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## REASON ANALYSIS AND IMPROVEMENT MEASURES FOR EXCESSIVE TEMPERATURE OF THRUST BEARING TILE IN BCL525/A CENTRIFUGAL COMPRESSOR

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*This paper examines the BCL525/A centrifugal compressor of a 3.5 million tonne/year diesel hydrocracking unit at a petrochemical company, and provides a detailed analysis of the causes and remedies for overheating of the compressor's thrust bearing. Since the machine's first operation in 2020, the thrust bearing pad temperature has remained high for a long time. Traditional optimization methods, such as replacing oil products, using paint-film oil filters to filter lubricating oil, and increasing lubricating oil pressure in the bearing pads, have not resulted in a significant increase in thrust bearing pad temperature. The primary issue has been identified as the design of the lubricating oil supply channel and the properties of the bearing surface material. A number of optimization measures were implemented, including enlarging the lubricating oil supply hole in the thrust bearing, adjusting the direction of lubricating oil supply and discharge from the bearing, and effectively reducing thrust bearing temperature, significantly improving equipment safety and stability. A technical troubleshooting guide for similar equipment was developed.*

**Keywords:** circulating hydrogen compressor, thrust bearing.

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## АНАЛИЗ ПРИЧИН И МЕРЫ ПО УСТРАНЕНИЮ ЧРЕЗМЕРНОЙ ТЕМПЕРАТУРЫ ПОВЕРХНОСТИ УПОРНОГО ПОДШИПНИКА В ЦЕНТРОБЕЖНОМ КОМПРЕССОРЕ BCL525/A

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*Рассмотрен центробежный компрессор BCL525/A установки гидрокрекинга дизельного топлива нефтехимической компании мощностью 3,5 млн т в год, а также подробно проанализированы причины и меры по устранению проблемы перегрева упорного подшипника компрессора. С момента первой эксплуатации машины в 2020 г. температура подушек упорных подшипников долгое время оставалась высокой. Традиционные методы оптимизации, такие как замена нефтепродуктов, использование мас-*

ляных фильтров с лакокрасочной пленкой для фильтрации смазочного масла и повышение давления смазочного масла в подушечках подшипников, не привели к существенному повышению температуры подушек упорных подшипников. Установлено, что основная проблема заключается в конструкции канала подачи смазочного масла и свойствах материала поверхности подшипника. Был принят ряд мер по оптимизации, включая увеличение отверстия для подачи смазочного масла в упорном подшипнике, регулировку направления подачи и выпуска смазочного масла из подшипника, эффективное снижение температуры упорного подшипника, со значительным повышением безопасности и стабильности работы оборудования. Разработано техническое руководство по устранению неисправностей аналогичного оборудования.

**Ключевые слова:** циркуляционный водородный компрессор; упорный подшипник.

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**Introduction**

**Introduction to Basic Parameters of Centrifuge.** The circulating hydrogen compressor is the core equipment in the hydrocracking unit, playing an irreplaceable role. This device adopts BCL525/A centrifugal compressor, driven by a steam turbine. The main parameters are shown in Table 1. The compressor adopts a parallel arrangement of impellers and a vertical sectional structure of the casing, with an impeller diameter of 520 mm. The process gas enters the fifth stage impeller for compression in sequence, and the system does not have an intermediate gas cooler.

The main components of this centrifugal compressor include the stator (casing, partition, seal, balance disk seal, end cover), rotor (shaft, impeller, spacer, balance disk, shaft sleeve, half coupling, etc.), as well as supporting bearings, thrust bearings, and shaft end seals.

Table 1

**Basic Parameters Table of BCL525/A Centrifugal Compressor**

Serial Number	Designation	Design value
1	Model	BCL-525/A
2	Compressed medium	Recycle hydrogen
3	Inlet temperature, °C	65
4	Inlet pressure, MPa	10.31
5	Outlet pressure, MPa	13.04
6	RPM, r/min	9680
7	Rated flow rate, Nm <sup>3</sup> /h	934 585

