Revision of the AMB-Supported Coolant Pump after the Long-Term Operation in the Power Plant

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Abstract: Within a research project the conventional bearing system of a cooling water booster pump was substituted with active magnetic bearings (AMBs). This AMB-supported pump was installed and tested in the inter-cooling circuit of a 500 MW block-unit in a lignite power station as a demonstration plant. The aim was to proof the suitability of magnetic bearings for using on turbo machines under operation conditions in a power station [1]. After the phase of commissioning the pump was used in a long term operation as the main operation pump [2]. The pump was subjected to a revision after an approx. three and a half year running time. Thereby the condition of the pump, especially of the bearing components was checked. The disassembling of the pump was covered by some difficulties, caused by corrosion of mechanical parts. In addition with detected damages on single components, countermeasures for prevention had to be derived. Furthermore design criterions, applicable materials and requirements e. g. for the shaft seals can be concluded.
This report gives an insight into the increase of experience and knowledge collected during the revision of the AMB-supported coolant pump.

Keywords: Active Magnetic Bearing, Touch Down Bearing, Coolant Pump, Long-Term Operation, Power Plant, Corrosion, Wear

Introduction

Failures on conventionally supported turbo machines due to the bearing system can be reduced by usage of magnetic bearings. Besides economic and ecologic advantages, the safety of the plant increases e. g. the complete inflammable lubricants and supplying units of fluid film bearings become no longer necessary and the incendiary composition can be reduced. To demonstrate the applicability of magnetic bearings for turbo machines in power stations a conventionally supported cooling water booster pump was converted to fully active magnetic bearings. The pump was installed as the third coolant pump in a 500 MW block-unit of the lignite power station in Boxberg that is operated by Vattenfall Europe Generation AG. After the successful commissioning the pump was set into long term operation as main coolant pump within the regular operation of the power station. For that term, the pump worked reliable and stable. Neither the AMBs nor other components like sensors, power amplifiers or the control units caused any failure of the pump.
In the frame of the regular main revision of the block-unit power station in the year 2009 the AMB-supported coolant pump was set to a revision too. The objective of this revision was to examine the condition of the components of the bearing system after continuous operation under power station conditions for almost three and a half years. In conjunction with that, the examination should be documented and if necessary, measures of repairing and maintenance should be carried out to ensure the further operation as main coolant pump in the power station.

Coolant pump SM 400/400 A with AMB

Fig. 1 shows a sectional view of the coolant pump, retrofitted to active magnetic bearings. The pump is used as a pressure booster pump in the inter-cooler circuit of power stations block-unit and supplies e. g. the gas-cooler and power switch of the generator and the coolers for the deionised water and the sealing oil.

