Sudan University of Science and Technology
College of Graduate Studies

Study of Pressure drop in Heat Exchangers

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Mechanical Engineering.

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Verse

قال تعالى:

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صــدق اللــه العظيم

سورة طه

Dedication

This research is dedicated to

My parents with great love

My friends

And my colleagues

Eng. Amir AbuBakr

Abstract

Heat exchangers are frequently used in industry especially in steam and gas turbines power plants, as air pre-heaters or economizers and the like. These are mainly used to recover part of the thermal energy in exhaust and flue gases.

The measure of performance of these equipments is usually given as a heat ratio which is a measure of the heat recovered from the exhaust. Heat exchangers suffer from pressure losses due to the resistance to fluid flow through the passages on both sides of the exchanger. The pressure drop means in most cases, a loss in the useful work output.

In this research the investigation concentrates on the thermal ratio and the pressure drop in heat exchangers applied in existing power stations. Three of the largest power stations in Sudan are examined: namely:

i. Khartoum Refinery Company (at Elgili).
ii. Khartoum North Thermal Power Station.
iii. Kenana Sugar Factory.

Temperatures and pressures were measured and calculations were carried out and the results were presented, and discussed.

Kern methods for calculating the pressure drop were examined using data obtained from unit (2) phase (I) in Khartoum North thermal power station.

The results obtained revealed that:

a) The thermal ratio of heat exchangers, in addition to their dependence on the thermal properties of the material from which they are made,

was affected by the method of design and the inlet conditions. The results of the tests showed that for the shell and tube type of heat exchanger used in Kenana Sugar Factory, the thermal ratio was 0.52 while it was about 0.777 for the rotary heat exchanger used in Khartoum North thermal power station, phase (II) unit (4).

b) The least pressure drop amounting to about (190 pa) i.e. about 1.6% of the inlet pressure, when using bar heaters as in Khartoum Refinery Company, and the highest pressure drop was (1830 pa) i.e. about 7.7% of the inlet pressure drop, when using Rotary heat exchangers, as in phase (II) unit (4) of Khartoum North thermal power station.

الخلاصة

المبادّلات الحرارية تستخدم كثيرا في الصناعة خاصةً فـي محطـات القدرة الغازية والبخارية، كما في سـخانات الهـواء قبـل الاحـتراق ووحـدات الاقتصاد وما شابه، هذا بشكل رئيسي تستعمل لاستعادة جـزء مـن الطاقـة الحرارية في غازات المدخن والعادم.

قياس الأداء لهذه الأجهزة عادة يقـدر بالنسـبة الحراريـة الـتي تحـدد للمبـادّل الحـراري كميـة الحـرارة المسـتعادة مـن العـادم. لكـن المبـادّلات الحرارية يصاحبها هبوط الضغط بسبب المقاومة إلتي تعـوق تـدفق المـوائع خلال الممرات على جانبي المبـادّل. هبـوط الضـغط ،تقريبـاً فـي كـثير مـن الحالات يقلل من ناتج الشغل المستفاد.

في هذا البحث، يركّز التحقيق على النسبة الحرارية وهبـوط الضـغط في المبادّلات الحراريـة المسـتخدمة فـي ثلاث مـن محطـات القـدرة فـي السودان وهي:

i. شركة مصفاة الخرطوم (ألجيلي).

ii. محطة توليد الخرطوم بحري الحرارية.

iii. مصنع سكّر كنانة.

لقد تم قياس وحساب درجات الحرارة والضـغوط ، و عرضـت النتـائج. ثـم استعملت طريقة (Kern) لحساب هبوط الضغط باستعمال القـراءات الـتي تم الحصول عليها من الوحدة (2) المرحلة (II) في محطة الخرطوم بحـري الحرارية.

