3. Steam Turbine • Boiler

3.1 Steam turbine

3.1.1 Main engine turbine
Kawasaki Heavy Industries, Ltd. constructed and delivered 6 units to Korean shipbuilders (5 units to Daewoo Shipbuilding & Marine Engineering Co., LTD. and 1 unit to Hanjin Heavy Industries & Construction Co., Ltd.), 2 units to Fudong-Zhonghua Shipbuilding (Group) Co., Ltd. in China and 3 units to Kawasaki Shipbuilding Corporation.

Mitsubishi Heavy Industries, Ltd. constructed and delivered 1 unit to Hyundai Heavy Industries Co., Ltd. and 4 units to the domestic shipyards (1 unit to Universal Shipbuilding Corporation and 3 units to Mitsubishi Heavy Industries, Ltd.).

With respect to acquisition of new orders, Kawasaki Heavy Industries, Ltd received the order of 1 unit for Korean shipyard and 2 units for the domestic shipbuilders, and Mitsubishi Heavy Industries, Ltd. stayed in receipt of no order, since the constructions of LNG tankers have been postponed due to the recent delay of LNG project. However, it is extremely significant that Kawasaki Heavy Industries, Ltd. has received the order of the first unit of main engine turbine of highly efficient reheat type from the domestic shipyard, since the future trend of main engine for propulsion may be predicted.

Mitsubishi Heavy Industries, Ltd. has carried out the development of reheat cycle plant of which steam temperature and pressure are raised, and they have succeeded in the development of new system of which efficiency has been improved by more than 15%. However, they have not succeeded yet in receipt of order. Figure 3.1.1 shows the sectional view of reheat type steam turbine.

This system was developed in rivalry with the electric propulsion system by diesel generation, and whole system of LNG tanker’s steam plant is improved with placing the main engine boiler and turbine as core target of improvement. It is considered to be greatly meritorious to attempt further performance improvement by the application of most modern technology with maintaining the advantages like the high reliability and maintenance-free which the steam turbine plant has enjoyed.

In the present state that the LNG tankers will be continuously constructed from now on, the construction of the larger hull size has been already realized and the electric propulsion by diesel generation has been already applied as a propulsive main engine to this kind of vessel. Also, the
investigation of electric propulsion by gas turbine generation system is being carried out, and it is considered that the change of main propulsion engine in future will depend on the result of adoption of electric propulsion and the result of the highly efficient reheat turbine.

3.1.2 Turbine for auxiliary machinery:
As the production results of turbine for auxiliary machinery in 2007, Shinko Ind. Ltd. manufactured 480 units (generator turbine, cargo pump turbine, tank washing turbine), and Mitsubishi Heavy Industries, Ltd. manufactured 32 units (all generator turbines) respectively on the basis of completion at their factories.

Shinko Ind. Ltd. has delivered for the first time the generator turbine of 6000kW for FRSU (Floating Storage Regasification Unit).

Further orders of cargo • ballast turbines for tankers and generator turbines for offshore facilities from the shipyards in Japan, Korea and China will be most likely to come in future.

Under the circumstances that the demand of exhaust heat recovery system has been increasing due to recent surge of oil price, targeting on the reefer container vessel which needs large quantity of electric power, Mitsubishi Heavy Industries, Ltd. has developed the exhaust heat recovery system (Fig.3.1.2) including exhaust gas economizer, steam turbine, power turbine, shaft generator and control system which may economize the fuel consumption by about 8%. Such economization of fuel is considered to be very meritorious. They have attempted to improve the performance of turbine with application of the most new technology and they have finished the simulation taking into consideration the various modes of operation of the control system, and therefore, it is said that the above system is highly reliable.

3.2 Boilers

3.2.1 General
The amount of marine transport in the present world increases every year as BRICs (Brazil, Russia, India and China) develop. The amount of the ship building, therefore, has increased for these several years, and it has been said that this state will be continued until about 2010. A lot of VLCCs (Very Large Crude Carriers) and large container ships equipping the large exhaust gas economizer were built in 2007. Moreover, a lot of VLBCs (Very Large Bulk Carriers) equipping the composite boiler to carry efficiently the iron ore and the original coal were built along with the demand for the crude steel

Fig. 3.1.2 Schematic diagram of exhaust heat recovery system

[Seiji Utou]
production in China and so on.
Making use of advantages of steam turbine plant in LNGCs (Liquefied Natural Gas Carriers), MHI (Mitsubishi Heavy Industries Co.) and KHI (Kawasaki Heavy Industries Co.) have developed the next generation steam turbine and boiler for reheat cycle plant, which can improve the plant efficiency dramatically. Kawasaki Shipbuilding Corporation has already been ordered the LNGC of 177,000m³ with the Kawasaki UTR-2 of which steam condition is 10MPa, 565°C. However, it has been said that the tonnage of LNGCs have been excess in supply due to excessive ship-building and/or another cause.