**Introduction to centrifugal thrust bearings.** Thrust bearings can be divided into Mitchell bearings and Kingsbury bearings. In this unit, Kingsbury type thrust bearings are used, whose main function is to withstand the residual axial thrust that the compressor cannot completely offset, as well as the axial thrust generated by the diaphragm coupling. According to design requirements, thrust bearings are usually installed in the bearing box outside the supporting bearing. Kingsbury thrust bearings have the characteristic of double-sided thrust, with the bearing body horizontally divided into upper and lower halves and equipped with two sets of thrust elements. Each group usually contains six thrust blocks (special series may have more), which are placed on both sides of the thrust disc during rotation. The working surface of the thrust tile is cast with a layer of Babbitt alloy and evenly installed in the groove of the fixed ring. The thrust tile can tilt around its pivot

point, thereby uniformly bearing the axial thrust that varies along the rotation axis. In general, thrust bearings are equipped with oil control rings, whose main function is to reduce the disturbance and agitation of lubricating oil when the shaft rotates at high speed, thereby reducing the power loss of the bearing. The axial position of the thrust bearing is adjusted by adjusting the pad, and the thickness of the adjustment pad is processed during assembly.

**Working principle of centrifugal thrust bearing.** Under the thrust block, there are sequentially placed upper leveling blocks, lower leveling blocks, and base rings, which are equivalent to three layers of parts stacked on the base ring. The thrust block and leveling block are in contact through spherical pivot points. When the load on each thrust block is different, it will cause the bearing to be unbalanced. Due to uneven force on the thrust block, it will deflect. At this time, the load on each thrust block can be automatically adjusted by overlapping the upper and lower leveling blocks until the load on each thrust block is the same, and the bearing reestablishes balance. In the case of large deflection and pivot angle of the shaft, the position of each tile can be balanced accordingly to produce uniform oil film pressure. The structure of the thrust bearing is shown in Fig. 1.

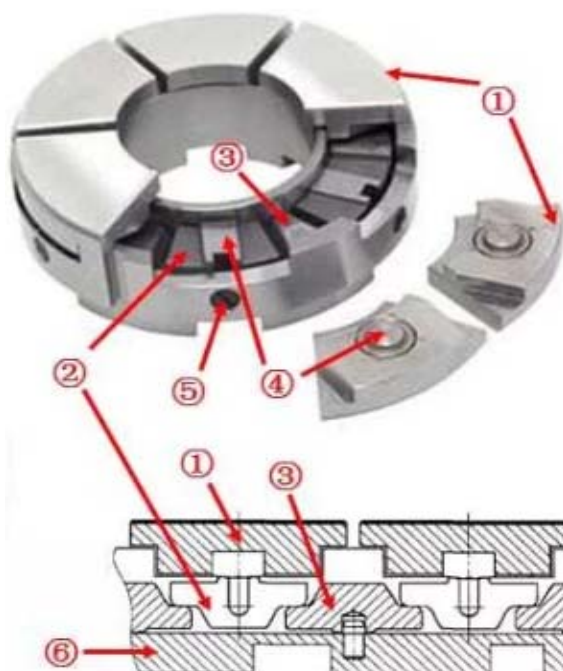


Fig. 1. Picture of valve plate damage:

1 – thrust pad; 2 – up horizontal alignment block;  
3 – down horizontal alignment block; 4 – contact area  
of tile spherical fulcrum; 5 – tile block circumferential  
positioning pin; 6 – base ring

**Working mode of centrifugal thrust bearing.** Lubricating oil enters the bearing cavity from the bottom groove of the bearing disc, passes through the gaps between the bearing blocks and the rotation of the thrust disc, and is brought into the pressure bearing surface of the thrust block. The oil is carried to the outer circumference by centrifugal force, and then flows out of the bearing body through the oil discharge hole on the upper part of the oil control ring.

There are three conditions for the formation of liquid friction between the two surfaces of a thrust bearing:

- 1) a wedge-shaped gap should be formed between the two surfaces;

2) there must be a sufficient amount of lubricating oil with appropriate viscosity between the two surfaces;

3) there should be sufficient relative motion speed between the two surfaces.

The purpose of the work – analyze the causes of excessive increase in the surface temperature of the thrust bearing in the BCL525/a centrifugal compressor and propose measures to eliminate them.

