A Diagnostic Simulator Applied to Engineering Training*

Stefan Kluj

Gdynia Maritime University
ul. Morska 83, 81-962 Gdynia, Poland

A four-stroke, medium speed, diesel engine fault simulator is the subject of this article. The mathematical model simulates an engine operation under various conditions and introduces various defects. This model presented here has been designed and implemented based on a software program called *Turbo Diesel 3*, which is utilised for the teaching of the relationship between the diesel engine technical state and its operating parameters, functions and features. In this article, the author looks at the evaluation and the live run modes, as well as what to expect in the inspection of engine parameters.

INTRODUCTION

The first version of the PC-based diesel engine simulator described in this article, called *Turbo Diesel for Windows*, was developed in 1994 [1]. The author completed the latest version, called *Turbo Diesel 3*, in 2003. The *heart* of the program is a mathematical model of a diesel engine, based on the physical structure of a modelled object (see Figure 1).

The model has been developed using an actual factory's test bed results and classic thermodynamic equations. The package allows an engine operation under selected initial conditions (for example torque, RPM and ambient air pressure), as well as variable technical states (for example a dirty air blower, broken piston rings, a worn fuel pump and so on). The simulated engine reacts naturally under almost any combination of factors, although some combinations make the operation impossible as they would in real life.

In order to validate the software, it was necessary to model an actual engine so that the calculated values produced by the software could be compared to those values measured on the real engine (see Figure 2).
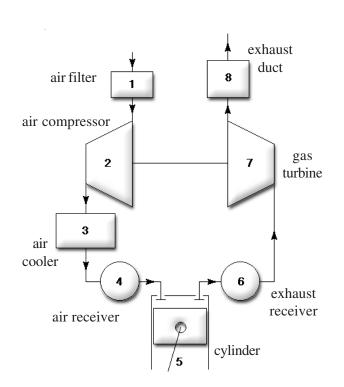
Figure 1: The simplified model of the turbocharging system.

The diagnostic simulator is designed to faciltate the teaching/learning of the principles of generic diesel engine operation. It is not designed to be used in the teaching of the operation of any specific engine or any type of engine.

The simulator has been designed with great care about the user interface (see Figure 3). The implementation of typical Microsoft Windows controls (ie menus, dialogues, pushbuttons and scrollbars) should
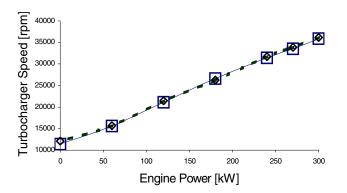
Figure 2: A comparison of the simulated and measured (dotted line and squares, respectively) turbocharger speed.

make the simulator operation easier, especially for the user who has at least basic experience with the graphics user interface. The simulator makes use of multimedia features that are typical of today's personal computers. The digitised engine sound has also been synchronised with engine speed in order to create the typical atmosphere found in an engine room.

The general approach to the diagnostic teaching of a diesel simulator application was based on the author's long-time academic experience in providing courses on diesel engine diagnostics, as well as in some earlier research and development activities [2-5]. The main teaching tasks implemented in the simulator are described and discussed in this article.

EVALUATION MODE

In the Evaluation Mode, the student can work in the instructor's absence while trying to learn the relationship between the technical state of the engine or the operating conditions on the one hand and the operation parameters on the other.

The recommended training plan for students is presented in the following list of steps:

1. The student has to start the engine and observe the operation parameters;
2. Later, the student can increase and decrease the engine load and observe the parameters;
3. The student should find his/her way of controlling the engine by changing some of the parameters and observing the effect on the gauges; the
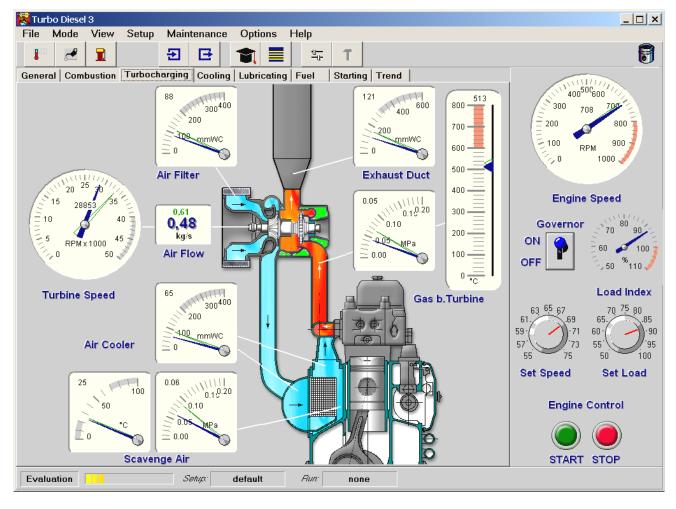

