

## The finding of diesel engine faults and an example syllabus in maintenance training

Stefan Kluj

Gdynia Maritime University  
Gdynia, Poland

**ABSTRACT:** The finding of diesel engine faults and an example syllabus in maintenance training are the subjects of this article. The *Turbo Diesel 3* diagnostic simulator simulates an engine operation under various conditions and introduces various defects that the user has to resolve. The first part of the course is aimed for the teaching of the relation between the diesel engine technical state and its operating parameters, while the second component is aimed at the teaching of maintenance strategies. These are important elements to consider in maritime engineering education.

### INTRODUCTION

The first version of the PC-based diesel engine simulator, called *Turbo Diesel* for Windows, was developed in 1994 [1][2]. The latest version, called *Turbo Diesel 3* (see Figure 1 for the main window of the simulator) was completed by the author in 2003 [3]. The *heart* of this program is a diesel engine mathematical model, based on the physical structure of the modelled object. The model has been developed using the actual factory test bed results and the classic thermodynamic equations. The package allows for engine operation under selected initial conditions (eg torque, RPM, ambient air pressure) and variable technical state (eg 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 have done in real life [4].

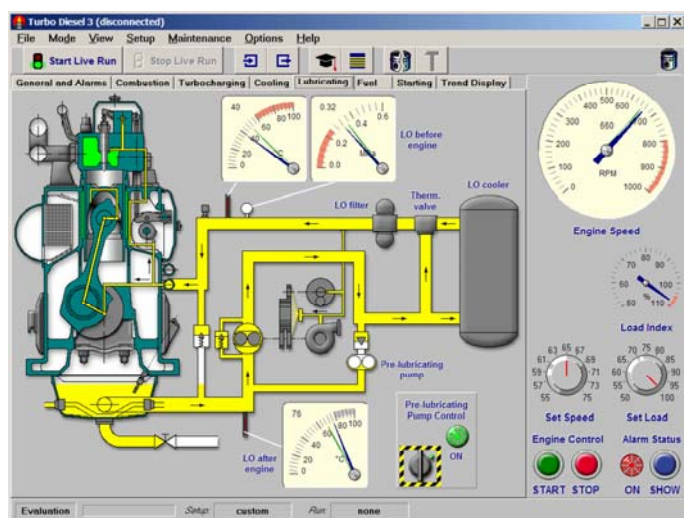


Figure 1: The main window of the simulator, *Turbo Diesel 3*.

The syllabus consists of two main parts, namely:

- The Evaluation mode;
- The Live Run mode.

In the first component of the syllabus, called the Evaluation mode, the student learns to understand the relationship between an engine's state and the engine's parameters. This is particularly important for students in the early stages of their training. It also makes clear the importance of the application of the proper diagnostic method, since only the correct diagnostic methodology can enable the identification of the engine's faults.

In the second part, called Live Run mode, the student is obliged to put his/her knowledge into practice - ie run the simulated engine and take responsibility for its condition and maintenance. In the Live Run mode, the student becomes, in effect, a qualified user. He/she needs to monitor closely the engine operating parameters and carry out repairs when necessary. Apart from reacting to the student's actions, the software also generates random wear and tear factors, which means that no Live Run is ever exactly the same as another. The student's performance is logged and scored for assessment and debriefing.

Both modes are described in more detail below.

### EVALUATION MODE

In the Evaluation mode, students 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 following list gives the recommended training plan for students:

- The student has to start the engine and observe the operation parameters;
- Later, he/she can increase and decrease the engine load and observe the parameters;
- The trainee should find his/her way around the engine by changing some of the parameters and observing the effect on the gauges. The program tutorial shows how to carry this out and how to start making diagnoses by observing the gauges;
- The current simulation set-up and the engine parameters can be saved in the set-up file;
- The trainee can also load a previously saved simulation set-up from a file (which is much faster than making a new calculation).

It is very important to know that multiple simulations can be mixed freely. Furthermore, each simulation can be selected from the given range (see Figure 2).