جملة النتائج التي حصلت هي:

أ). النسـبة الحراريـة للمبـادّلات الحراريـة، بالإضـافة إلـى اعتمادهـا علـى الخواص الحرارية للمواد التي صنعت منها، تتأثّر بالشكل التصـميمي وحالـة المـوائع عنـد المـدخل. إنّ نتـائج الاختبـارات أعطـت للمبـادل الحـراري ذو الأنبوب والغلاف من المبادّلات الحرارية المستعملة في مصنع سـكّر كنانـة، النسـبة الحراريـة حـوالي 0.52 ، بينمـا حـوالي 0.777 للمبـادّل الحـراري

الدوّار المستعمل في محطة توليد الخرطوم بحري الحراريـة، المرحلـة (II) الوحدة (4).

ب).حيث بلغ أقل هبـوط للضـغط حـوالي (190باسـكال)أي بنسـبة حـوالي 1.6% من قيمة الضغط عند المدخل، وذلك عند استعمال مبادلات القضبان الحرارية كما في شركة مصفاة الخرطـوم،بينمـا يلـغ أعلـى هبـوط للضـغط حوالي (1830باسكال)أي بنسبة حوالي 7.7% من قيمة هبوط ضـغط عنـد المدخل، وذلك عند إستعمال المبادّل الحراري الدوّار، كما في المرحلة (II) وحدة (4) في محطة توليد الخرطوم بحري الحرارية.

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Nomenclature

Symbol	Quantity	Coherent SI Unit
ΔP	Total pressure drop	$N/m^2 = kg/(m.s^2)$
D	Tube inside diameter	m
U	The main velocity	m/s
u	Velocity, velocity component	m/s
P	Pressure	$N/m^2 = kg/(m.s^2)$
P	Tube pitch	m
A	Surface area	m^2
S	Cross-sectional area	m^2
r_o	Outer tube radius	m
f_o	Friction factor	--
D_h	Hydraulic diameter	m
η	Viscosity	$(N.s)/m^2 = kg/(m.s)$
λ	Thermal conductivity	W/(m.K) = $(kg.m)/s^3.K)$
t	Thickness	m
ρ	Density	kg/m^3
K_a	Inlet factor	--
V_{max}	Maxim. fluid velocity between tubes	m/s
α	Overall heat transfer coefficient	$W/(m^2.K)$
η_w	Water viscosity	$(N.s)/m^2 = kg/(m.s)$

ΔT_{LM}	Logarithmic mean temperature difference	K
ΔT	Temperature difference	K
δ	Boundary layer thickness	m
δ	Thickness, liquid film thickness	m
ΔP_s	Shell side pressure drop	$N/m^2 = kg/(m.s^2)$
C_p	Specific heat capacity at constant pressure	$J/(kg.K) = m^2/(s^2.K)$
m	Mass flux (mass velocity)	$kg/(m^2.s)$
M	Mass flow rate	kg/s
n_r	Number of tubes in rows	--
ΔP_c	Cross – flow pressure drop	$N/m^2 = kg/(m.s^2)$
n_t	Number of tubes in column	--
C'	Tube clearance	m
N	Number of baffle plate	--
N_T	Number of tubes	--
D_e	Equivalent diameter	m
D_s	Shell inside diameter	m
S_s	Factor	--
L_b	The baffle spacing	m
P_T	Tube pitch	m
L_B	The distance between baffles	m
ΔP_w	The windows zone pressure drop	$N/m^2 = kg/(m.s^2)$
S_m	Flow area near the center	m^2
D_{OTL}	The tube bundle diameter	m
L_c	The baffle cut distance	m
S_{sb}	Shell-to baffle leakage area	m^2
S_{st}	Tube-to baffle leakage area	m^2
δ_{st}	The radial clearance between tube and baffle	m
δ_{sb}	The radial clearance between shell and baffle	m
N_c	Number of cross rows	--
S_w	Window flow area	m^2

P_{TP}	Spacing between tube rows in flow direction	m
D_w	Equivalent diameter in windows zone	m
R_B	Correction factor for the influence of bypass	--
R_L	Correction factor for the influence of leakage	--
N_{cw}	Number of effective cross-flow rows in window zone	--

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