### Failure analysis

Since the first start-up of the unit in February 2020, the temperature of the main thrust bearing has generally been high, averaging around 105 °C and reaching a maximum of 117 °C. The temperature curve is shown in Fig. 2.

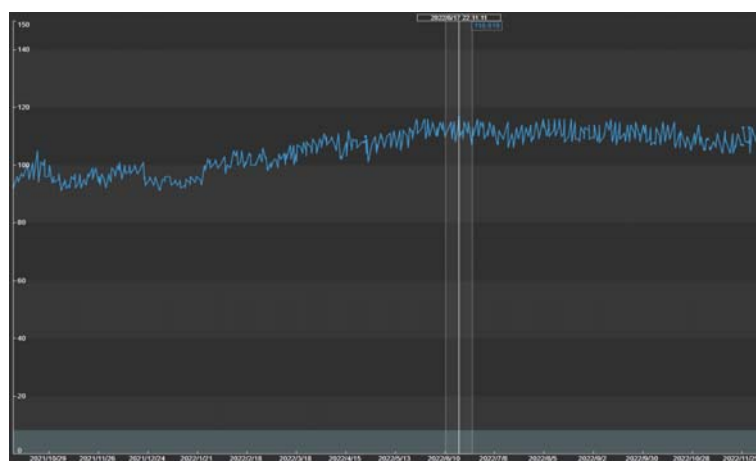


Fig. 2. Trend chart of thrust bearing tile temperature

Analyzing the reasons for the high temperature of the thrust bearing tile, the main causes of the high temperature of the thrust bearing include the following situations:

– firstly, excessive load. When the load of the unit exceeds the design requirements, the friction and heat borne by the bearing increase, resulting in an increase in bearing temperature;

– secondly, improper assembly of the bearing shell may result in insufficient thrust clearance or poor fit between the thrust pad and the thrust disc, leading to temperature rise. In addition, poor lubrication is also an important factor, as low oil pressure, insufficient supply, and poor oil quality can all affect the lubrication effect. During the operation of the unit, the bearings rely on the oil film to support the rotor load, but as the load changes (such as increasing speed), the oil temperature, oil film formation, and bearing capacity will also change accordingly. Insufficient oil supply can lead to poor cooling of the bearing, and insufficient cleanliness of the lubricating oil can increase friction, resulting in an increase in bearing temperature;

– finally, quality defects in bearings, such as tile material or surface roughness issues, can also reduce the bearing's resistance to friction, leading to an increase in tile temperature.

At the first start-up of the unit, the temperature of the bearing shell increased rapidly. The centrifuge was inspected without stopping, with a focus on the forced lubrication system, including the outlet oil pressure of the system, the inlet oil pressure, flow rate, and inlet oil temperature of each lubrication point of the compressor, and other process parameters, all of which were within the normal range. At the same time, the oil return of the unit is smooth, and the sampled oil is visually clean and free of impurities.

After laboratory analysis, there were no significant abnormalities in the viscosity, ignition point, pour point, and moisture content of the lubricating oil. Observation shows that when changing the operating conditions (such as increasing the speed to increase the inlet and outlet pressure difference of the centrifuge), the temperature of the main thrust tile is positively proportional to the inlet and outlet pressure difference of the unit. Due to the mechanism of axial force generation and the effect of the balance tube, the thrust bearing should not exhibit significant temperature gradient changes. After online external investigation, it has been preliminarily determined that the abnormal temperature of the thrust bearing is not caused by external factors. It is suspected that it may be due to poor lubrication inside the thrust pad, which prevents the lubricating oil from fully flowing and taking away frictional heat in a timely manner, or the lubricating oil has not fully formed a film on the contact surface of the pad and is in a boundary lubrication state. In addition, the working conditions of the compressor are unstable, the axial force adjustment is frequent, and the film-forming ability of the lubricating oil on the working surface is affected, resulting in a high temperature of the thrust pad. The normal control range of lubricating oil pressure for thrust bearings is 0.025–0.13 MPa. We attempted to increase the inlet oil pressure of thrust bearings to the upper limit, but the effect was not significant.

