Dorota ŁOZOWICKA
Maritime University of Szczecin, Szczecin

THE ADAPTATION OF A MARINE BOILER FOR A SIMULATION LABORATORY WORKPLACE

Key words

Marine boiler, simulation, mathematical modelling, didactics.

Summary

The automatic regulation of a marine boiler is analysed. A laboratory stand for the presentation of marine boiler operation was constructed, even though the device is not a functioning boiler. The boiler drum is substituted by a water reservoir. The working characteristics of the boiler and reservoir are analysed.

Introduction

A marine water tube boiler is analysed, especially the automatic regulation of the boiler operation. The test stand for the simulation of boiler operation could be useful for the demonstration its function to students of technical universities without the expense and time of putting the boiler in motion. Some changes in boiler installation should be made using automatic control equipment [1], [2] on the constructed laboratory stand. The boiler drum will be substituted by a water reservoir. Vapour consumption will be simulated by a water basin.

Mathematical modelling of the boiler and reservoir is used for the estimation of the analogue of physical processes. Feed-water regulation is multi-parameter regulation. The main control impulse is dependent on the vapour rate of flow. Additional correction of the impulse is dependent on the water level in drum. The difference between the vapour rate of flow and water supply is given for the controller. This problem could be treated as one-parameter regulation, if water level fluctuation is an input impulse for feed-water regulation [3].

1. Dependence of water level and boiler load

The automatic control system has to provide the value of input signal at the postulated level and compensate for the influence of disturbances (known or unknown). Using a Laplace transform, the time variable signal is transformed at a different type of signal to make analysis easier. Problem formulated of the time field is described by the multinomial of the complex variable. The differential equation is put on the Laplace transform double sided (initial conditions are nullity), then the proportion of the transform of the input signal and output signal is dependent on the dynamic characteristic of the element, independent of the input signal. The dynamic characteristics of the element are described by its transfer function [4].

Using the SIMULINK toolbox of the MATLAB program, the marine boiler is identified based on the characteristic of a real boiler [5]. The transfer function is estimated and used for formulating the mathematical model of the boiler. The real function describing the dependence of the water level and the boiler load is rather complicated, but this function can be distributed for the inertial and integral elements. The proposed system is presented in Fig. 1.

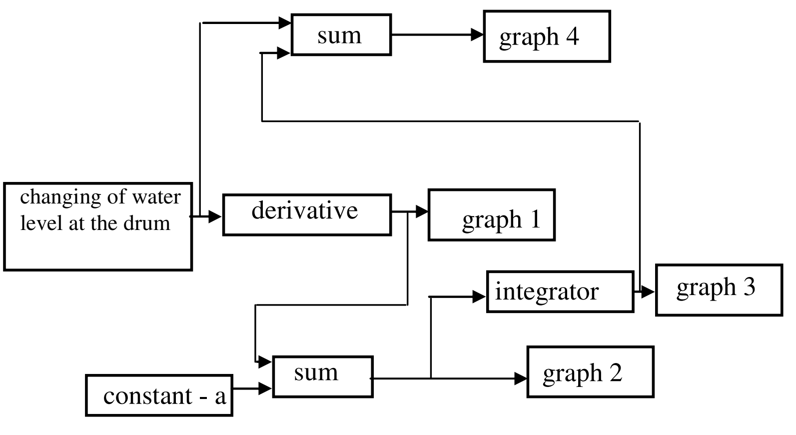

Fig. 1. Block diagram of the system

During the first step the differential of function is calculated. The results of this operation are given in Graph 1. In the graph, the water level as function of boiler load is presented [3]. Using Graph 1, constant a = *0.0038169* (independent on time) is fixed. On Graph 2, the inertial element of the I^{st} order is presented. This element is calculated by subtracting constant a from the differential function. Gain $k = 1.6$ and inertial constant $T = 10$ are fixed (ordinate of asymptote gives k value, T value is fixed for 0.632 k), and the transfer function is formulated as follows:

$$G(s_1) = \frac{1,6}{1+10s} \tag{1}$$

Graph 3 presents the integral element (Graph 2 presents the integration of the function) [2].

Integration constant $Tc = 250$ is fixed based on the graph, and the following transfer function is formulated:

$$G(s_2) = \frac{1}{250s} \tag{2}$$

The verification of gain and the choice of constants are made by the creation of the system presented in Fig. 2.

