring roughness Ra   | new:1.15μm       | new:3.25μm       |                                           |
|                            | old:3.99μm       | old:3.19μm       |                                           |
| dynamic ring flatness      | new:0.006μm      | new:0.0022μm     |                                           |
|                            | old:0.0023μm     | old:0.0039μm     |                                           |
| static ring flatness       | new:0.0007μm     | new:0.0008μm     |                                           |
|                            | old:0.0025μm     | old:0.0031μm     |                                           |
| dynamic ring rigidity (HS) | 53                | 87                | A standard requires ≥70                  |
| static ring rigidity (HS)  | 133               | 118               | A standard requires 100~120              |

From the table2, here are the conclusions:
1. A and B mechanical seals, the dynamic ring materials are graphite, static ring material are SiC, they are the common material used in the sealing, the testing is qualified, Exclude material selection exception.
2. For the difference of the manufacturing process, A dynamic ring rigidity is 34HS higher than B. So, the B vender is easier to abrasion.
3. The roughness comparison of the new ones, A vender is 1-2 μm rougher than B vender, but the old ones from A is smaller than both the new ones of A and B, that means after long time running and lubricating, the matching surface is smoother.
4. The flatness of dynamic ring, A is 0.006-0.0016 μm bigger than B. the flatness of static ring is comparable.

3.2. Spring pressure comparison of the mechanical seal
Spring pressure comparison of mechanical seal of A and B vender are tested.

Table 3. Interaction pressure of the dynamic and static ring

| vender | 1#                  | 2#                  | Note:                             |
|--------|---------------------|---------------------|-----------------------------------|
| B vender | 24.821N (new sample) | 29.485N             | Standard 33-45N                   |
| A vender | 30.612N (stuck pumps) | 34.575N             |                                   |

Note: A’s pump mechanical seal spring is 16.30mm in normal relaxation state, after fixing in the pump, the 1-2# length is 13.00mm, 12.06mm. B’s pump mechanical seal spring is 16.30mm in normal relaxation state, after fixing in the pump, the length is about 13.00mm.

Interaction pressure of the dynamic and static ring of A vender is 6~10N bigger than B vender. The pressure is lower, the torque is lower, which is good for staring. But if the pressure is too small will influence the sealing effect. Compare the A’s 1# and 2# sample, the bigger pressure 2# pump’s starting torque is 0.05N.m higher than 1#. But both pumps’ starting torque is not higher than 0.30N.M (the normal torque is 0.5-0.6N.m), so the normal pump can start, Exclude the spring pressure problems.
3.3. Turn torque comparison of dynamic and static ring.
The problem pumps’ dynamic and static turn torque is higher than 0.8N.m (in the test limit, the dynamic
ring slips with the static ring, and the static ring turns together). the normal fixed pump’s turn torque is
about 0.25N.m.

The start torque at vacuum state is 0.1N.m higher than the normal state. the vacuum suction exits in
the mechanical sealing binding surface after the rear liquid-film excreting. Turn the axial of the pump,
we can feel the pump is blocked and stuck. Both A and B are the same. But the turn torque is lower than
the start torque, so, though blocked, but still can work.

3.4. The start torque comparison, change the capacity of the new and old pump,
The normal pump’s starting torque is about 0.50~0.65N.m, the stuck pump’s start torque is 0.8N.m, so
the stuck pump can’t start. After change a new capacity on the stuck pump, the start torque is 0.65N.M.
but it still can’t start. So exclude the capacity reduction factors.

3.5. Verification of oil seal grease and mud contact reaction
Vitrificated the sealing oil type, the material of sealing ring and the oil sealing ring between the dynamic
and static ring. The sealing oil is silicone oil, the material of sealing ring is chemigum, the grease
between static ring and dynamic ring is silicone oil.

As the chemical chemistry of silicon oil, graphite (dynamic ring), SiC (static ring) are stable,
There is no contact reaction, in theory, but the gel mixture may produce some viscous substances, so
apply the gel on the surface of the dynamic and static ring, heat them at 60℃ and cool to -20℃, each
last for 48 hours, test the adhesion. No adhesion, so exclude the gel adhesion.

3.6. fit clearance contrast
Use the magnifier to check the fit clearance of the rings and measure them. The data is as bellows.

| items         | B vender                  | A vender                  | Note                                      |
|---------------|---------------------------|---------------------------|-------------------------------------------|
| dynamic ring  | new: width32.24μm, depth0.42μm
old: width72.23μm, depth2.33μm | new: width268.5μm, depth1.15μm
old: width108.74μm, depth5.23μm | New sample is from the stock water pump. old is from the stuck pumps |
| static ring   | new: width28.69μm, depth2.25μm
old: width47.5μm, depth0.48μm | new: width52.51μm, depth1.26μm
old: width19.99μm, depth0.7μm |                                           |

The stuck pumps dynamic ring pore is 36μm bigger than B venders. the stuck pumps static ring is
27μm smaller B venders. The new rings fit clearance, A’s is wider than B venders.

