AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

IMPROVING THE CONTROL SYSTEMS OF A 1/2 TON CAPACITY BOILER

مكتبة

By

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رسالة

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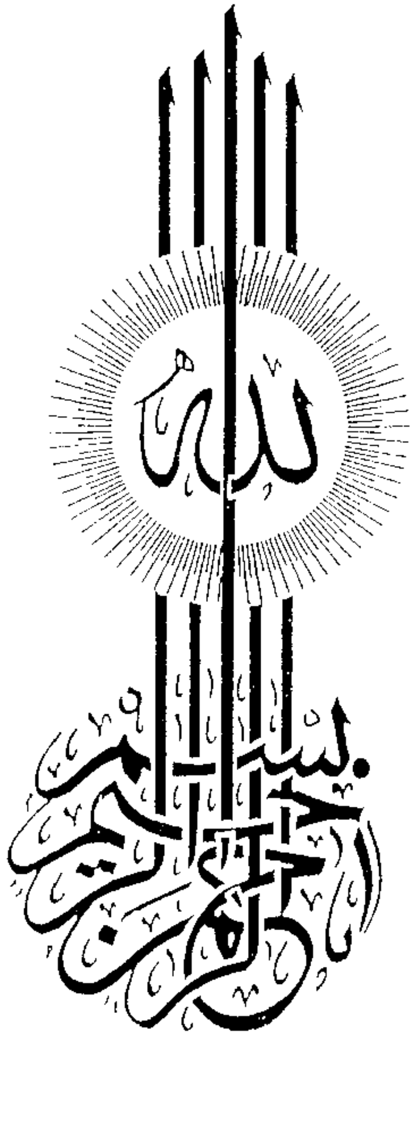

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STATEMENT

This dissertation is submitted to Ain Shams University for the degree of master in mechanical engineering.

The work included in this thesis was carried out by the author in the Department of Energy and Automotive Engineering, Ain Shams University, from 1986 to 1991.

No part of this thesis has been submitted for a degree or a qualification at any other University or Institution.

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ABSTRACT

In the present work, a modulated bang-bang control system has been developed and implemented on a fire tube boiler of half ton capacity. The system uses a pressure controller that has been developed to replace the existing pressure controller, without changing the elements of the firing system or the controller of the burner of the boiler. As a result of implementing such a control system, the dynamic performance of the boiler has been improved.

A configuration for the proposed pressure controller has been suggested. A functional block diagram for the proposed controller has been laid out. On the basis of the functional block diagram, a mathematical model for the proposed controller has been developed and investigated. As a result of the investigation, the proposed controller has been constructed and tested.

In order to identify the dynamic characteristics of the boiler, within the developed control system, a mathematical model for the boiler has been obtained by both The mathematical modelling and the experimental identification. In the theoretical modelling of the boiler, a non-linear mathematical model is obtained from the first principles and is solved using numerical methods. Then a linearized model for the boiler is obtained using standard linearization techniques.

The experimental identification of the boiler is based on the step-response technique. Therefore, a data acquisition and measurements system is used to acquire and record the measurements of the experimental tests that carried out on the boiler. The measurements system which is an advanced micro-processor based measurements system has sensors and transducers installed on the boiler. These sensors and transducers are interfaced to the data acquisition unit of the measurements system, through specially developed signal conditioning circuits. The experimental data of the tests carried out on the boiler are processed using an off-line method of system identification together with the results of the theoretical modelling (linearized model) to get the mathematical model of the boiler.

The developed controller is based on modifying the dynamic characteristics of a well established industrial controller. The proposed modifications of the controller are set to make the modified controller has a bang bang control action with a transfer function of one of the standard controllers. It is proved that the modified controller has a linear mathematical model of a PI controller.

The chosen industrial controller is firstly constructed from commercially available electronic components and tested

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experimentally. The controller was then modified in order to alter its dynamic characteristics as stated above, i.e., make the controller has a bang bang control action with a transfer function of one of the standard controllers. Experimental tests were carried out on the developed controller together with an electric motor similar to that of the burner of the boiler to investigate the effect of changing the parameters of the developed controller on its performance.

Since the developed controller has a linear mathematical model, it is adjusted using one of the known tuning relations. On the basis of the results of the boiler identification, the tunable parameters of the developed controller are adjusted according to an integral criterion.

The developed controller is implemented on the boiler to construct the developed control system of the boiler. Then, the developed control system is tested experimentally to investigate the effect of the disturbances from the make up water and load changes, and the influence of changing of the set-point on the performance of the developed control system.

The existing control system is evaluated by both theoretical analysis and experimental tests to use the results of the evaluation in making a comparison between the existing and the developed control systems. The theoretical analysis includes the investigation of the control indices of the existing control system. The experimental tests are carried out on the existing control system to investigate the effect of disturbances from make up water and load changes on its performance.

A comparison between the performance of the existing and the developed control systems is then presented. The comparison is based on the theoretical analysis and the experimental tests of the two systems. The analytical comparison shows that for the developed control system, pressure is settled to a certain value with no steady state error, while the existing system has an oscillating pressure with large amplitude. Also the developed system has satisfied stability margins while the existing system is critically stable

The comparison of the experimental tests of the two systems shows that the developed control system has a very small variations in the pressure under the influence of load changes, while the existing system has large variations in the pressure even there is no changes in the load on the boiler.

Finally it is concluded that the developed control system improves the dynamic performance of the boiler by making the boiler more stable and limiting the variations in the pressure under load changes in a narrow range.

