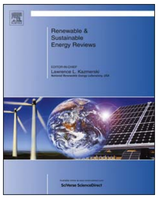
ARTICLE IN PRESS

Renewable and Sustainable Energy Reviews xx (xxxx) xxxx–xxxx

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser



A review on the large tilting pad thrust bearings in the hydropower units

Zhai Liming[a,b], Luo Yongyao[a,b], Wang Zhengwei[a,b,*], Liu Xin[a,b], Xiao Yexiang[a,b]

[a] *State Key Laboratory of Hydroscience and Engineering, Tsinghua University, Beijing 100084, China*
[b] *Department of Thermal Engineering, Tsinghua University, Beijing 100084, China*

ARTICLE INFO

Keywords:
Hydropower
Thrust bearing
Thermal-elastic deformation
Transient
Prediction
Improvement

ABSTRACT

Tilting pad thrust bearings are the key components in hydropower units. As the thrust loads increase with the unit capacities of the hydro turbines, many thrust bearings failed due to rub-impacts between the collar and pads. Some plants have to be shut down for up to one month to repair the damaged pads which has lead to enormous economic losses. The lubrication processes of thrust bearings are quite complex involving fluid-thermal-structural interactions between the pad, the collar, the oil film and the oil surrounding the pad. This paper reviews the bearing mechanism including the thermal-elastic deformation, the transient and dynamic characteristics, the bidirectional thrust bearing, as well as the various prediction methods on the lubrication performance. At last, an overview of some special designs including the covered materials, supporting system and hydrostatic jacking system to improve the thrust lubrication was briefly presented.

1. Introduction

Energy is the fundamental requirement for economic development. The installed electricity generating capacity in China have reached nearly 1300 GW which was generated 65% through thermal, 33.5% through renewables and 1.5% through nuclear by the end of 2014. As the most important renewables for electrical power production worldwide, hydropower provides about 14% of the electricity in the world and about 23% in China. Large hydro generator units usually arrange the shaft system vertically in order to minimum the shaft deflections which cause large vertical thrust along the shaft from both the large weight of the rotating components and the axial hydraulic thrust on the turbine runner. Thus, large hydrodynamic thrust bearings are commonly used which allow substantial axial load to be transferred from the rotating components to the stationary components via a thin lubricating film with extremely low friction and practically no wear [1].

The load capacity of thrust bearings became the main factor that restricted the growth of hydro generator unit capacity after the first hydro turbine generator unit was put into operation at the end of the 19th century. In 1912, Kingsbury thrust bearing with the thrust load of 184 t was first applied in Holtwood Hydropower Plant located in Pennsylvania, USA, which made it possible to design much larger hydroelectric units with substantial axial load. Fig. 1 presents the development history of hydro power projects in the world in the recent 100 years. Weights and sizes of both the generator and hydro turbine are increasing as well as their thrust bearings. Table 1 lists several typical hydro power units and the thrust bearing parameters in China. Now the single rated capacity of the hydropower units have reached 840 MVA with a hydro turbine of 700 MW in Three Gorges Hydropower Plant and 889 MVA with a hydro turbine of 800 MW in Xiangjiaba Hydropower Plant,. The largest load capacity of the thrust bearing has increased to about 6000 t. Fig. 2 illustrates the development of the thrust bearings for hydro generators units manufactured by Harbin motor co., LTD, one of the largest electric generator set manufacturer in China, with the thrust load increasing greatly. The thrust bearing co-produced by Harbin motor co., LTD and ALSTOM for the Three Gorges Hydropower Plant has the largest load capacity of 5410 t up to now in the world. In addition, the loads of the bidirectional thrust bearings for the pump storage plants (PSP) have reached up to about 1000 t, but are quite lower than the directional thrust bearings for conventional hydropower units.

As the thrust load increases, many thrust bearing failures have happened in the world. In Russia, the thrust bearing with a capacity of 1450 t for 250 MW hydro turbine unit in Bratsk Hydropower Station was broken down in 1982. In America, the 4050 t thrust bearing for the 600 MW hydro turbine unit in the Grand Coulee Hydropower Station was burnt-out in 1981. In China, many times of “thrust bearing burning” accidents happened with the load from 650 t to 3800 t in the hydropower plants such as Wujiangdu, Longyangxia, Dahua, Gezhouba, Baishan, etc. In recent years, the accidents mainly occur in the pump storage units because of the low load capacity of the bidirectional thrust bearing and the frequent starts and stops for the grid demand [4–6]. According to the statistics, bearing failures mainly involving thrust bearings account for around 40% of operating losses in

---

[*] Corresponding author at: Department of Thermal Engineering, Tsinghua University, Beijing 100084, China.
E-mail address: wzw@tsinghua.edu.cn (W. Zhengwei).

http://dx.doi.org/10.1016/j.rser.2016.09.140
Received 29 May 2015; Received in revised form 6 July 2016; Accepted 30 September 2016
Available online xxxx

Please cite this article as: Zhai, L., Renewable and Sustainable Energy Reviews (2016), http://dx.doi.org/10.1016/j.rser.2016.09.140