Figure 3: The simulator main window for *Turbo Diesel 3*.

program instruction shows how to do this and how to start making certain diagnoses by observing the gauges;

4. The current simulation set-up and the engine parameters can be saved as a set-up file;
5. The trainee can also load a previously saved simulation set-up from a file, which is much faster than making new calculations.

It is very important to know that multiple simulations can be mixed freely, and each of them can be selected from the given range (see Figure 4).

The complete list of the possible simulations is as follows:

· Air filter: an increase of air path resistance;
· Air blower: a decrease of air flow efficiency;
· Gas turbine: an increase of gas path resistance;
· Air cooler: a decrease of air resistance;
· Gas leak through the piston rings or valves (or both);
· Fuel effective quantity decrease;
· Change in injection advance angle;
· Decrease in cooling efficiency;
· Increase in friction coefficient;
· Change in engine speed;
· Change in engine load;
· Change in ambient air pressure and temperature;
· Alterations in air cooling water flow;
· Change in cylinder cooling water temperature;
· Change in lubricating oil temperature;
· Drop in lubricating oil pressure at the oil filter air filter – increase in air path resistance.

Every change in the technical state or in the operation conditions starts the calculation process. The calculation loop has to be repeated many types until the balanced conditions listed below are fulfilled:
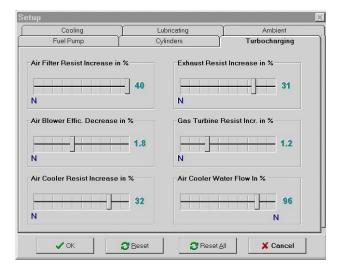

Figure 4: The simulation mixing window.

· The power required by the air compressor has to be balanced with the power produced by the gas turbine within the given range;
· The air mass flow, delivered by the air compressor, has to be balanced with the gas flow consumed by the gas turbine within the given range;
· The pressure drop on all passive flow resistors has to be balanced with the compression ration produced by the air compressor.

It takes up to a few seconds until the engine parameters are stable, depending on the actual fault set-up.

LIVE RUN MODE

The Live Run mode is rather like other computer simulations (a flight simulator for example); the operator has to act as a qualified user, working with the computer, which simulates dangerous situations, faults and so on. Although the scenario is written by an author, random factors are also introduced by the computer.

Each Live Run starts with the engine in a particular technical state (set by the instructor or loaded from a previously created and saved set-up). As time proceeds, any faults that are present from the outset become aggravated and affect the engine's parameters. The student monitors the engine state and can carry out repairs or maintenance at any time, as well as correct actions so that more efficient and economical running of the engine is achieved. It should also be noted that negligence, as well as wrong or unnecessary actions, may lead to a loss of economical efficiency.

A complete list of the various maintenance activities available in *Turbo Diesel 3* is presented below:

· Cooling pump repairs;
· Water temperature controller adjustments;
· Cooling system washing;
· Lubricating pump repairs;
· Oil filter cleaning;
· Oil temperature controller adjustments;
· Engine bearing repairs;
· Turbocharger general repairs;
· Air side washing;
· Gas side washing;
· Air filter cleaning;
· Air cooler cleaning;
· Exhaust system cleaning;
· Cylinder general repairs (piston rings and cylinder head);

·   Fuel pump general repairs;
·   Fuel pump adjustments.