The thrust pad temperature of the compressor is designed to operate within 120 °C. During this period, the compressor was monitored and operated, and the temperature of the compressor was maintained at around 114 °C until the first shutdown and maintenance of the unit in April 2024. Measures such as increasing oil inlet pressure and reducing oil inlet temperature have been taken in the operation process, but the improvement is not significant.

#### Renovation measures

**First dismantling inspection and handling situation.** In July 2021, during a brief shutdown of the equipment, a minor repair inspection was conducted on the unit. The specific inspection data is shown in Table 2. The main purpose was to investigate the cause of the high temperature of the main thrust tile. After dismantling and inspection, it was found that the main thrust tile had coking phenomenon, no scratches on the tile surface, and no peeling phenomenon.

Table 2

2021 Bearing Inspection Data Sheet

Serial Number	Item	Standard value	Actual measurement value
1	Deviation in tile thickness (mm)	$\leq 0.02$	0.01
2	Thrust disk deviation (mm)	$\leq 0.02$	0.005
3	Clearance between thrust bearing shells (mm)	0.25–0.35	0.3
4	Pre tension amount of coupling (mm)	$\leq 1.5$	1.5

Through this inspection, the reasons for the high temperature of the thrust bearing caused by improper assembly of the bearing shell and quality defects of the bearing were ruled out. At the same time, it was found that the bearing block had coking phenomenon. The main causes of coking are poor lubrication, high temperature, improper assembly, and improper operation. So poor lubrication may be an important factor causing high temperatures in thrust pads.

The main measures taken this time are to scrape and perform PT testing on the bearing shells (not replaced); expand the oil return hole of the control ring, as shown in Fig. 3, from 18 to 19.5 mm, and increase the oil return volume; clean the fuel tank at the gas station.



Fig. 3. The position of the oil control ring return port

In this unit dismantling inspection, in order to eliminate the possibility of paint film formation causing excessive temperature of the bearing shell. Add a paint film filter to the oil tank of the lubricating oil station to filter out impurities such as paint film that may be generated in the lubricating oil. At the same time, upgrade the brand of the lubricating oil from Turbo 46 to Turbo S4 GX46 to improve the stability of the oil. After replacement, the temperature of the thrust bearing slightly improved, dropping from 105 °C to around 100 °C.

**First major overhaul, dismantling and handling situation.** During the first major maintenance period of the device in April 2024, a major overhaul inspection was conducted on the centrifugal unit. During this inspection, there was still coking on the main thrust tile, scaling on the surface of the main thrust tile, and four wear marks on the tile surface. The measured maximum and minimum thickness differences of the tile blocks were 0.03 mm, which was too large (standard deviation  $\leq 0.02$  mm). The thrust clearance of the thrust tile was 0.30 mm, and the measured deflection of the thrust disc was 0.02 mm, both of which were within the normal range. The PEEK seal of the balance drum is intact, and the gap data conforms to the design documents without any problems found. This time, the main task is to clean and measure the tile blocks, and then grind them to ensure that the thickness deviation of the tile blocks is less than 0.01 mm before reinstalling them. The oil return hole of the control ring continues to be enlarged from 19.5 to 21 mm.

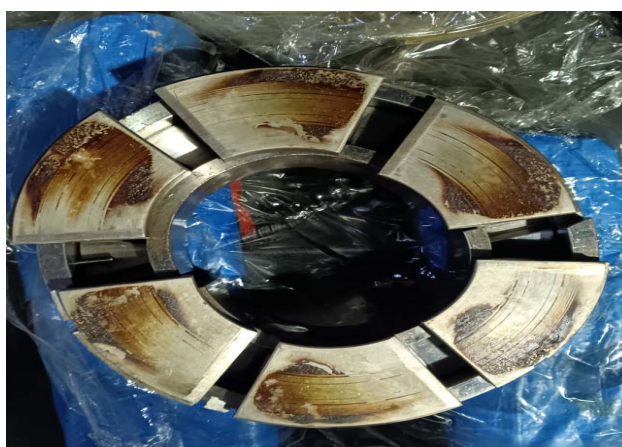


Fig. 4. Diagram of coking situation during dismantling and inspection of thrust block

After the maintenance was completed, the temperature of the thrust bearing significantly improved after the unit was started, with an average decrease of about 15 °C in the temperature of the bearing shell compared to before the maintenance. After the miracle, the unit operated smoothly, and the temperature of the thrust bearing was controlled at around 90 °C, with a significant decrease in the temperature of the bearing shell. The temperature trend before and after expanding the oil hole is shown in Fig. 5.

