TRANSNAV
http://www.transnav.eu

the International Journal
on Marine Navigation
and Safety of Sea Transportation

Volume 14
Number 1
March 2020

DOI: 10.12716/1001.14.01.03

LNG Carrier Main Steam Turbine Reliability in the Exploatation Period of Time

I. Poljak, J. Orović & V. Knežević
University of Zadar, Zadar, Croatia
V. Mrzljak
University of Rijeka, Rijeka, Croatia

ABSTRACT: In this paper the LNG carrier with steam turbine propulsion plant maintenance records has been analysed. Actual observed data from the ship, built in 2001, are from ship maintenance history data from September 2002 until August 2010. During the analysed period, main propulsion turbine had one major failure and several minor failures. The ship had three dry docks and one was prolonged due to increased requirements for cargo transport. Total running hours of the main propulsion turbine in the observed period of time were 63204 hours. The list of failures and influence of each mentioned failure of main turbine propulsion machinery is discussed and analysed in respect to the propulsion autonomy of the vessel.

1 INTRODUCTION

Marine steam propulsion plants are very rarely employed nowadays due to higher fuel consumption of such systems compared with diesel motor engines. Although the efficiency analysis of its main components: main and auxiliary turbines [1] and steam boilers [2] with steam air heaters [3] in the exploitation of LNG carriers show higher energy efficiency than diesel engine efficiency, the problem lies in heat loss during steam condensation in main condenser. The advantage of steam propulsion plant compared to diesel engine plant is that marine steam propulsion plant typically needs less maintenance due to its simplicity. It is normal for such systems to open one turbine casing in each dry-dock for internal inspection. Intermediate inspection of turbines is very rare and is utilized only in the case of obvious failures. In order to have better insight to failure occurrence of marine steam propulsion turbine, LNG carrier maintenance data had been taken into consideration for the period of eight years where reliability of such system is discussed.

2 STEAM PROPULSION PLANT

Observed steam propulsion plant has main turbine consisting of one high pressure turbine casing and one low pressure turbine casing with astern turbine incorporated inside the low pressure turbine casing, Figure 1. Maximum continues rating (MCR) of analysed main turbine is 26800 kW at 89 rpm. Normal continues rating (NCR) of the main propulsion turbine is 24120 kW at 85.9 rpm which is 90% of MCR power [4]. This is the operating point where main turbine will run for most of its service time.

Rated steam condition for the main turbine is: steam temperature of 520°C, steam pressure at ahead stop valve 5.9 MPa and main condenser vacuum of approximately 40 mmHg at sea water temperature of 27°C. As both turbines are running at high speeds and main propulsion shaft rotates at significantly lower speed it is required to employ reduction gear to satisfy such requirements. Reduction gear is usually of tandem articulated, double reduction and double helical gear type [4]. Characteristics of the high pressure and low pressure turbines are given in Table 1.

Both turbines are fixed above the main condenser. The low pressure turbine shaft is passing through the main condenser top and carries astern turbine which freely rotates when main propulsion turbine is running in ahead direction. Low pressure turbine shaft is heavier and more stressed compared to high pressure turbine shaft. In port, when main turbine is stopped it should turn with the turning gear with few revolutions per minute to smoothly pass the cool down period in order to prevent damage to turbine stator and rotor blades.

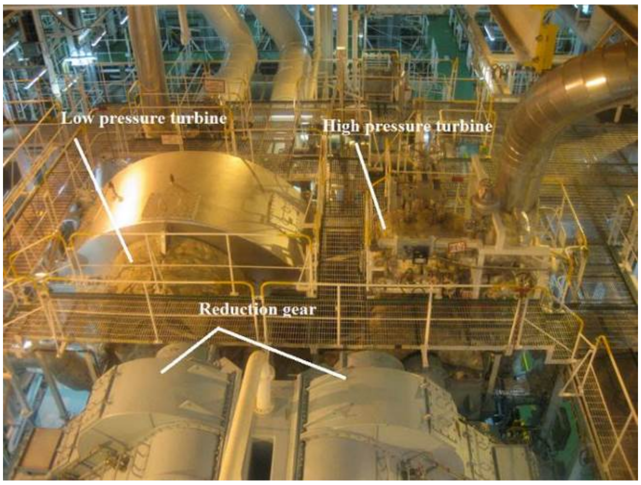

Figure 1. Main propulsion turbine layout

Table 1. Main propulsion turbine characteristics [4]

Turbine casing	MCR rpm	NCR rpm	Critical speed rpm	Number of stages
High pressure	5888	5683	4320	Curtis wheel + 8 stages
Low pressure	3408	3289	2280	8 stages

3 FAILURE EVENTS OF MAIN STEAM TURBINE

Main propulsion steam turbine failures had been collected for the exploitation period of 8 years. All data were taken out from the main propulsion turbine maintenance log [5]. Overview of running hours, failure dates and failure descriptions are given in Table 2. The ship was built in 2001 and the first dry dock was carried out in 2004. The second dry-dock was in 2006, and the third one in 2008. Accumulated running hours of the main turbine at the end of observed period were 63204 running hours.