The overall cost of the selected repairs is added to any previous repairs and maintenance costs. This is a very important measure of a trainee's competence level and can be used for his/her overall assessment. The engine user who has spent less money for simulated engine operation costs (maintenance, repairs and fuel) will usually be more desired by a company, compared to someone responsible for higher operation costs. The author's experience has shown that, for example, trainees, who have been engaged in significant practice as an engineer-officer at sea, require less money on running a simulated engine than young inexperienced cadets.

INSPECTING ENGINE PARAMETERS

There are many different diesel engine and ambient parameters that can be continuously monitored while running the *Turbo Diesel 3* model engine. Indeed, gauges show more than one value. Figure 5 illustrates a simulation example of a change in the combustion curve caused by a late fuel injection.

For single gauges, the two readings are visible, namely: the current and the reference value. On multiple gauges, one can see the actual value for each cylinder and the reference value common to all three cylinders. The bigger the difference between the actual and reference values, the worse the technical
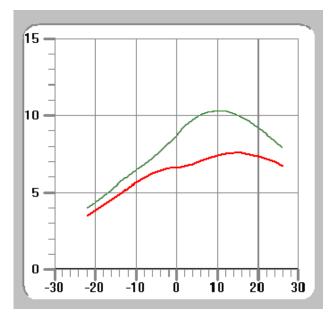

Figure 5: Simulation example of a change in the combustion curve caused by late fuel injection (the upper curve is the reference curve, whereas the lower one represents the actual curve).

state is. The principle that deviations should be used instead of the actual parameter values is very important – especially for the student with little or no experience with engine simulators. The trainee can hardly estimate if the observed parameter value is correct, so the parameter deviation is of a great help for any analysis.

The gauges are combined into panels in order to group logically the related parameters. An example of the lubricating system panel is shown in Figure 6.

The list of engine parameters that can be inspected in *Turbo Diesel 3* is given below:

·   Engine revolution speed;
·   Engine load;
·   Actual engine revolution speed;
·   Engine torque;
·   Engine power;
·   Engine specific fuel consumption;
·   Engine mean effective pressure;
·   Cylinder combustion pressure curves (separate for each cylinder);
·   Cylinder maximum pressure (separate for each cylinder);
·   Cylinder exhaust gas temperature (separate for each cylinder);
·   Cylinder mean indication pressure (separate for each cylinder);
·   Lubricating oil inlet pressure;
·   Lubricating oil inlet temperature;
·   Lubricating oil outlet temperature;
·   Cooling water inlet pressure;
·   Cooling water inlet temperature;
·   Cooling water outlet temperature;
·   Ambient air pressure;
·   Ambient air temperature;
·   Turbocharger revolution speed;
·   Scavenge air pressure;
·   Scavenge air temperature;
·   Air flow;
·   Exhaust gas pressure before the turbine;
·   Air pressure drop at the air filter;
·   Air pressure drop at the air cooler;
·   Air temperature after the air cooler;
·   Exhaust gas temperature before the turbine;
·   Exhaust gas pressure after the turbine.

CONCLUSION

The diagnostic simulator is based on the mathematical model of the high power, medium speed, four-stroke diesel engine and is particularly suited for diagnostic engineering education. It provides instructors with a
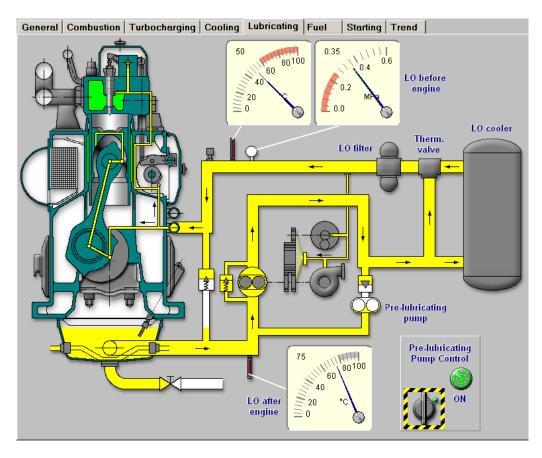
Figure 6: The lubricating system panel.

powerful teaching tool, and students with an excellent training unit, the use of which leads to an increased understanding of the relationship between an engine's technical state and its operating parameters.