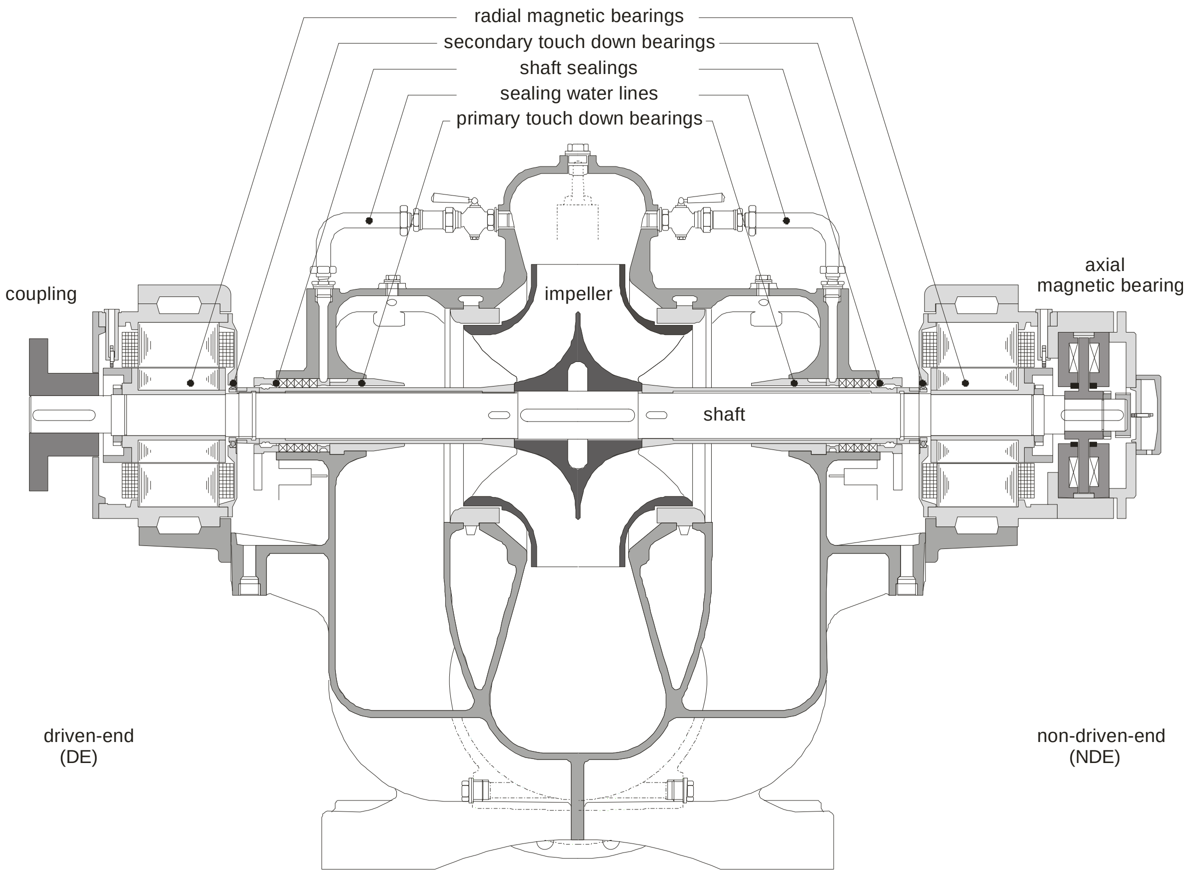

Fig 1: Sectional view of the cooling water pump SM 400/400 A with active magnetic bearings

The pump is a horizontal, single stage centrifugal pump with a single volute casing. The casing is parted horizontally in the shaft level. The bearing pedestals are outside the pump casing. The double suction construction of the impeller equalizes the loads in axial direction and minimizes the axial bearing forces. The shaft sealing system is carried out via stuffing box packing close to the magnetic bearings. The pump is driven over a pole changing electromotor with two nominal speeds. The main parameters of the pump are given for both the nominal speeds in table 1.

Table 1: Main parameters of the pump SM 400/400 A

Parameter	Value	Unit
Nominal speed	985/1475	rpm
Nominal capacity	915/1400	m^3/h
Specific energy	137/319	J/kg
Delivery head	14/32.5	m
Shaft power	120/180	kW

Pump operation in the power plant block unit regime

The cooling water quantity, required for the supply of the coolers in the inter-cooler circuit, is dependent on the outside temperature and also on the operation mode of the power station block-unit and can be regulated by a control valve. The pump works at the design point with high speed during the warm summer months. This point is characterized by the highest level of efficiency and the lowest bearing loads. The temperature of the cooling system is kept constant by a throttling of the delivery rate over the control valve in the cold winter months. This reduction of the delivery rate leads to considerable deviations from the design point of the pump and at a constant engine output for a rising pressure in the system. If the cooling requirements are further reduced, the pump can be driven with the lower speed, e. g. when the boilers operate in mono-unit operation. The highest pressures and loads of the pump appear by starting up against the closed gate valve on the pressure side.

Consequences of load changes during pump operation

Deviations from the design point lead to an increasing of forces acting the impeller and therefore the loads on the AMBs on the one hand [3]. The compensation of these loads is made by corresponding bearing forces which can be obtained by a current rise. The current heat losses enlarge and cause an increasing of temperature in the bearings until a stationary temperature is reached. The elevated temperature has a negative influence on the life span of bearing components, especially the insulation materials.