3.7. Molecular diffusion migration adhesion validation of the bad water quality.
The morphology and material of the contacts between dynamic rings were analysed using EM scanning.
The comparison found that the contact surface of the A vender stuck pumps has more Ca, Mg and Si
elements, the calcium content can reach 18.23%, the remaining test point of atomic percent of Ca is
7.98%, Si element is 7.13%, and the new dynamic ring is only 0.32%.Mainly attached to the dynamic
ring hole around, on both sides of the white edge, white edges have different depths of pits.
Table 5: EM scanning of the stuck pumps’ ring and the new pumps’ ring

| Elements | Stuck static ring | New static ring | Stuck dynamic ring | New dynamic ring |
|----------|------------------|----------------|-------------------|------------------|
|          | Weight percent   | atomic percent | Weight percent    | atomic percent   |
| C        | 8.03             | 16.78          | 74.41             | 86.09            |
| O        | 29.61            | 46.47          | 3.65              | 3.17             |
| Si       | 20.46            | 18.29          | 21.27             | 10.52            |
| S        | 1.55             | 1.22           | 0.30              | 0.13             |
| Fe       | 13.64            | 5.24           | 7.13              | 4.46             |

The Ca and Si (white impurities) are mainly sticking to clearance of the dynamic ring. Fig.3 is the Analysis of the EM scanning topography of the stuck dynamic and static ring. We can see the white impurities sticking to the clearance, presented irregularly.

Surface material composition test of the dynamic and static rings of B venders, and test the long operating test rings fit surface. The Si, content is only 2.866%~4.320%, do the EDX test on the new rings, shows that only 4.450~4.484%Si on the surface, no significant migration abnormalities were observed. The result is showing at the table 5.

Table 6. EDX result comparisons of the dynamic ring

| Elements | long-term running dynamic ring EDX result of B venders | EDX result of new dynamic ring of B venders |
|----------|-----------------------------------------------------|------------------------------------------|
|          | 1#(%) 2#(%)                                        | 1#(%) 2#(%)                              |
| Si       | 4.32  2.866                                       | 4.450  4.484                            |
| Fe       | 4.074  0.789                                     | 1.474  1.099                            |
| K        | 3.062  0.626                                     | 0.778  0.666                            |
| Ca       | 2.223  0.213                                     | 0.561  0.480                            |
| Ba       | 1.572  0.239                                     | 0.197  0.154                            |
| Zn       | 0.070  0.015                                     | 0.026  0.021                            |
| Cr       | 0.057  0.015                                     | 0.017  0.018                            |
| Ni       | 0.042  0.008                                     | 0.009  0.008                            |
| Cu       | 0.028  0.006                                     | 0.008  0.007                            |
| Plastic  | 84.551  95.212                                   | 92.448  93.035                          |

Summary: from the EDX and the EM scanning topography, there are some small pores are existed in the dynamic and static fit rings, the calcium carbonate, magnesium carbonate in the water were grinded and filled into the fix clearance of the dynamic and static ring. The high content of Si appeared on the dynamic ring should be the SiC diffusion migration from the static ring. After running, the water furs adsorption in the fit clearance, and the molecular diffusion migration make the static ring and dynamic ring adhesion.
3.8. Results of Long-Term Operation of the Water Pump Are Confirmed from A Venders

Long-term operation is tested in the A vendors for 500 hours continuously, the water is tap water, after half a year, restart the pump, the pump is running well. This shows this stuck pump problem has a lot to do with the water quality. That is, poor water quality calcium and magnesium ion adsorption migration accelerated the adsorption adhesion stuck after a long time stop.

4. Conclusion

As all the analysis above, the main reasons of stuck pump are the bad water quality, the calcium carbonate, magnesium carbonate in the water were grinded and filled into the fix clearance of the dynamic and static ring. After a long time stop, the contacting surface had a long-term force extrusion contact, which makes the molecular diffusion and migration leads to adhesions. Besides, the fit clearance is also related to the stuck problems. Larger fit clearance is more likely to absorb furring and migrate. The big fit clearance between the dynamic and static ring and the bad water quality are the main causes for the heat pumps stuck issues. Control the fitting clearance and the water quality is the effective way to prevent pump stuck.

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