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Effective EEDI Performance Achievement by MAN B&W G-Type Ultra Long Stroke Marine Diesel Engine: A Review

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ABSTRACT:

Man Diesel & Turbo G-Type ultra long stroke marine diesel engine was introduced in October 2010.This ultra long stroke means it has been designed to have reduced engine speeds and there by achieving high efficiency ships with reduced fuel consumption as well as reduced CO_2 emissions. The ultra long stroke diesel engine with capability of using large size propeller and there by engines with comparatively low speeds can be used for propulsions of large bulk carriers and oil tankers. This arrangement facilitates the effective implementation of EEDI. In this paper we review the effectiveness of this engine in implementation and achievement of EEDI and thereby achieving reduced CO_2 emissions. In this paper, we also study the selection of propeller sizes to achieve the optimum design ship speeds and thereby comply with EEDI requirements.

KEYWORDS:

Man B&W G-Type engine; Ultra-long stroke; EEDI and CO_2 emissions

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NOMENCLATURE:

EEDI	Energy efficiency design index
DWT	Dead weight tonnage
IMO	International maritime organization
Nm	Nautical miles
NCR	Normal continuous rating
p/d	Propeller pitch / propeller diameter
SMCR	Specified maximum continuous rating
SFOC	Specific fuel oil consumption
VLBC	Very large bulk carrier

1. Introduction

In this paper the performance of G Type Man B&W engines with regards to EEDI compliance is reviewed. Superiority of G type over S type has been reviewed too. The IMO based EEDI (Energy Efficiency Design Index) is mandatory index required on all new ships contracted after 1 Jan 2013 [1-3]. The index will be used as a reference instrument to fulfil international requirements regarding CO_2 emissions on ships. The EEDI represents the amount of CO_2 emitted by a ship in relation to the transported cargo and is measured in gram of CO_2 per dwt per nm. The EEDI value is calculated on the basis of maximum Cargo capacity (yet 70% for container ships), propulsion power, ships speed, SFOC and fuel type depending on the date of ship contract [4]. The EEDI is required to be a certain percentage lower than the IMO defined reference value depending on the type and capacity of the ship. The main engines 75% SMCR (Specified Maximum Continuous Rating) value is used as standard in the calculation of the EEDI, in which also the CO_2 emissions from the auxiliary engines of the ship is included. Thus a ship bigger than 20000 dwt and built after 2025 is required to have a 30% lower EEDI than in 2013. In general as per the Man B&W reports it is observed that the highest possible propulsive efficiency required to provide the given ship speed is obtained with the largest possible propeller diameter d, in combination with the corresponding, optimum pitch/diameter ratio p/d. To achieve the above ultra-long stroke engines are required to implement higher diameter propellers for the propulsion efficiency. Fig. 1 depicts the nomenclature of MAN B&W engine.

The G-type Man B&W engine [5] achieves SFOC reduction via a combination of several factors, such as:

1. Higher ratio of peak pressure to mean effective pressure
2. Reduced compression ratio (Two stroke miller cycle)
3. A variable exhaust valve controls the engine’s compression ratio at high loads in order to avoid excessive firing pressures in the cylinder. To achieve this, hydraulically operated exhaust gas valve is closed later compared to standard operation. This is also called as “Two stroke miller effect”.
4. Ultra large stroke to bore ratio.
5. High pressure tuned turbochargers [6].

Randy Herold observed that simple geometric relationships of engine cylinder with longer stroke-to-bore ratio will have smaller area exposed to the combustion chamber gases compared to shorter stroke-to-bore ratio [7]. The smaller area leads to reduced heat transfer and increased efficiency. It is known that, scavenging is the phenomenon of the exhaust products in the cylinder are replaced by fresh air and which is also affected by the stroke to bore ratio in an uni-flow scavenging in large two stroke marine engines. As the stroke-to-bore ratio increases, the fresh air has to travel longer distance between the intake ports to the exhaust ports and this result in higher scavenging efficiency which would further lead to lower pumping work because less fresh air is lost via charge short circuiting. Reduced main bearing friction due to reduced nominal frictional force of the mating surfaces on both the inner liner and the crank shaft bearing surfaces. As the stroke-to-bore ratio decreases, the bearing friction increases because the larger piston area transfers larger forces to the crankshaft bearing. However, the shorter stroke results in reduced power cylinder friction originating at the ring/cylinder interface.