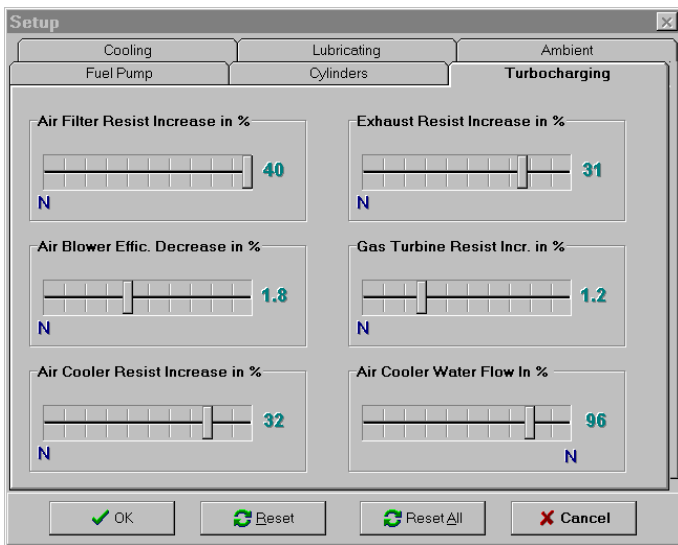


Figure 2: The fault mixing window.

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

- 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 compression ratio produced by the air compressor.

It takes a few seconds until the engine parameters are stable depending on the actual fault set-up. There are many different and possible diesel engine and ambient parameters; these can be continuously monitored while running the *Turbo Diesel 3* model engine. Notably, gauges show more than one value (see Figure 3).

The bigger the difference between the actual and reference values, the worse the technical state is. The principle that deviations should be used instead of the actual parameter values is very important, especially for those students who lack

experience with the simulated engine type. The student can hardly estimate if the observed parameter value is correct, so the parameter deviation is of a great help for analysis.

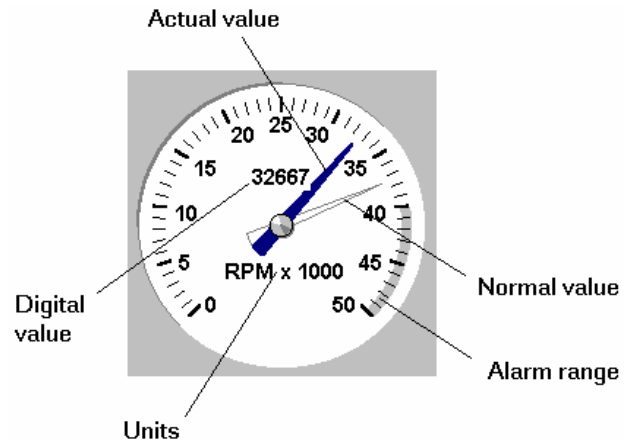


Figure 3: Actual and normal values of the parameter.

### 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 against 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.

In this instance, 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 parameters. The student monitors the engine state and can carry out repairs or maintenance at any time (Figure 4 shows the maintenance window); correct actions lead to more efficient and economical running, while negligence and wrong or unnecessary actions lead to a loss of economical efficiency.

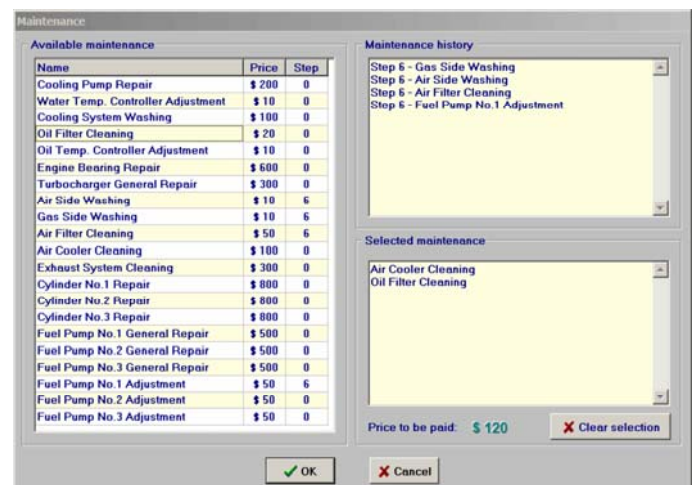


Figure 4: The maintenance window.

The global cost of the selected repairs is added to any previous repair and maintenance. This is a very important measure of the student's competence level and can be used for his/her assessment. The engine user, who has spent less money for the simulated engine operation costs (maintenance, repairs and fuel), will be usually more wanted by a company compared to someone who produces higher operational costs.