4 FAILURE ANALYSIS

According to Table 2 all failures may be divided into two main groups as critical and non-critical failures. Critical failure has direct impact on capability of the system to provide its output [6], i.e. failure which has direct impact to the main propulsion operation. Non-critical failure does not cause immediate inability to produce required function. Non-critical failures further may be categorized as degraded and incipient [7].

For the observed turbine, critical failure occurred on 05.05.2004. At that time, main propulsion turbine had 20232 running hours. Vessel reported higher vibration on the main turbine at all running ranges and company decided to proceed vessel at reduced speed to dry-dock for inspection. According to the maintenance log of the main propulsion turbine, high pressure turbine sixth stage rotor blades and diaphragm of the sixth stage were exchanged due to scratches. At the same time, planned dry dock maintenance of scale deposit removal from the low pressure turbine first stage was carried out.

Table 2. Main propulsion turbine failure events

Date	Running Hours	Failure description
23.09.2002	7200	Astern turbine safety control oil valve exchanged.
05.04.2003	12240	Astern turbine steam temperature PT sensor exchanged.
13.06.2003	13704	Flexible spider clutch for coupling main turbine control oil pump No1 and electromotor exchanged.
13.06.2003	13704	Flexible spider clutch for coupling main turbine control oil pump No2 and electromotor exchanged.
18.09.2003	15192	Local manoeuvring side telegraph bell exchanged.
05.05.2004	20232	Sixth stage of high pressure turbine blades exchanged due to scratches on the upper halves of diaphragm casing.
05.05.2004	20232	Sixth stage diaphragm exchanged.
05.05.2004	20232	Forward labyrinth seal springs renewed.
05.05.2004	20232	Scale deposit at first stage of low pressure turbine cleaned.
05.05.2004	20232	Steam pressure transmitter at first stage outlet exchanged.
12.05.2004	20232	High pressure bleed steam shut of valve solenoid valve exchanged.
29.08.2005	31152	Flexible spider clutch for coupling main turbine control oil pump No1 and electromotor exchanged.
11.01.2006	34032	Flexible spider clutch for coupling main turbine control oil pump No1 and electromotor exchanged.
12.12.2006	41232	Flexible spider clutch for coupling main turbine control oil pump No1 and electromotor exchanged.
18.01.2007	41976	Main propulsion turbine revolution counter exchanged.
21.05.2007	44856	PT sensor for main turbine steam temperature at steam chest exchanged.
11.06.2007	45096	High pressure turbine bleed shut off valve limit switch exchanged.
18.01.2008	49560	Flexible spider clutch for coupling main turbine control oil pump No2 and electromotor exchanged.
26.03.2008	51048	Flexible spider clutch for coupling main turbine control oil pump No1 and electromotor exchanged.
26.04.2008	51768	Main turbine lube oil pump No2 electromotor bearing exchanged.
08.06.2008	52608	Main turbine reduction gear dry air fan exchanged.
21.07.2009	53824	Main turbine manoeuvring log unit at bridge station exchanged.
10.08.2010	60902	Main propulsion turbine bridge telegraph CPU unit exchanged.

High pressure turbine blades scratches are not regular issues and they have to be treated instantly in order to avoid serious turbine damages due to metal particles which may enter to further turbine stages. For this type of failure it is difficult to say what was the exact cause but in similar cases this type of failure is usually connected with water droplets at high pressure stages which are carried over from the main boiler or from undrained pipelines. High pressure turbine casing drain is placed beyond 4th turbine stage and if draining is not appropriate water may enter to further stages with steam flow through the rotor. Water droplets increase rotor vibrations and erode turbine blades. Figure 2 shows high pressure turbine second stage blade erosion at the same turbine discovered during the third dry-dock.

