A Hybrid Diesel Engine Simulator as a Skill Development Tool for Marine Engineering Undergraduates

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Abstract— This paper explains a prospect of using a scenario from a marine engine room simulator as a device for educating marine engineer undergraduates. Basic technical parameters have been indicated for the entire scenario of the marine engine room simulator which is used to educate marine engineer undergraduates of the General Sir John Kotelawala Defence University (KDU), Sri Lanka. The Hybrid Diesel Engine Simulator (HDES) is primarily a training method that simulates a realistic engine room set-up, through a controlled environment for marine engineer undergraduates and engine room watch keepers training on-board ships in operational circumstances. Further, HDES can be utilized for training engine room watch keepers in both war and peace times equally. Subsequently, to comprehend the actual operational parameters of Main engines and Auxiliary engines and the smooth functioning of the vessel, the engine room watch keepers will be able to respond to any defect with efficiency, expertise, and confidence gained from training in similar situations. The authors argue that the projected tutorials in the simulator could significantly contribute to the development of alert and responsible machinery utilization of trainees during marine engine room operations.

Keywords*: *hybrid diesel engine simulator, niigata 6M26AGT marine diesel engine, thermodynamics, engine room watch keeper, machinery control room (MCR), console, simulation mode, actual mode

I. INTRODUCTION

The first-ever learning programs through simulator were made in the early 1970's and, as software based teaching, they openly had an inverse academic orientation from the traditional teaching with computer support. Generally, simulation teaching can be distinguished in majors as teaching offered by the trainer (support of the teaching subject with the aid of collaborative simulation), use of simulation and interaction with the trainer and individual or collective use by the trainees (Laskowski, R., Chybowski, L. and Gawdzińska, K., 2015).

Qualitative advancement of the learning progression at university domain, marine engineering education depends mostly on the development of hands on skill training sessions and educational software. Therefore, this Hybrid Diesel Engine Simulator (HDES) is designed and developed with Niigata marine engine and Arduino based control systems to conduct realistic engine room scenarios and performance evaluation of the current technical state of engines and devices. Further, this platform provides facility for marine engineering undergraduates to develop skills on management, operational and support activities (Tsoukalas, et.al.; 2008).

The HDES is primarily a training method that simulates a realistic engine room set-up, though a controlled environment for engine room watch keepers training in ship operation circumstances. Further, HDES can be utilized for engine room watch keepers training in both war and peace times equally. Subsequently, to comprehend the actual operational parameters of Main engines, Auxiliary engines, management issues and re-establishment of damages of engine room. In addition, engine room watch keepers are trained to respond, against any defect or damage with efficiency, knowledge and confidence to overcome realistic status quo inside the engine room (Cao, H. and Zhang, J., 2020). The realistic engine room operation scenarios and crisis generated in the HDES contributes invaluably in driving away fear among the trainees and in improving team building traits, thereby preparing them for unforeseen hardships and emergencies at sea.

Analytical study reveals that 90 % of engine room breakdowns were occurred due to operator's negligence or errors. Therefore, HDES is designed and developed as a perfect teaching method to train modern ship crews in the following areas;

a. Asses watchkeeper's behaviour in emergencies or crucial situations.
b. Enhance practical knowledge on previously acquired theoretical aspects.
c. Improve the ability on problem solving
d. Spareparts ordering and identification for replacement.

II. DESIGN FEATURES

A. Outfit

The HMES of General Sir John Kotelawala Defence University (KDU), Sri Lanka is comprised with Niigata 6M26AGT Marine Diesel Engine and Microcontroller based work stations. The Machinery Control Room is comprised with two work stations;one is operated by the instructor and other is handled by a trainee during simulations. This is a unique simulator that can directly start the engine remotely (from the main console at the work station) and monitor realistic parameters such as starting air pressure, fresh water temperature, lubricating oil pressure, sea water temperature, fuel pressure and exhaust temperature. Further, safety alarms and automatic cutouts are incorporated with this HDES for the safety of both the Marine Diesel Engine and control system. Moreover, both workstations are availed with data storing facility to carry out the analytical study by undergraduates, on completion of exercises. In addition, the same workstations can be utilized to create simulated scenarios while the engine is on run. However, the requirement of delivering the experience on watchkeeping and engine room resource management is met by said activities.

Figure 1: HDES at Marine Engineering Laboratory

The said engine was acquired from a naval vessel which was decommissioned lately. The installation parameters of the ship and general specifications of the engine are tabulated as follows.

Table 1: Main Engine Parameters

Parameters	Value	Unit
Length Overall	60.43	m
Dead Weight	600	tones
Speed	10	Knots
Main Engine Specifications		
Type	Inline, single acting, 4 stroke, diesel engine	
Make	Niigata	
Model	6M26AGT	
Weight	12,700	kg
Cylinder Bore	260	mm
Piston Stroke	400	mm
Cylinder Number	06	
Max rpm	390	
Max continuous output	850	HP
Rotation	Clockwise	
Starting System	Compressed Air	
Governor		Hydraulic

Source: Operation manual of Niigata 6M26AGT Marine Diesel Engine

B. Operational Modes

HDES has two operation modes namely; **Actual** and **Simulation.** Starting, stopping and commissioning of the engine to be done in actual mode and all simulations to be done in simulation mode. Therefore, two consoles are available for controlling, responding and simulation of the entire system and are named as student's console and instructor's console.