One very important feature of the presented simulator is its low cost and the possibility for it to be also used for standalone education. This makes this kind of a simulator very attractive for low budget colleges, especially in developing countries. Also, ship owners may find the simulator particularly useful and attractive, because of the possibility of installing this simulator onboard a ship.

The well-designed and executed complete teaching programme, including a set of earlier prepared educational instructions, is also part of this simulation package.

REFERENCES

1. Kluj, S., The role and mission of a PC-based engine room simulator. *Proc. ICERS 2*, Rimouski, Canada (1995).
2. Kluj, S., The marine diesel engine diagnostic computer simulator ARGUS. *Proc. 18th Internationale Tagung der Ingineur Hochschule für Seefahrt*, Warnemünde, Germany (1988).
3. Kluj, S., The role and mission of the engine room simulator. *Proc. 3rd East-West Congress on Engng. Educ.*, Gdynia, Poland, 162-165 (1996).
4. Kluj, S., The relation between learning objectives and the appropriate simulator type. *Proc. 5th Inter. Conf. on Engine Room Simulators*, Singapore (2001).
5. Kluj, S., The application of the diesel engine simulator for the diagnostic training. *Proc. IASTED Conf. on Applied Simulation and Modeling*, Rhodes, Greece (2004).

BIOGRAPHY

Dr Stefan Kluj was born in 1949 in Poland. He graduated from the Technical University of Gdañsk, Poland, in 1974 and, eight years later, he received a PhD degree in engineering. He is currently at the Gdynia Maritime University, Gdynia, Poland.

He is a British Chartered Engineer and a Fellow in the British Institute of Marine Engineering, Science and Technology.

8th *Baltic Region Seminar on Engineering Education:* Seminar Proceedings

edited by Zenon J. Pudlowski, Norbert Grünwald & Romanas V. Krivickas

These Proceedings consist of papers presented at the *8th Baltic Region Seminar on Engineering Education*, held at Kaunas University of Technology (KUT), Kaunas, Lithuania, between 2 and 4 September 2004. Eight countries are represented in the 29 papers, which include two informative Opening Addresses and assorted Lead Papers. The presented papers incorporated a diverse scope of important and current issues that currently impact on engineering and technology education at the national, regional and international levels. The level of Lithuanian participation indicates the nation's commitment to advancing engineering education in the higher education sector.

In this era of globalisation, much needs to be done and achieved through creating linkages and establishing collaborative ventures, especially in such a highly developed area as the Baltic Sea Region, and the KUT definitely leads the way in these endeavours. Hence, the aim of this Seminar was to continue dialogue about common problems and challenges in engineering education that relate to the Baltic Region. Strong emphasis must be placed on the establishment of collaborative ventures and the strengthening of existing ones.

It should be noted that the Baltic Seminar series of seminars endeavours to bring together educators, primarily from the Baltic Region, to continue and expand on debates about common problems and key challenges in engineering and technology education; to promote discussion on the need for innovation in engineering and technology education; and to foster the links, collaboration and friendships already established within the region.

The papers included in these Proceedings reflect on the international debate regarding the processes and structure of current engineering education, and are grouped under the following broad topics:

- Opening addresses
- New trends and approaches to engineering education
- Quality issues and improvements in engineering education
- Specific engineering education programmes
- Innovation and alternatives in engineering education
- Important issues and challenges in engineering education
- Case studies

All of the papers presented in this volume were subject to a formal peer review process, as is the case with all UICEE publications. It is envisaged that these Proceedings will contribute to the international debate in engineering education and will become a source of information and reference on research and development in engineering education.

To purchase a copy of the Seminar Proceedings, a cheque for $A70 (+ $A10 for postage within Australia, and $A20 for overseas postage) should be made payable to Monash University - UICEE, and sent to: Administrative Officer, UICEE, Faculty of Engineering, Monash University, Clayton, Victoria 3800, Australia. Please note that sales within Australia incur 10% GST.

Tel: +61 3 990-54977 Fax: +61 3 990-51547