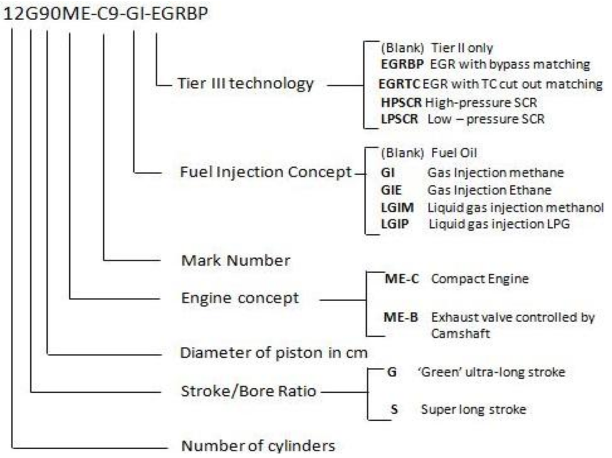

Fig. 1: Engine type designation

2. Propeller efficiency analysis with respective to SMCR and SFOC

Man B&W states that, propellers having highest possible propulsive efficiency required to provide the given ship speed is obtained with the largest possible propeller diameter (d), in combination with the corresponding, optimum pitch/diameter ratio (p/d). This is shown as an example illustrated for a 205000 dwt large cape size bulk carrier with service ship speed of 14.7 knots, see the black curve in Fig. 1. The needed propulsion SMCR power and speed is shown for a given optimum propeller diameter d and pitch/diameter ratio in Fig. 1 [8-9]. According to the black curve as shown in Fig. 1, the existing propeller diameter of 8.3m may have the optimum p/d ratio of 0.71 and the lowest possible SMCR shaft power of about 17680kw at about 88rpm. The black curve shows that if a larger propeller diameter of 8.8m is possible the necessary SMCR shaft power will be reduced to about 17120kw at about 78rpm i.e. the bigger the propeller the lower the optimum propeller speed. If the pitch for this diameter is varied, the propulsion efficiency drops and the necessary SMCR shaft power will increase and the red curve in the graph in Fig. 2 indicates the same.

It is very clear that if the diameter of the propeller is incremented the propelling efficiency of the propeller increases drastically. So selecting a larger diameter propeller would be more advantageous even though the optimum p/d ratio would involve in very low propeller speed (in relation with required main engine speed in terms of rpm). Thus when using approximate lower p/d ratio, compared with optimum ratio, the propeller/engine speed may be increased and will only cause a minor extra power increase.

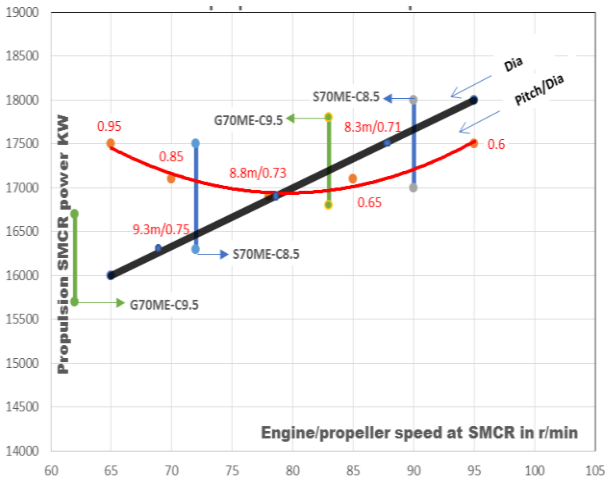

Fig. 2: Relation between propulsive SMCR and speed

The influence of the propeller diameter, pitch diameter ratio on the required SMCR is shown in Fig. 2. The efficiency of a two-stroke main engine particularly depends on the ratio of the maximum (peak) pressure and the mean effective pressure. Higher ratios will result in higher engine efficiency i.e. lower SFOC. Furthermore, the higher the stroke/bore ratio of a two-stroke engine the higher the engine efficiency [8-9]. This means for e.g. that an ultra-long stroke engine type, as the G70ME-C9.5, may have a higher efficiency compared with shorter stroke engine type like a super long stroke S70ME-C8.5. The application of new propeller design technologies may also motivate use of main engine with lower rpm [8-9]. Thus for the same propeller diameter these propeller types can demonstrate an up to 4% improved overall efficiency gain at the same or slightly lower propeller speed. Thus purpose of EEDI is to reduce CO_2 [10].