1) Machinery Control Room (MCR) for instructor – Instructor console:

Figure 2: Instructor console

Simulation of scenarios, interchanging the modes of the control system and monitoring actual parameters shall be done from this console. Since the actual parameters are to be monitored by skilled personal while the system is on simulation, it has been enabled for the instructor to avoid actual failures to the system. However, all responses are to be done from the student's console if any alarm arises while the system is on either simulator or actual mode.
Further, trainees can practice the issues of management, supervision, and damage re-establishment in the engine system. Trainees are assessed on the aspects of the response time of identifying an amplifying situation and respond well before triggering an alarm or make necessary preventive measures with a minimum time after triggering an alarm.

2) Machinery Control Room (MCR) Workstation for undergraduate – Student's console:
All initial activities shall be done through the said console which includes, starting/ stopping of the main engine, starting/ stopping of auxiliary machinery and acceptance of remote to local controls. Further, the student shall be able to accept alarms, overrun alarms, respond for actions generated by the instructor's console and management of engine room machinery resources by having over control.

Figure 3: Student's console

C.. Engine Room
Engine room is comprised with an HP air compressor, lub oil and fresh water coolers, standby lub oil pump, fuel pump and a fuel tank along with the main engine.
All system lines are laid meeting the need of traceability and painted as per the standard colour code.

D. Control System
The control system of the HDES consists with two modes namely Remote and Local. The local control system is a Microcontroller based control system which is almost similar to a PLC based control system. Selection of modes is enabled with a Remote-Local selector switch.

1) Local Mode –
Direct end–to–end controlling is enabled when operated in local mode. The Control signal is directly forwarded from the local control panel to the input card of the microcontroller input card. According to the given algorithm, the signal is directed to the output card of the microcontroller and through relevant relays and contactors, the control signal will be transmitted.

2) Remote Mode –
Once the system is changed into the remote mode, all signals receiving from the local port will be omitted and connects with the remote module of the console and microcontroller. The remote module is interfaced with a wifi card enabling fully duplex communication within the console, sensors and machinery.

3) Consoles –
Both trainer's and students' consoles and 42" touch displays and the entire control system run on a MS Windows based software program. Data acquisition and transmission is done through aforesaid USB connected wifi module.

III. RESULTS AND OUTCOMES

Exercises are designed at the outset of thermodynamics, concept of marine diesel engines, ship's machinery, engine propulsion systems and watch keeper's role. The practical session is encompassed with Marine Diesel Engine system tracings, fueling and preparation of engine for the startup. Further, the session is limited to four hours and with 10 crew members maximum. In this exercise, real time engine operation is restricted to 30 minutes to maintain the economy of effort. Further, the major concern factor of HMES operation is to facilitate undergraduates to obtain hands on skills; performing basic operational activities such as starting up, follow operating procedures and supervising. Procedures to follow when operating the HDES are as follows.

A. Pre-Checks

i. Trace the system lines to confirm no leakage.
ii. Check main engine sump, air compressor, turbocharger and rocker arm lubricating oil levels.
iii. Check fuel level in service tank and cooling water level in the expansion tank.
iv. Check the pressure in compress air bottles (Max.15 bar).
v. Open valves of lubricating oil, fuel and compressed air bottle valves.
vi. Check power availability of the control system.
vii. Carryout visual inspection of the engine.

B. Starting Procedure

Subsequently, starting procedure should be conducted by watch keeper and start the engine accordingly.

i. Switch on the lubricating oil priming pump and rocker arm lubricating pump.
ii. Open De-compression valves and turn the engine manually.
iii. Put the engine lever stop position and crank the engine 2/3 turns with compressed air.
iv. Close De-compression valves and put the engine lever in start position.
v. Conform manual turning gear disengage.
vi. Touch the start button (If Remote)/Open the starting air valve (If locally) and start the engine.

C. After Starting the Engine

Then, after starting the engine followings are to be monitored by the watch keepers and record accordingly.

i. Check the main engine lubricating oil pressure.
ii. Check the RPM at the set point.
iii. Close the starting air valve properly.
iv. Be alert with engine sound, if any abnormal sound or vibration comes, make sure to stop the engine.

D. While Running the Engine

Finally, following are to be observed to continue the operation of the engine.

i. Check all the parameters and be alert with any abnormalities.
ii. Check Lubricating oil pressure/ temperature.
iii. Check Engine RPM.
iv. Check Cooling water pressure/ temperature.
v. Check Secondary cooling water (Sea water) pressure/ temperature.
vi. Check Exhaust temperatures.