3.2.2 Production quantity
Figures 3.2.1 and 3.2.2 show annual production numbers and production weights of each marine boiler based on the Statistics of Industrial Products for Ships taken by the Ministry of Land, Infrastructure, Transport and Tourism during 15 years from 1993, but the production numbers and weights in 2007 are only for 6 months from January to June. In the statistics, marine boiler makers have produced 42 for the main boiler, 212 for the auxiliary boiler, 100 for the exhaust gas economizer and 114 for the others including heat-medium boilers. In 2006, 107 for the main boiler, 346 for the auxiliary boiler, 168 for the exhaust gas economizer and 102 for the others had been produced.

Fig. 3.2.1 Boiler production by annual report of marine industrial statistics

Fig. 3.2.2 Boiler production by annual report of marine industrial statistics
3.2.3 Major trends

(1) Main boilers

In 2007, 39 main boilers for the LNGCs were produced by the two companies. The MHI produced 2 boilers of 40 t/h class, 6 boilers of 50 t/h class, 19 boilers of 60 t/h class and 4 boilers of 70 or more t/h, and the Kawasaki Plant Systems Co. produced 2 boilers of 50 t/h class, 6 boilers of 60 t/h class. The 39 main boilers production decreased by 9 boilers compared to that of 2006.

As for orders received in 2007, orders for a total of 11 main boilers were received with Mitsubishi Heavy Industries Co. receiving orders for 1 boiler in the 40 t/h class and 2 boilers in the 70 t/h class and Kawasaki Plant Systems Co. receiving orders for 6 boilers in the 50 t/h class and 2 boilers in the 60 t/h class. The number of main boilers ordered in 2007 suddenly decreased to 11 from 28 ordered in 2006. This is really due to an alternative propulsion systems such as DFE (Dual Fuel diesel engine plant with Electric propulsion motor) and DRL (Diesel engine plant with Re-Liquefaction system) to replace the steam turbine propulsion in worldwide LNG demands.

(2) Auxiliary boilers

Figure 3.2.3 shows the number of production and received order of main and auxiliary boilers by 10 boiler manufacturers in 2007, where the data are classified by boiler capacity. In the Fig. 3.2.3, the reason why the production to 11 ton/h or more has increased is due to building of the VLCCs and large container ships. And also, the reason why the order received to 26 ton/h or more has decreased is due to the decrease of main boilers.

Figure 3.2.4 shows the number of production and received order of composite boilers by the same 10 boiler manufacturers in 2007. According to the Fig. 3.2.4, the composite boiler has mainly been adopted at 1.0 to 3.0 ton/h capacity. According to these manufacturers' data, 290 oil fired boilers were produced in 2007, but 199 oil fired boilers were produced by 9 boiler manufacturers in 2006.
(3) Exhaust gas economizer
Figure 3.2.5 shows the number of production and received order of exhaust gas economizers by the 10 boiler manufacturers in 2007. 271 economizers including 19 large exhaust gas economizers for turbo-generation plant were produced. In addition, the number of received order in 2007 was 268, which was also satisfactory. In the 268 economizers, 20 were the large exhaust gas economizers. In the background of the number of ship building increased and the double hull structure mandated for new build oil tankers, the production of exhaust gas economizers is doing well.

![Production and order received of exhaust gas economizer in 2007](image)

Fig. 3.2.5 Production and order received of exhaust gas economizer in 2007

(4) Heat medium boiler
37 heat-medium boilers, which have calorific values: $4.60 \times 10^2$ to $1.26 \times 10^4$ MJ, were produced in 2007. The heat-medium boilers are adopted for inland vessels, and being almost produced by Miura Co., Ltd exclusively.

[Yoshiharu Itami]

4. Gas turbine · Others

4.1 Marine gas turbine

4.1.1 General
The gas turbine has several advantages of the high output density, low vibration, good operational performance and easy maintenance, low NOx, etc. and it is able to provide the protection of environment (low NOx) and favorable residential atmosphere (low noise and low vibration), and therefore, the numbers of gas turbines have been adopted for generator engines of the large cruising passenger carriers which are operated in the sea area around Arctic Ocean where the severe control of environmental protection has been applied specially in recent years.