On the other hand the reduction of the delivery flow by the control valve leads to a pressure rise inside the pump. So increase the leakage at the shaft seals, because the sealing water will directly piped from the pressroom via the sealing water lines to the packing glands - see Fig. 1. The leaked sealing water penetrates into the bearing housings through the secondary touch down bearings in the bearing covers. Besides that greater loads of the shaft seals cause higher wear and tear at the sealing components, connected with an increase of the leakage and a shortening of durability of the seals. Higher loads and wear in the touch down bearings are induced as a result of the high pressure at the impeller when the AMBs are switched off during this operation mode.

Revision of the pump

For its revision the pump was dismounted from the plant. An on-site inspection was not possible as the pump had to be dismantled. Fig. 2 demonstrates the dismounted pump, prepared for its transportation to the workshop.

The inspection included all relevant components for the suspension of the shaft:

- bearing housings
- radial and axial position sensors
- radial and axial electromagnetic actuating elements
- touch down bearings
- pump housing
- shaft seals

These components were maintained, repaired respectively renewed due to their condition.

Fig. 2: AMB supported coolant pump after long term operation

Bearing housing. The permanently occurring leakage at the shaft seals resulted in substantial deposits on the housings of bearings and the pump. These deposits obstructed the parting lines between the bearing housing and the pedestals and impeded the disassembling. The ever-present moisture by the slightly alkaline leakage water (pH = 8,5) resulted in a considerable corrosion in the sphere of influence (interaction with atmospheric oxygen). Fig. 3 exemplarily demonstrates the deposits on the bearing cover with secondary touch down bearings and pitting corrosion on the bearing housing.

Fig. 3: Deposits and pitting corrosion on the bearing housing

Radial and axial position sensors. The position sensors of the AMBs are located out of reaching for leakage in direction to the shaft ends. Fig. 4 shows the driven-end-sited (DE) measuring system for the determination of the radial shaft position. The bearing cover was dismantled here. There is one eddy current sensor per x- and y-axis used. The right picture shows the axial position sensor. It measures against a sensor plain on the non-driven-end-sited (NDE) shaft end. In the levels of the measuring systems there were no damages due to deposits, corrosion or mechanical contact detected.

Fig. 4: DE-sited radial measuring system for shaft position and axial position sensor

Radial and axial electromagnetic actuating elements. Fig. 5 shows the stator and the rotor of the DE-sited radial AMB. The lower part of the stator core has explicit corrosion marks due to the ingress of leakage water. Rust on the surface of the rotor core demonstrates that leakage water also penetrated into the clearance between rotor and stator. The extent of corrosion varied between booth radial magnetic bearings. The different proportion of water ingress has to be interpreted by the magnitude of the shaft position orbit while operation. Thus the stresses and wear of the stuffing box packing of the shaft seals on both sites differ. On the NDE-sited radial AMB the rotor is centred more precisely than on the DE-sited radial AMB. In addition to this also revolving loads exist that are transmitted by the coupling and affect the DE-sited AMB. Due to those loads the deviation of the shaft has a bigger magnitude. On the axial electromagnetic actuator was no damage detected.

