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A simple non-linear drum boiler model

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This note gives an improved version of a previously published model for a drum boiler.

1. Introduction

A simple model for a drum boiler was presented by Åström and Eklund (1972). The model describes the response in output power due to variations in three inputs, fuel flow, feed-water flow and steam-valve position. The model has only one state variable which accounts for the major energy storage. The model of Åström and Eklund (1972) has been validated by experiments on a 160 MW plant. This model required five parameters. In this paper an improved model is given. The model has a better physical interpretation and can be described by four parameters only.

2. Analysis

It is assumed that the reader is familiar with the paper of Åström and Eklund (1972). Their equation (3.6) is questionable. Since the flow is supersonic, the mass flow would be a linear function of pressure and not a square root function. The measurements given in Fig. 10 do, however, support the equation. This is due to the fact that the gauge used was not compensated for steam pressure. This can be seen as follows.

The mass flow is given by

$$w = A\sqrt{(\Delta p \cdot \rho)}$$

where Δp is the pressure drop and ρ the gas density. Assuming an ideal gas, we get

$$\rho = \frac{p}{nRT}$$

Hence

$$\omega = A\sqrt{[\Delta p \cdot p/(nRT)]}$$

To obtain a flow measurement it is thus necessary to measure both the pressure drop Δp, the absolute pressure and the temperature. In the particular case the gas temperature is constant. To simplify the construction of the gauge it is frequently assumed that p is also constant. The estimate of the mass flow is then

$$\hat{w} = A\sqrt{[\Delta p \cdot p_0/(RT_0)]} = w\sqrt{[p_0 \cdot /p\psi]}$$

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If the true mass flow is a linear function of pressure, the actual gauge reading then becomes a square root function as is shown in Fig. 10 of Åström and Eklund (1972). In the particular case it has been verified that this is indeed the case.

If eqn. (3.6) of Åström and Eklund (1972) is replaced by a linear function, the eqn. (3.9) should be changed to

$$P_0 = \alpha_4(u_2 p^{9/8} - \alpha_5)$$

Again making a simple fit to the experimental data we find

$$\alpha_4 = 0{\cdot}6, \quad \alpha_5 = 0$$

The model (5.1) thus becomes

$$\frac{dp}{dt} = -0{\cdot}0018 \,.\, u_2 p^{9/8} + 0{\cdot}02 u_1 - 4{\cdot}4 \times 10^{-4} u_3$$

$$P_0 = 0{\cdot}6 u_2 p^{9/8}$$

The curves in Fig. 12 of Åström and Eklund (1972) will now all go through the origin and they will also be convex.

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Reference

Åström, K. J., and Eklund, K., 1972, *Int. J. Control*, **16**, 145.