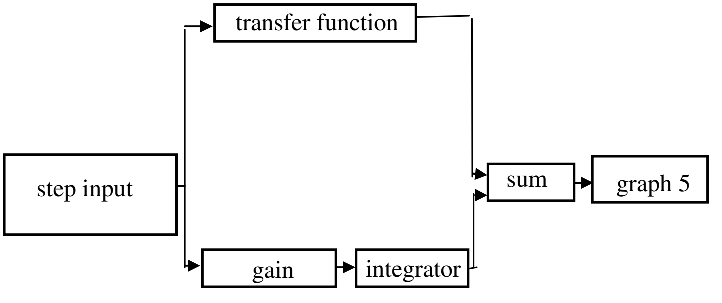

Fig. 2. Block diagram of the verification of gain and the choice of constants

Graph 5 presents the sum of both functions. This graph is compared with the graph that presents the dependence of the water level and the boiler load of a real marine boiler. The result of this comparison was positive. Detailed diagrams are presented in [2].

2. Dependence of water level and water inflow

Based on real boiler characteristics, it is established that the dependence of water level and water inflow is linear (integral element). The integration constant $Tc = 420$ is fixed, and the following transfer function is formulated:

$$G(s_3) = \frac{1}{420s} \tag{3}$$

The dependence of water level and water inflow is presented in Diagram [2].

3. The mathematical model of the boiler

The mathematical model of the boiler is formulated by parallel connecting the transfer functions $G(s_1)$, $G(s_2)$, $G(s_3)$ (Fig. 3). The dependence of water level in the drum as a function of boiler load and the simultaneous water inflow in relation to time is presented in Graph 6 (Fig. 4). The mathematical model of the boiler shows the real physical processes in the boiler.

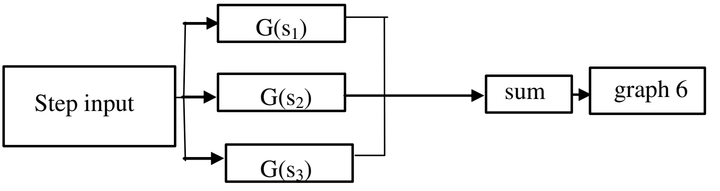

Fig. 3. Block diagram of boiler model

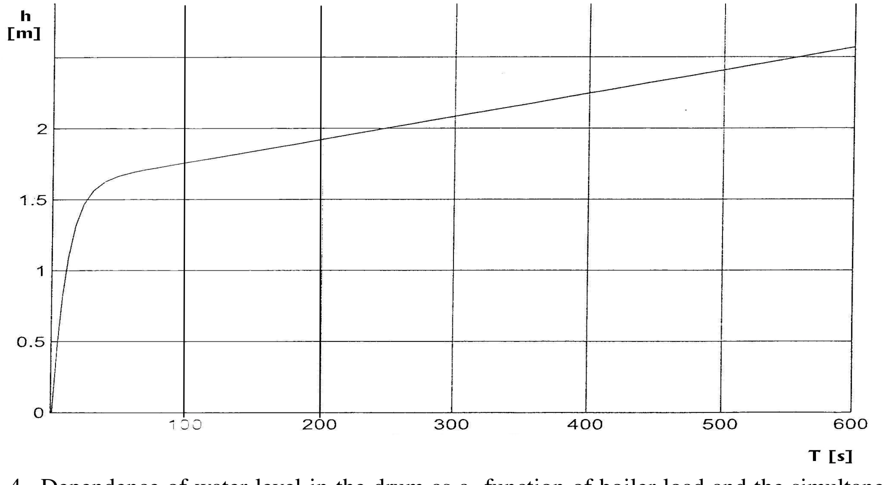

Fig. 4. Dependence of water level in the drum as a function of boiler load and the simultaneous water inflow in relation to time

Detailed description of the model is presented in [2].

4. Mathematical model of water reservoir

On the constructed laboratory stand, the boiler drum will be substituted by water reservoir and vapour consumption will be simulated by a water basin. The water reservoir should have a similar transfer function and the characteristics of the real object.

The mathematical model of water reservoir is given in [6]. This model is used for formulating the following transfer function based on the Laplace transform:

$$\frac{x(s)}{y(s)} = \frac{k}{T \cdot s + 1} \tag{4}$$

This transfer function form indicates that it is an inertial element of the I[st] order. Using a SIMULINK toolbox and data from [2], the system with the water reservoir is checked. Gain *k = 1.8* and the inertial constant *T = 46.64* are fixed. The block diagram of water container model is presented in Fig.5.