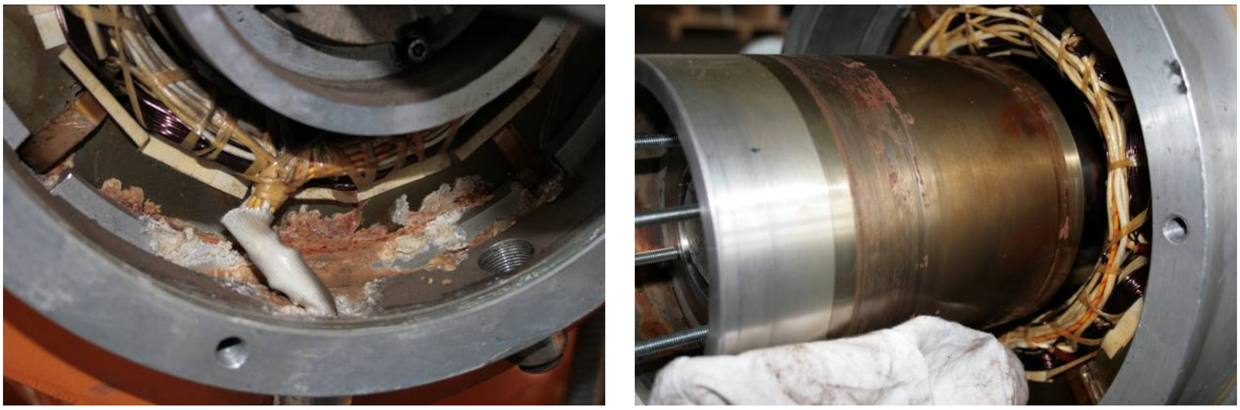

Fig. 5: DE-sited radial AMB with corrosion marks due to water ingress

The penetrated leakage water had no impact to the coil systems of the bearings. Electrical faults could be precluded by appropriate tests.

Touch down bearings. The touch down bearing system at the pump is subdivided into the primary and the secondary radial touch down bearings and the axial touch down bearing. As primary radial touch down bearings the basic bushings of the shaft seals are used as water lubricated gliding bearings – compare Fig. 1. Grooved ball bearings are additional integrated in the bearing covers as secondary touch down bearings. They are used to avoid mechanical contact of rotor and stator parts of the radial magnetic bearings. Thrust rings that are mounted in the ring magnets form the axial touch down bearings. Fig. 6 shows the shaft in a sliding bush and a grooved ball bearing inside a bearing cover.

Fig 6: Primary and secondary radial touch down bearings

Measurements at the basic bushings had shown an abrasion of approx. 250 µm that required the exchange of the two basic bushings. These abrasions occurred in the phase of commissioning. The advanced corrosion at the grooved ball bearings as well required a replacement.

Shaft seals and pump casing. During the period of operation there was ever increasing leakage at the shaft seals. These could be reduced, neither by readjusting the stuffing box nor by new packing. The reason was the operational wear in the area of the shaft seals. At the shaft sleeves it came to abrasions due to the permanent friction between the shaft sleeves and the packing, like the brush marks shown in the left of Fig. 7. In the right picture corrosion and wear marks can be recognized in the stuffing box area of the pump cover. Thus the surface roughness in this area increases and leads to leakage between the packing and the pump cover. This area was newly bushed.

Fig 7: Wear in the area of the shaft seals at the shaft sleeve and in the pump cover

Conclusion and outlook

The active magnetic supported coolant pump was affected to the surrounding and operating conditions during the three and a half years lasting long term operation in the power station. The impairments detected at the following revision in the area of the magnetic bearings at the disassembled pump are a result from deposits and corrosion essentially by the leakage water of the shaft seals. The leakage did not lead to any malfunction or failure of the magnetic bearings. The components of the magnetic bearings were revised and provided with a corrosion protection. The components of the touch down bearings and the shaft seals, which were subject of mechanical wear, were revised respectively replaced. Therewith the pump was prepared for a further long term operation in the power station.
Following conclusions can be drawn from the results of the revision for future applications: Regarding the design of the magnetic bearings the impairments by leakage should be excluded by suitable measures, e. g. an encapsulation of the bearings or the usage of seals with low leakage (slide ring seals). Corrosion resistant materials should be selected for the bearing housings in case of aggressive media. The aggressiveness of the cooling medium was not foreseeable and was underrated at the design of the magnet bearings for the pump.
The results of the long term operation with the pump had proved, that this technology can be advantageous used at turbo machines in power stations. Changes in construction and design are necessary to achieve a high life time. The pump will further be used as the main operating pump as well as for the development in the fields of sensors, control algorithms and power electronics in the future.

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