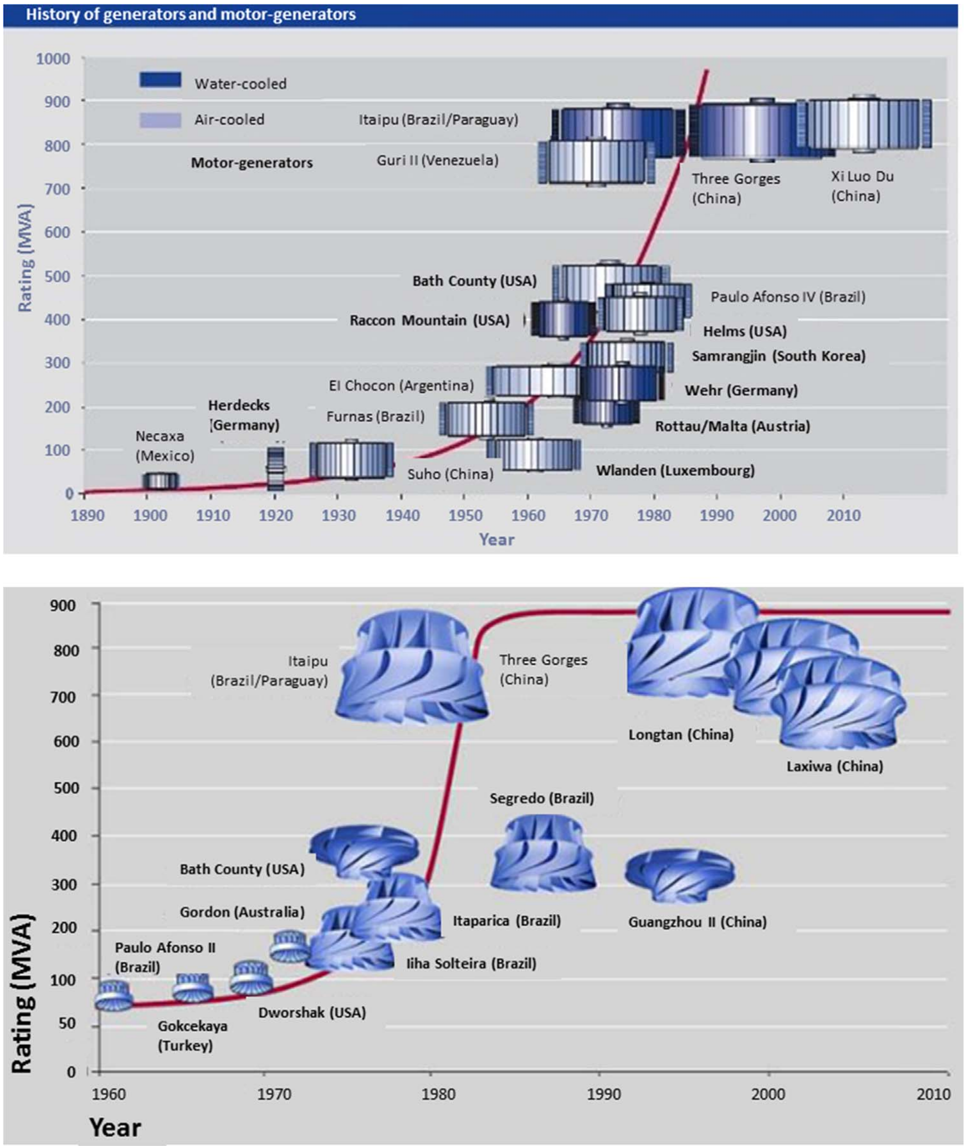


Fig. 1. Development of the hydro generators in the recent century [2].

the hydro power units. Fig. 3 shows a damaged sliding surface of a thrust bearing due to overload [7]. Therefore, it is very important to research the lubrication mechanism of the large thrust bearing.

Since the thrust bearings are one of the most crucial components in large hydropower units which greatly affects units' safe and stable operation, whose design and manufacture have attracted much attention. There are two main demands for the large thrust bearing design: one is that the bearing should have good lubrication within different speeds for both the rated condition and even the transient processes during starts and stops, the other is that the bearing should have enough load range in case of the uneven load distribution among the pads. In the past decades, many researchers have devoted themselves to the thrust bearings and promoted the development. Tanaka [8] reviewed some papers published mostly in the 1990s which is on

Table 1
Main parameters of the thrust bearings for several typical hydro power units in China.

	Three Gorges	Shuikou	Longtan	Xiaolangdi	Gezhouba	Yantan	Xiaowan	Laxiwa
Commissioning time	2003	1992	2007	2000	1980	1992	2008	2008
Unit number	8	7	7	6	13	4	6	7
Output power (MVA)	840	222.2	777.8	343	143	345.7	777.8	757
Rated speed (rpm)	75	107.1	107.1	107.1	62.5	75	150	142.8
Thrust load (KN)	54,100	41,000	35,257	34,700	33,000	27,500	26,460	25,600
Outside diameter (mm)	5200	4500	4500	4150	3900	3750	4000	4240
Inside diameter (mm)	3500	2600	2800	2740	2450	2350	2530	2740
Pad number	24	18	18	20	18	16	16	18
Pad area (cm^2)	4011	4800	4332	2870	3210	3260	3769	3198
Single pad load (KN)	2254	2278	1959	1870	1833	1719	1654	1422
Specific pressure (MPa)	5.6	6	4.5	5.9	5.6	5.3	4.4	4.4