On the other hand, the simply open type gas turbine, which is the main current at present, is characterized by the high fuel consumption ratio that is about 30~40% higher at rating output in comparison to diesel engine and by the needfulness of kerosene or light oil which unit price is expensive. Also, viewing the recent circumstances in the world, the price of crude oil rose to 70 dollars per barrel in 2006, and there is a sign of further rise since the oil price went upwards again and hit 90 dollars per barrel at the end of 2007, although it had fallen to the middle of 50 dollars per barrel level at the beginning of 2007. Taking into consideration that the fuel economy is important for marine engine, the gas turbine is being placed at the disadvantageous position in both fuel consumption ratio and fuel cost. However, the gas turbine has been continuously and actively adopted as main propulsion engine in the field of the naval vessels in which the advantages of gas turbine are required to the maximum extent as the demanded items to the main engine for propulsion.
4.1.2 The naval vessels

Looking at the domestic status, 14DD “Atago” on which LM2500 was installed in the method of 4 gas turbines 2 shafts GOGAG system (the improved type of DD vessel budgeted in 1988) went into operation, and the sea trials of 15DD, the 2nd sister vessel “Ashigara”, were carried out before she went into commission.

Also, the helicopter-carried-destroyer “Hyuga” (DD vessel) of 2004 project, on which LM2500 was installed in the method of 4 gas turbines 2 shafts GOGAG system, has been launched. And, the construction of the second vessel has been decided as 2006 project.

In the oversea market, as regards two kinds of new type of high speed vessel (LCS) which were ordered by US Navy and which construction have proceeded, the constructions of each one vessel (LCS-3, LCS-4) have been cancelled, however, LCS-1 on which the new type of marine gas turbine MT30 of GE make is installed, and LCS-2 on which LM2500 is installed are being satisfactorily built respectively by Lockheed Martine and General Dynamics. These gas turbines are used as main machinery for mechanical drive water jet pump.

The number of adoption of gas turbine for driving the electric propulsion generator has been increasing for recent years, due to the reason that gas turbine can make up the deficit of worse fuel consumption within the range of low output by constantly running it around the range of rating output for driving generator with maintaining advantage of the merit of high output density and low vibration.

To improve specific fuel consumption, British Royal Navy’s Type 45 destroyer is powered by two (2) gas turbine alternators (GTAs) driven by the WR-21 (Fig. 4.1.1), intercooled recuperated cycle gas turbine.

In 2007, the sea trials of the first vessel “Daring” started, and the second vessel “Dauntless” and the third vessel “Diamond” were launched, and the construction of the sixth vessel “Duncan” began.

For DDG-1000 destroyer (Zumwalt class) US Navy has decided to adopt MT30 of Rolls-Royce as a gas turbine for driving generator of electric propulsion system, and the total 8 vessels of DC-1000 type destroyer are planned to be constructed.

Fig. 4.1.1 Gas turbine WR-21

4.1.3 Commercial ships

Although the gas turbine is quite often adopted as the driving engine of propulsion generator for the large cruising passenger carrier, the aforesaid surge on fuel cost seems to influence on the market of gas turbine.

It has been decided that diesel generator 11.2kW of Wartsila make would be additionally installed as base load on the ship for which gas turbine generator had been used for propulsion and hotel load, and the improvement works have been orderly carried out. This is because the fuel cost is cheaper due to heavy oil burning in addition to the less fuel consumption resulted with the recent advancement of environmental counter measures.
In 2007, the modification works of 2 ships among 4 of Millennium class of Celebrity Cruise have been completed, and the similar modifications of 2 ships among 4 of Radiance class of Royal Caribbean Cruise started.

4.1.4 Others
In the market of onboard power generator which is another market of marine gas turbine, 4 units of M1A-35 type main generator made by Kawasaki Heavy Industries, Ltd., which had been newly developed and which output had been raised to 2,400kW, were completed and delivered for DDH “Hyuga” of 2004 project.

4.1.5 Summary
As described at the beginning of this Clause, the price of crude oil hit the highest record in history and any fall in price could not be anticipated in future, therefore, in order that the gas turbine could be adopted from now on for marine main engine and marine generator of commercial ships, it is earnestly desired that the fuel consumption ratio that is faults of gas turbine could be improved and W-21 of intercooled recuperated cycle would be adopted to many applications and 「Super Marine Gas Turbine (SMGT)」 (2,500kW class) which is the recuperated cycle gas turbine as mentioned in Fig.4.1.2 would be installed on board the actual ship.

Fig. 4.1.2 Super Marine Gas Turbine

(References)
(2) http://www.mlit.go.jp/sogoseisaku/tec/topics/imgees/2-7.pdf

[Hitoshi Nishiue]