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INTRODUCTION

Fire tube boilers are predominately of simple and sturdy construction and are relatively inexpensive (low initial capital cost). Thus these boilers become the corner stone in many industrial processes in modern industries. The fire tube boilers are greatly used for processing as in case of industrial processes like sizing and bleaching in textile industry, drying up and canning in food industry, and cleaning and pressing in laundries, or for heating as in case of heating oil for transporting and refining in oil industry, and heating installation for buildings. In these applications, the fire tube boiler is used either as a steam generator (generating steam), or as a hot water producer (heating water).

The fire tube boilers, or the boilers in general, are classified mainly according to the use; boilers are stationary or mobile, the furnace position; boilers either are externally fired or internally fired, and the fuel; boilers are oil fired, gas fired, or coal fired. There are two general configurations of the fire tube boilers. The first, the horizontal return tubular boiler, which consists of a shell (drum) suspended above an external furnace. The second, known as the scotch type, is an internal furnace boiler and is considered as a self contained boiler. Most fire tube boilers are designed to utilize a multi-pass arrangement for the combustion gases to promote maximum heat transfer, but the four-pass is currently the practical limit. There are two designs for returning the fire tube passes, the first is the dryback design, in which the reversing chamber is extending the entire shell diameter, and the second is the wetback design which has the reversing chamber surrounded by the boiler water.

The fire tube boilers are limited to generate either hot water or saturated steam only, since steam and water are contained in a single shell. The practical upper limit on operating pressure for standard fire tube boilers is 18 bar and capacity 11,500 kg of steam per hour. But it is common to fined fire tube boilers with capacities less than 7000 kg per hour. The steaming rate is about 15 to 20 kg of steam per sq meter of heating surface per hour in the horizontal return tubular type, and is about 20 to 25 kg per sq meter of heating surface per hour in the scotch type. The efficiency of the fire tube boiler depends mainly on the fuel type and the number of basses of the fire tubes; as example for three-pass, oil fired boilers, the efficiency is about 78% or better.

The primary requirements of the fire tube boilers are that, the steam must be delivered safely at the desired condition as regards its pressure, temperature, and quality; and also, at the required rate. Also, the boiler should rapidly meet the changes in the load.

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In most fire tube boilers, specially oil and gas fired types, the used control system is the on/off type, which can not meet the requirements of the boiler mentioned above. The on/off control system can not keep the pressure variations in a narrow range and makes the boiler pressure affected by the changes in the load. Also, the on/off control system, in most cases is critically stable and that may cause the boiler to go instability.

Therefore, the present work aims to develop a control system for the fire tube boiler, oil or gas fired, and uses the half ton capacity boiler, installed in the steam laboratory, as an application. The purpose of development of this control system is to make the proposed system overcome the disadvantages of the existing one, the on/off control system, with minimum changes in the components of the burner of the boiler.

So, in the present work a modulated bang-bang control system is devised, constructed and implemented on the boiler. The devised control system can keep the variations in the pressure in a narrow range, and make the boiler more stable, by quenching the limit cycles in the output pressure.

So, chapter [1] is devoted to survey the various types of controllers that have a bang-bang control action. Chapter [2] is devoted to boiler identification to be used in identifying the dynamic characteristics of the boiler in the proposed control system. The mathematical model of the boiler has been investigated by both theoretical modelling and experimental identification. In the theoretical modelling of the boiler a nonlinear mathematical model has been obtained. Then the linearized model of the boiler was investigated. The experimental identification is obtained from the step-response technique, using an advanced micro-processor based measurements system to carry out all necessary tests.

In chapter [3] a configuration of the proposed pressure controller has been suggested. The proposed controller was then modified to have a bang bang control action and a transfer function of one of the standard controllers. Then the mathematical model of the modified controller has been developed. The developed pressure controller was tested experimentally.

In chapter [4] the developed pressure controller was implemented on the boiler to build the developed control system of the boiler. Then the developed control system was analysed and tested experimentally.

The existing control system of the boiler was evaluated by analytical analysis and experimental tests in chapter [5] for the purpose of comparison between the developed and the existing systems.

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In chapter [6], a comparison between the performance of the developed and the existing control systems has been investigated on the basis of the analytical analysis and the results of the experimental tests of the two systems.

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CHAPTER ONE

SURVEY OF THE PREVIOUS WORK

INTRODUCTION

From a historical view, the early well-defined feedback control, is the James Watts's flyball governor developed in 1788. But, the general application of feedback control began to appear in the late 1920's and early 1930's. A significant date in the history of automatic feedback control systems is 1934, when the first general theory of automatic control was published. In 1950, with the discovery of the root-locus method by Evans, the development of linear control theory for single-input, single-output time-invariant systems was essentially complete.

Analytical techniques for nonlinear control systems, however, were in their infancy before 1950. Only the phase-plane method, suitable for analysing second-order systems, was available. Around 1950, the describing function method which is easily applicable to closed-loop systems was developed. Also around 1950, Tsypkin in the soviet Union and Hamel in France managed to develop the theory of relay control (on-off control) systems to a significant degree of completeness.

In class of Fire Tube Boilers, the relay control systems are of widespread usage. Since, the relay as a power element, is simple and rugged and is capable of applying full power to a plant in a short time. For this reason, a well-designed relay system often possesses optimum manifestations in achieving fast response time.

The disadvantage of the relay system is that when the goal of control is nearly reached (i.e. when the output and the input nearly correspond in a follow-up system) the relay tends to chatter. Also, the output of the relay systems is characterized by the existance of large fluctuations due to limit cycles.

In developing the control system of the Fire Tube Boiler, the main requirement is that the controller must has a bang-bang control action. Thus, a survey for various types of nonlinear control systems, which have a bang-bang control action, is presented. Then, the analysis and the applications of these control systems will be given.

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