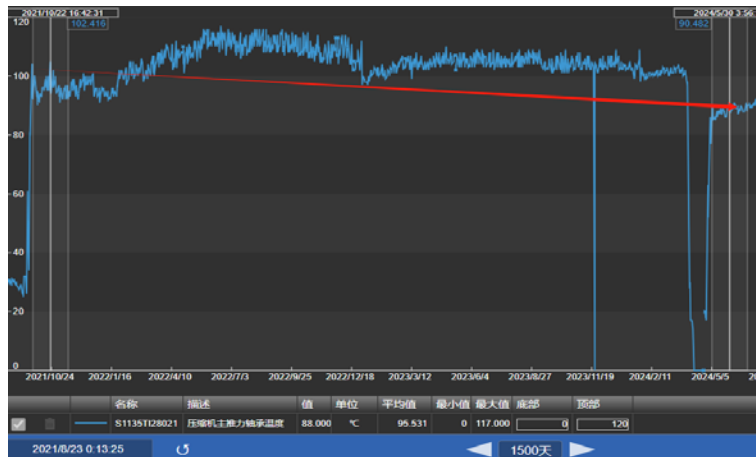


Fig. 5. Comparison chart of temperature trend before and after expanding the oil return hole

## Results

In response to the high temperature problem of the main thrust bearing of the circulating hydrogen compressor unit, a series of measures were taken, such as increasing oil pressure, adding a paint film oil filter, and expanding the oil return hole, to reduce the temperature of the bearing from about 112 °C before the transformation to 88 °C.

After the transformation, the unit runs smoothly and can meet the production requirements of the device, creating favorable conditions for ensuring the safe and stable operation of the unit.

At the same time, in order to completely solve the problem of high bearing temperature in the unit, the material of the thrust bearing retaining plate was modified in the subsequent maintenance work. The steel retaining frame was replaced with copper material, which has better thermal conductivity and relatively lower friction coefficient. At the same time, the bearing blocks were slotted to improve lubrication effect, enhance heat transfer performance, reduce bearing wear, and completely solve the problem of high bearing temperature in the unit.

## Suggestions and recommendations

To address the issue of high temperature in the main thrust tile of the circulating hydrogen compressor unit, the following solutions are adopted:

1. Control the expansion of the oil return hole in the oil ring, increasing the diameter of the oil hole from 18 to 21mm. Properly increase the lubricating oil inlet pressure of the thrust bearing to timely remove the heat generated by the friction of the bearing shell, thereby reducing the temperature of the thrust bearing.

2. Improve lubrication quality. By changing the lubricating oil grade and using highly stable oil products, this oil station is a joint oil station that supplies oil to the steam turbine and compressor. There is a risk of steam leakage into the lubricating oil at the steam seal of the steam turbine, which can cause the oil to deteriorate and also affect the operation of the main thrust bearing. Oil products are sampled and tested regularly every month.

3. Strictly control the quality. The maintenance process strictly controls the quality of the site, develops detailed maintenance specifications and procedures, ensures that each maintenance is carried out in accordance with the standards, checks and cleans the alignment and bearings of the unit, and measures the clearances between various parts step by step to confirm whether all fasteners are tightened in place, avoiding additional friction and heat generation caused by misalignment of the unit, inappropriate bearing clearances, dirt, sludge or other impurities in the lubrication system, loose fasteners, etc., resulting in increased thrust bearing temperature or even bearing failure.

4. To reduce the impact of paint film on the temperature of the bearing shell, it is possible to consider using paint film stripper. Paint film stripper is a liquid composed of aromatic compounds and high solubility solvents, which has a strong ability to dissolve the paint film. Its components can effectively penetrate into the paint film, causing it to swell and eventually peel off. Some domestic petrochemical companies have taken relevant measures, which have had a certain effect on the problem of excessive bearing temperature caused by the influence of paint film. However, further research and analysis are needed to determine whether the long-term use of paint film stripping agents will affect the quality of lubricating oil.

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