## EXAMPLE OF A SYLLABUS

Presented below is an example of a syllabus of the training course (based on the *Turbo Diesel* application). This has been developed by the author and tested with both young cadets and experienced engineering officers.

The syllabus has been based on the following assumptions:

- The time unit is 90 minutes, ie two lesson hours with or without a short break. Typically, such a time unit takes place every week;
- The training group consists of 10-12 students who are controlled and supervised by a single teacher/instructor;
- Each student uses his/her own PC workstation with *Turbo Diesel 3* installed and connected via a LAN to the instructor workstation;
- The instructor uses his/her own workstation with the *Turbo Diesel Instructor* software installed and connected via a LAN with student workstations;
- Each student can use the printed *Turbo Diesel* manual and has already heard the lectures on diesel engine diagnostics.

The complete syllabus can be listed as follows.

### 1. Introduction:

- *Turbo Diesel 3* basics;
- Operational instructions;
- Inspection of engine parameters;
- First steps.

Aim: *To learn how to operate Turbo Diesel 3.*

Mode: *Evaluation and Live Run*

Time: 90 minutes.

### 2. Start, stop and load changes:

- Engine parameters when stopped;
- Engine parameters when running;
- Engine parameters under different speeds and loads;
- Actual and reference parameter values.

Aim: *To learn how the engine's parameters change under different loads and engine speeds.*

Mode: *Evaluation*

Time: 90 minutes.

### 3. Different operating conditions simulation (minimum and maximum values of the range):

- Ambient air (pressure and temperature);
- Cooling water (pressure and temperature);
- Lubricating oil (pressure and temperature).

Aim: *To learn how the engine's parameters change under different operating conditions.*

Mode: *Evaluation*

Time: 90 minutes.

### 4. Single simulations (middle and maximum value of the range):

- Air filter: an increase of the air path resistance;

- Air blower: a decrease of the air flow efficiency;
- Gas turbine: an increase of the gas path resistance;
- Air cooler: a decrease of the air resistance;
- Gas leak through the piston rings or valves (or both);
- Decrease in the fuel effective quantity;
- Injection advance angle change;
- Decrease of cooling efficiency;
- Friction coefficient increase;
- Engine speed;
- Engine load.

Aim: *To learn how the engine parameters change when a single fault occurs. The typical fault symptoms should be collected as a final result.*

Mode: *Evaluation*

Time: 3 x 90 minutes.

### 5. Multiple simulations (mixing every single simulation with other single simulations):

- Air filter fault with all other simulations;
- Air blower fault with all other simulations;
- Gas turbine fault with all other simulations;
- Air cooler fault with all other simulations;
- Gas leak through the piston rings with all other simulations;
- Fuel effective quantity decrease with all other simulations;
- Injection advance angle change with all other simulations;
- Decrease of cooling efficiency with all other simulations;
- Friction coefficient increase with all other simulations;
- Engine speed with all other simulations;
- Engine load with all other simulations;

Aim: *To learn how typical fault symptoms change when other faults occur.*

Mode: *Evaluation*

Time: 6 x 90 minutes.

### 6. Live Run mode exercises.

- The first 20 steps and the saved Run (discussion);
- The next 20 steps and the saved Run (discussion);
- The next 20 steps and the saved Run (discussion);
- General maintenance strategy discussion based on the examples.

Aim: *To learn maintenance strategy rules.*

Mode: *Live Run*

Time: 3 x 90 minutes.

### 7. Live Run mode assessment:

- The first Live Run assessment;
- The second Live Run assessment;
- The results discussion.

Aim: *To test the student's diagnostic and maintenance knowledge level.*

Mode: *Live Run*

Time: 3 x 90 minutes.

Total estimated time: 18 x 90 minutes. = 27 hours.

## CONCLUSION

The syllabus presented above has been used practically by the author for more than 10 years. This has been well tested but is not the only possibility on how to teach diesel engine fault finding and maintenance strategies [5].

The author's experience has shown that those trainees who have engaged in significant practice as an engineer officer at sea require less time and money on a simulated engine operation when compared with young inexperienced cadets. This means that, in many cases, they do not use the diagnostic knowledge learned when working in the Evaluation mode, but instead rely on their experience and apply the maintenance as they would do in real life.

The experience shows that the simulator can be utilised effectively only in conjunction with the appropriate syllabus. Furthermore, there is an important and direct relation between the learning objectives and the selection of an appropriate simulator type [6].

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