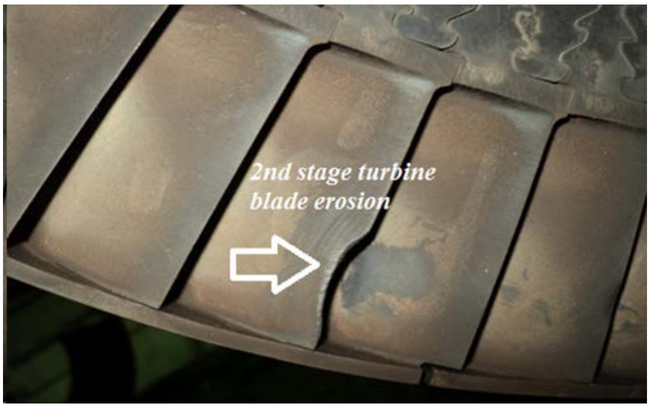

Figure 2. High pressure turbine rotor blade erosion

Non critical failures which are listed due to degradation of the materials are:

- Astern turbine safety control oil valve exchanged.
- Astern turbine steam temperature PT sensor exchanged.
- Flexible spider clutch for coupling main turbine control oil pump No1 and electromotor exchanged.
- Flexible spider clutch for coupling main turbine control oil pump No2 and electromotor exchanged.
- Local manoeuvring side telegraph bell exchanged.
- Steam pressure transmitter at first stage outlet exchanged.
- High pressure bleed steam shut of valve solenoid valve exchanged.
- Main propulsion turbine revolution counter exchanged.
- PT sensor for main turbine steam temperature at steam chest exchanged.
- High pressure turbine bleed shut off valve limit switch exchanged.
- Main turbine lube oil pump No2 electromotor bearing exchanged.
- Main turbine reduction gear dry air fan exchanged.
- Main turbine manoeuvring log unit at bridge station exchanged.
- Main propulsion turbine bridge telegraph CPU unit exchanged.

The most frequent and recurring failure is related to flexible spider clutch for coupling the main turbine control oil pump No1 and No2 with electromotor. As this failure is recurring it may be assumed that hydraulic pump and electromotor are not aligned properly what causes frequent spider damage. This type of failure may be corrected once vessel enters dry-dock.

The second group of recurring failures refer to monitoring equipment i.e. PT temperature sensors and pressure sensors that were exchanged three times. These failures are unavoidable because selected PT sensors operate at high temperatures and have limited working temperature range (slightly above operating temperature). Owner decided to mount cheap solution in the beginning but frequent failures do not justify owner's first choice.

Control equipment failures related to navigation equipment include: local manoeuvring side telegraph bell failure, main propulsion turbine revolution counter failure, main turbine manoeuvring log unit at bridge station failure and main propulsion turbine bridge telegraph CPU unit failure. These failures are not expected in such number. It is a compulsory requirement that main turbine telegraph order log is working due to safety requirements and restoration of manoeuvring in the case of incident.

Miscellaneous failures are related to: astern turbine safety control oil valve failure, high pressure bleed steam shut of valve solenoid valve failure, high pressure turbine bleed shut off valve limit switch failure, main turbine lube oil pump No2 electromotor bearing failure and main turbine reduction gear dry air fan failure. Miscellaneous failures are of low frequency and they are in expected occurrence range.

Incipient failures/faults are caused due to non-perfect condition of equipment so that a degraded or critical failure might occur [7]. In order to prevent incipient faults, according to Table 2, corrective actions were taken: forward labyrinth seal springs were renewed and scale deposit at low pressure turbine first stage was cleaned.

5 CONCLUSION

In this paper failure events of main propulsion turbine on LNG carrier were analysed. Analysis defined three main groups of failures for the main propulsion turbine in presented time range: critical failures, non-critical failures due to deterioration of material and non-critical incipient failures or faults.

The non-critical failures due to material deterioration are listed as: main propulsion turbine control system failures related to the flexible spider clutch with 7 failures, miscellaneous failures with 5 failures, control equipment related to navigation with 4 failures and monitoring equipment with 3 failures. Incipient failures: related to labyrinth seal and scale deposit at low pressure turbine with totally 2 events. Non critical failures may be treated in the port or during anchorage and they have low impact to propulsion turbine reliability. The frequency distribution of failures related to flexible spider clutch has to be improved in order to avoid possible dangerous situation with two control oil pumps in failure. This will cause stoppage of the main propulsion turbine. In order to avoid such risk, spare part kit should be on board the vessel for quick repair. The other weak points were control equipment failures related to navigation equipment where company should upgrade the system in order to avoid future failure occurrences.

High reliability of the main propulsion turbine at sea is required as vessel has restricted contact with shore services and spare parts supply. It may be concluded that main propulsion steam turbine had high reliability in exploitation period.

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