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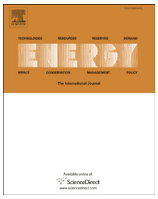

A numerical study of air preheater leakage

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ABSTRACT

The purpose of the research is to quantify direct leakage for a Ljungström air preheater. The leak flow path was assumed to be similar to flow through an orifice and a theoretical approach was used to calculate leakage. A 2D CFD model with a geometry similar to the one considered in the theoretical approach was also developed to calculate leakage. It was noted that for the different leak gaps investigated, the theoretical calculated leakage was always lower than the CFD calculated leakage. This can be attributed to the fact that the leak gap geometry and actual orifice flow geometry are not identical. Using the 2D CFD model, the leak flow was quantified for various seal settings across the operating air temperature range.

An actual air preheater CFD model was also developed. This model was unable to accurately calculate the hot end leak due to inaccurate temperature calculation in the hot end leak gap. After applying a correction factor to the hot end leak, it was possible to determine the direct leakage.

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1. Introduction

Air preheaters are found in most steam generating plants to heat combustion air and enhance the combustion process. In most applications, flue gas serves as the energy source and the air preheater is considered to be a heat trap which collects and transfers heat from the flue gas to incoming air. This process can increase the overall boiler efficiency by 5%–10% [1]. Air preheaters are usually found directly behind the boiler as shown in Fig. 1. In a typical coal fired power plant, the air preheater will receive flue gas from the economizer and combustion air from the FD (Forced Draught) fans. The hot air produced by the air preheater enhances combustion and is required for drying and transportation of fuel in pulverized coal fired boilers [2].

Air preheaters have a general operating fault known as leakage [3]. Leakage occurs when part of one gas stream flowing through a sealing system leaks into the other gas stream. The quantity of leakage is dependent on seal clearance area and static pressure difference between the air and flue gas streams flowing through the air preheater.

1.1. Ljungström air preheater

A regenerative heat exchanger transfers heat indirectly by convection as a heat storage medium is periodically exposed to hot and cold flow streams. Ljungström is the most common type of regenerative air preheaters', it is commonly referred to as a rotating matrix air preheater. Fig. 2 shows a typical arrangement drawing of a Ljungström air preheater.

The air preheater consists of a cylindrical shell and rotor which is packed with bundles of heating surface elements (typically corrugated and undulated plates) which is rotated between counter flowing air and flue gas streams. Bearings in the upper and lower support beams guide the rotor at the central shaft. A typical rotor speed of one to three revolutions per minute is achieved by a motor driven pinion engaging a rotor encircling pin rack. The shaft can either be aligned horizontally or vertically, however the vertical arrangement is more common [2].

In the vertical shaft arrangement as shown in Fig. 2, hot flue gas enters from the top and cold air enters from the bottom. In

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List of symbols

Symbol	Description
β	orifice diameter ratio
μ	dynamic viscosity, Pa·s
ρ	density, kg/m^3
A	cross sectional area, m^2
C_d	orifice coefficient
D_h	hydraulic diameter, m
f	Fanning friction factor
h	specific enthalpy, kJ/kg
k_{exp}	expansibility factor
L	characteristic length, m
$\dot{m}$	mass flow rate, kg/s
p	pressure, Pa
q	heat transfer rate, W
Re	Reynolds number
T	temperature, °C
t	time, s
$\vec{V}$	velocity field
v	velocity, m/s
X	correction factor
Z	number of radial seals under the sector plate
$\langle O_2 \rangle_{\dot{m}}$	oxygen content weighted by mass flow, %

Subscripts

Subscript	Description
APH	air preheater
fg	flue gas
in	inlet
out	outlet

such a flow arrangement, the hot end is at the top, and the cold end is at the bottom. During operation, the rotor experiences a temperature differential between the hot and cold ends causing the rotor to expand and distort. This distortion creates gaps between moving and stationary parts allowing air to leak into the flue gas stream. The leak gap exists even without rotor distortion however under operating conditions the gap increases. Air to flue gas leakage can be minimised by cold presetting axial and radial seal plates to minimise gaps in the hot operating condition [2].