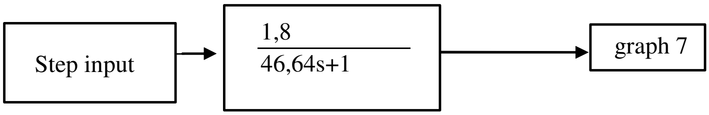

Fig. 5. Block diagram of water container model

Graph 7 presents the changes of water level in time (Fig. 6). The mathematical model of the water reservoir is close to the mathematical model of the boiler (comparison of Graph 6 and 7), but it is impossible to obtain identical characteristics because of the different working medium in both systems.

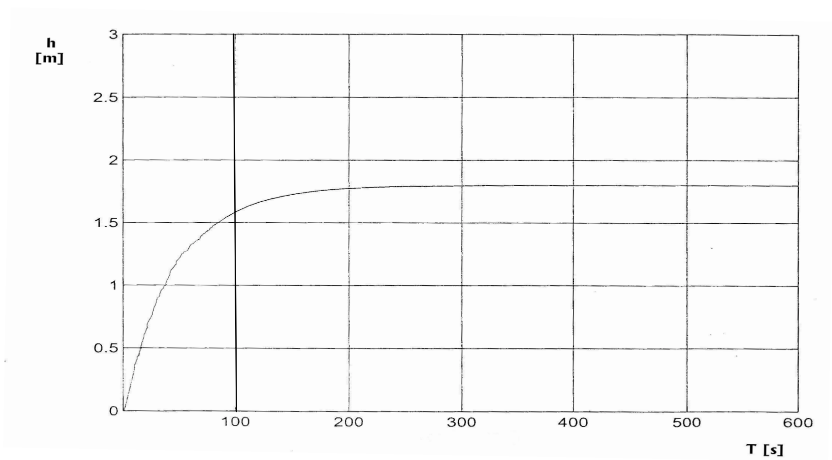

Fig. 6. Changes of water level in time

Conclusions

A laboratory stand for the simulation of boiler operation was constructed for didactic demonstration. During the laboratory lectures, it will be possible for students to get acquainted with boiler construction and an automatic control system.

Water inflow and firing processes are automatic. During the operation of the boiler, the water level in the drum is automatically controlled according to vapour consumption. When substituting the boiler with a water reservoir, and vapour consumption with a water basin, it is impossible to precisely simulate the real process; however, for didactic demonstration of feed-water regulation, the proposed solution is satisfactory.

Bibliography

1. Kasprzyk G.: The project of adaptation of laboratory stand with VX boiler in simulation condition work. (in Polish).Praca dyplomowa nr 8/95, Politechnika Szczecińska, Szczecin 1995.
2. Łozowicka D.: The project of adaptation of the VX boiler for laboratory stand of marine engine room simulator (in Polish). Praca dyplomowa nr 12/97, Politechnika Szczecińska, Szczecin 1997.
3. Perepeczko A.: Marine vapour boilers (in Polish). Wydawnictwo Morskie, Gdańska 1979.
4. Takahashi Y.: Rabins M.J., Auslander D.M., Controlling and dynamic systems (in Polish), Wydawnictwo Naukowo Techniczne, Warszawa 1976.
5. Findeisen W.: Technique of automatic regulation (in Polish), Państwowe Wydawnictwo Naukowe PWN, Warszawa 1965.
6. Thomas Y.: Larminat P., Automatic control- linear systems (in Polish). Wydawnictwo Naukowo Techniczne, Warszawa 1983.

Recenzent:
Janusz BADUR

Adaptacja kotła okrętowego do stanowiska laboratoryjnego symulowanych warunków pracy

Słowa kluczowe

Kotły okrętowe, symulacje, modelowanie matematyczne.

Streszczenie

W pracy zaprezentowany został projekt utworzenia stanowiska do symulacji pracy kotła bez konieczności jego uruchamiania. Proponuje się zastąpienie walczaka kotła przez zbiornik wodny. W oparciu o charakterystyki kotła oraz zbiornika wodnego przeprowadzono analizę, w jaki sposób możliwe będzie przedstawienie rzeczywistych procesów występujących w kotle na projektowanym stanowisku laboratoryjnym.