3. SMCR and propulsive efficiency for large Capesize bulk carrier

Man B&W had conducted a case study [8] on a 205000 dwt large capsize bulk carrier to find the potential for reducing fuel consumption by increasing the propeller diameter and introducing the G70ME-C9.5 as main engine. Birger Jacobsen [8-9] made a study on referring to the ship speeds of 14.7 knots and 14 knots respectively, two potential main engine types pertaining layout diagrams and SMCR points have been drawn in Fig. 3. The S70ME-C8.5 engine type (91rpm) has often been used in the past as a prime mover in projects for large cape size bulk carrier therefore, a comparison between the new G70ME-C9.5 and the existing S70ME-C8.5 is of major interest in this paper. The nominal readings of SMCR for a ship with different contract timings were clearly shown in the Tables 1 and 2. The table gives the actual power, ship speed, propeller diameter, number of blades for each Man B&W engine types. From the Table 1, we have the engine model 6G70ME-C9.5 operates at lowest power to the designed speed of 14knots and 14.7Kn at the propeller diameter of 9.3m. It should be noted that the ships speed stated refers to NCR = 90% SMCR including 15% sea margin. If based on calm weather i.e. without sea margin, the obtainable ship speed at NCR = 90% SMCR will be about 0.6knots higher [8]. If based on 75% SMCR, as applied for calculation of EEDI the ship speed will be about 0.2knot lower, still based on calm weather conditions i.e. without any sea margin.

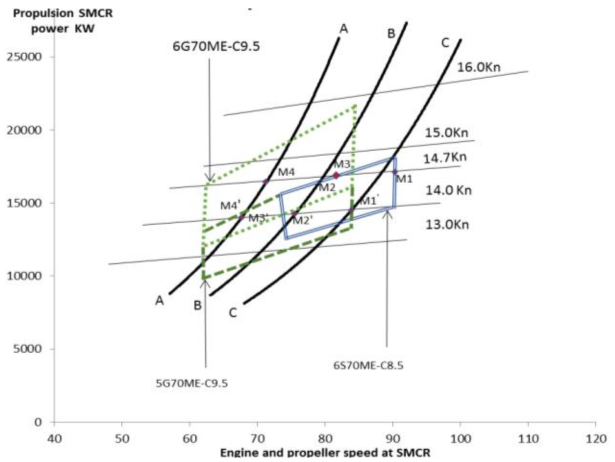

Fig. 3: Power vs. Speed of the vessel at SMCR

Table 1: SMCR relating to the ship speed of 14knots, prop diameter and number of blades in propeller

SMCR possibilities	Ship design speed in knots / prop Dia. x No. of blades	MAN B&W Engine Type	kW x rpm
M1'	14.0 / 8.3m x 4	6S70ME-C8.5	15190 x 84
M2'	14.0 / 8.8m x 4	5G70ME-C9.5	14720 x 75
M3'	14.0 / 9.3m x 4	5G70ME-C9.5	14260 x 67
M4'	14.0 / 9.3m x 4	6G70ME-C9.5	14260 x 67

Table 2: SMCR relating to the ship speed of 14.7 knots, prop diameter and number of blades in propeller

SMCR possibilities	Ship design speed in knots	MAN B&W Engine Type	kW x rpm
M1	14.7 / 8.2m x 4	6S70ME-C8.5	17840 x 91
M2	14.7 / 8.7m x 4	6S70ME-C8.5	17270 x 81
M3	14.7 / 8.7m x 4	6G70ME-C9.5	17270 x 81
M4	14.7 / 9.3m x 4	6G70ME-C9.5	16640 x 71

4. EEDI on the bulk carrier designed for 14.7/14.0 knots

Man B&W [9] had conducted a case study on the propulsion of 205000Dwt in which 6G70ME-C9 is favoured for large cape size bulk carriers. Further for very large bulk carriers (VLBC), the 7S80ME-C9 and 7G80ME-C9 engine types are almost exclusively used as main propulsion engines. The impact of ship speed/SMCR on the EEDI is shown in Fig. 3 and 4, valid for 205,000dwt large capesize bulk carrier with the design ship speed of 14.7knots and 14.0knots. Fig. 4 shows that for the design ship speed of 14.7knots, the two 6G70ME-C9 cases are the only ones to meet the 2015 reference EEDI. For the reduced design ship speed of 14.0 knots, see Fig. 5. With the G70ME-C9 engines, it will now be possible to meet the 2020 reference EEDI without further optimisation of hull and/or propeller.