1.2. Leakage

Air flow leaking from the air stream to the flue gas stream is referred to as leakage. It can be reported in kilograms per seconds (kg/s), but can also be expressed as a percentage of the flue gas inlet flow. Leakage is undesirable because it represents fan power which has been wasted in transporting air which bypasses the combustion zone. Leakage also has the potential to reduce an air preheater's thermal performance.

For a Ljungström air preheater, leakage can be categorized as direct and entrained. Direct leakage occurs when higher pressure air leaks into the lower pressure flue gas stream through gaps between the rotating and stationary parts.

This leakage path is usually formed when the radial seals pass under the radial sealing plate or sector plate in a Ljungström air preheater. Fig. 3 shows the typical sealing system of a Ljungström air preheater.

Entrained leakage can be described as being a result of the rotation of the matrix from one stream to the next [4]. Air is carried into the flue gas stream as the heating surface components or baskets are rotated from the air stream to the flue gas stream. This

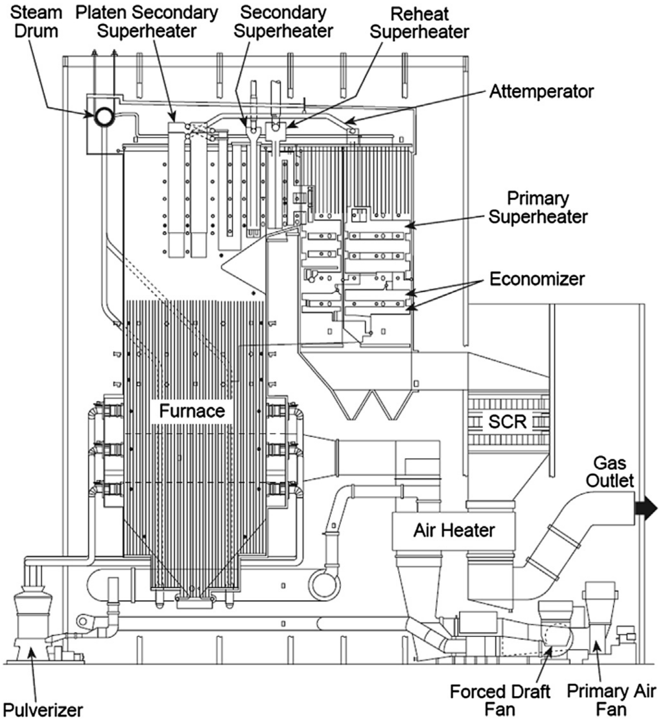

Fig. 1. A typical coal fired boiler showing the position of the air preheater [2].

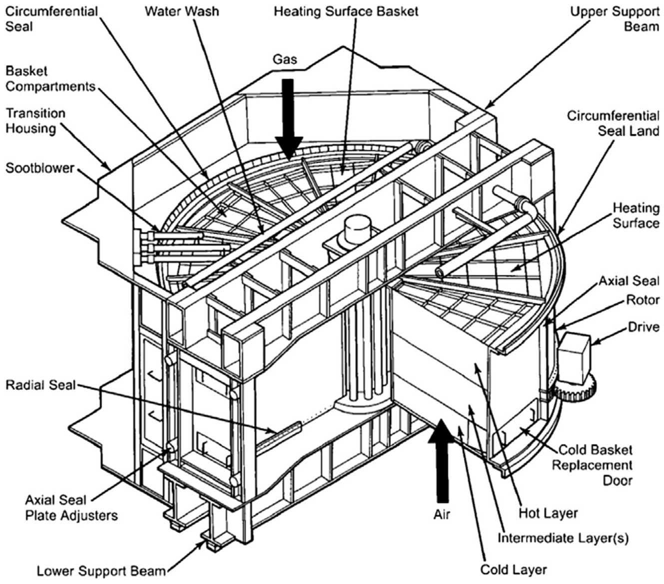

Fig. 2. Vertical shaft Ljungström type air preheater [2].

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