E. Stopping Procedure

Following procedure will be followed in stopping the simulator.

i. Reduce engine RPM up to idle RPM
ii. Run the engine for 05 - 10 minutes and monitor whether the main engine parameters are normal (Lub oil pressure, Fresh Water temperature, Lub Oil Temperature)
iii. Switch mode from **Simulator** to **Actual**
iv. Check for air pressure of control air, prepare crew for manual emergency stop if control air drops.
v. Transfer **local** controls to **remote** controls (All controls to be on the student's console before shutting down the main engine)
vi. Shut down the main engine by student's console. Observe Lub Oil Stand By pump immediately kicks in after lubrication. In case of a system failure, remote or local starting to be enabled immediately after shut down.
vii. Shut down fuel pump, cooling water pump and observe for system leakages.
viii. Run the sea water cooling pump until the system temperature reaches ambient temperature and shut down.
ix. Observe for system leakages, abnormal leakage from the engine, any abnormality in head units, rocker assembly and crank case.

x. Transfer all controls to the local panel and shut down control system by the main breaker.

xi. Shut down consoles from the Machinery control room.

F. Preliminaries

The trainees are assigned to get familiar with the system initially and follow the preliminary operational procedures. Starting of the main engine will be done by the trainees as per the given procedure and closely monitored by an assigned engine room crew member. Subsequently, the instructor takes over control of the Marine Diesel Engine through his workstation and concurrently trainees to follow the instructor's commands. Ex: Increase RPM, loading the engine and etc. Accordingly instructor can change set-ups as per working conditions and state of the machinery, by creating operational turbulences such as failures, malfunctions and change of parameters through the instructor's console. Subsequently, scenario identification and reactiveness of trainees are monitored.

G. Simulation of a scenario- High Exhaust temperature

Marine Diesel Engine was started and operated at 255 rpm for 30 minutes in seven days. Mean coolant temperature (in & out of cooler), mean fresh water temperature, mean exhaust temperature in all six cylinders, mean lubricating pressure were recorded. Accordingly, same parameters for 300, 350 and 400 rpms were simulated respectively by using the system software and tabulated below.

Table 2: A template of experiment measurement table

rpm	Coolant in (°C)	Coolant out (°C)	FW_T (°C)	EXH_T (°C), Number of Cylinders						LUB_p (bar)
				1	2	3	4	5	6	
255	38	28	65	74	82	54	60	79	54	5.2
300	38	30	72	79	83	59	64	80	60	5.4
350	38	33	76	80	84	68	70	81	66	5.5
400	38	35	78	82	85	74	75	84	73	5.8

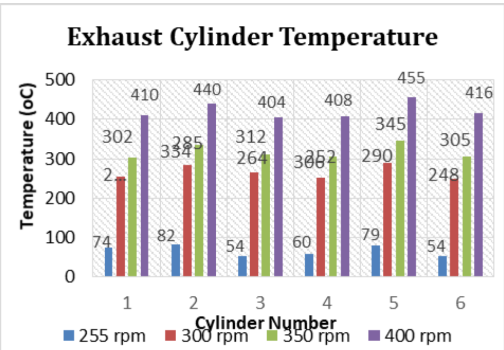

Figure 4: Individual Cylinder Exhaust Temperature as per different rpm

IV. DISCUSSION

In this experiment, the exhaust temperature of number 2 & 5 cylinders were high compared to the rest of the cylinder exhaust temperatures. Subsequently, an analytical study was carried out in this regard and matched with the theory learned during the class room lessons and understand followings in Figure 4.

i. Injection pressure may be low in both cylinders 2 & 5

ii. Injection nozzle spray pattern may be changed

iii. More Carbone deposited on cylinder head (outlet valves)

The most vital part of this investigation was the approaches of trainees on identifying the defect, rectification and repair action. Accordingly, referring to the spare parts catalogue and identifying a component which is to be replaced also observed.

V. CONCLUSION

This HDES equipped with two work stations facilitate individual training and control of the abilities of numerous watch keepers at the same time. Therefore, enlightening marine engineers employing Hybrid Marine Engine Room Simulator is the least expensive and the safest training and evaluating method in present day context. This HDES encompasses with Mictrocontroler based control system and is able to simulate 15 scenarios related to parameters and operational conditions. Subsequently, trainees can evaluate the performances of changes for selected active and economic parameters of the Niigata 6M26AGT Marine Diesel Engine operation and fuel supply system. Eventually, the acquired knowledge by undergraduates of marine engineering is tested in writing on completion of HMES exercises and is essential to prepare a report and submit it to the lecturer within a given time frame. The report should comprehend with following majors:

Purpose of the application – a short presentation of the completed exercise, methodology, conditions for the experiment (engine room operational condition; environmental conditions; set load; selecting measurement points; list of symbols with measure units);

Measurements – results e.g. in the form of a chart;

Computing – calculations of secondary (complex) values;

Presentation – plots with exercise results;

Recommendations – General evaluation of results and their values, accuracy and usefulness of methods applied for measurement and data processing, comparative analysis of experiment results and trends of parameter variation.

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