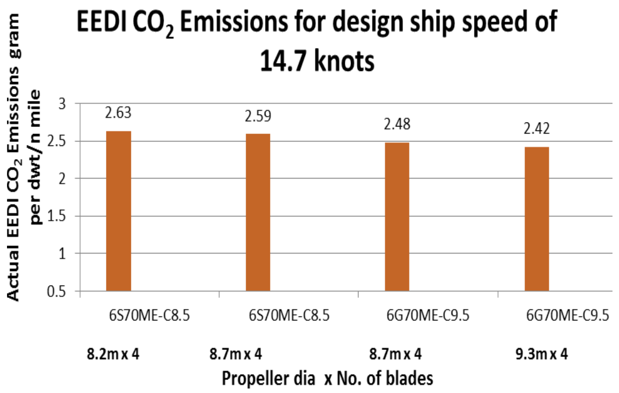

Fig. 4: Reference EEDI and actual EEDI for a design ship speed of 14.7knots

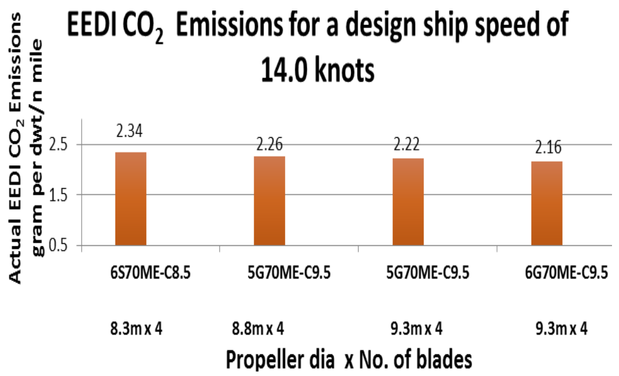

Fig. 5: Actual EEDI for a design ship speed of 14.0knots

Table 3: Contract timing of reference EEDI and actual EEDI for a design ship speed of 14.7knots

Contract date as stipulated by IMO	Reference EEDI CO_2 Emissions gram / dwt/n mile	Reference EEDI in %	6S70ME-C8.5 8.2m x 4 Actual EEDI CO_2 Emissions g / dwt/n mile	6S70ME-C8.5 8.7m x 4 Actual EEDI CO_2 Emissions gram / dwt/n mile	6G70ME-C9.5 8.7m x 4 Actual EEDI CO_2 Emissions gram / dwt/n mile	6G70ME-C9.5 9.3m x 4 Actual EEDI CO_2 Emissions gram / dwt/n mile
01/01/2013	2.81	100	2.63 (94%)	2.59 (92%)		
01/01/2015	2.55	90			2.48 (88%)	2.42 (86%)
01/01/2020	2.25	80				
01/01/2025	1.95	70				

Table 4: Contract timing of Reference EEDI and Actual EEDI for a design ship speed of 14.0 knots

Contract date as stipulated by IMO	Reference EEDI $C0_2$ Emissions gram per dwt/n mile	Reference EEDI in %	6S70ME-C8.5 8.3m x 4 Actual EEDI $C0_2$ Emissions g / dwt/n mile	5G70ME-C9.5 8.8m x 4 Actual EEDI $C0_2$ Emissions gram / dwt/n mile	5G70ME-C9.5 9.3m x 4 Actual EEDI $C0_2$ Emissions gram / dwt/n mile	6G70ME-C9.5 9.3m x 4 Actual EEDI $C0_2$ Emissions gram per dwt/n mile
01/01/2013	2.81	100				
01/01/2015	2.55	90	2.34 (83%)			
01/01/2020	2.25	80		2.26 (80%)	2.22 (79%)	2.16 (77%)
01/01/2025	1.95	70				

5. Conclusion

This review paper shows that, Man diesel & turbo G-type ultra long stroke marine diesel engine possessing reduced engine speeds and high fuel efficiencies has reduced CO_2 emissions. The efficiency curves and the observations with respective to SMCR of ultra-long stroke diesel engine emphasises the selection of higher diameter propeller and optimization will result in lower speeds and lower CO_2 emission in bulk carriers and oil tankers. The efficiency optimization is effectively achieved by selection of higher diameter propellers, ultra-long stroke engines, optimised pitch/diameter ratio and thereby effectively reduce CO_2. In this paper, we reviewed the effectiveness of Man B&W G type marine diesel engine as an efficient power source for propulsion of bulk carriers. This review paper also provides the design criteria of the propeller to get better optimum propulsive efficiency with respect to the hull design.

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