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A compression process model with integral equations for the scroll mechanism in a scroll compressor

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ABSTRACT

The work of a scroll compressor is performed by its scroll mechanism. In this paper, the coefficient of compression chambers of the scroll mechanism is defined. Based on energy counting system of the scroll compressor, the working process of a scroll compression chamber is analyzed and the compression process of the scroll mechanism in its working period is expressed by that of one scroll compression chamber. Thereafter, a compression process model with integral equations for the scroll mechanism is developed. The developed model uses the real working conditions (such as the suction and discharge temperatures, suction and discharge pressures, and flow rate) as the initial and supplementary conditions. The compression process model for the scroll mechanism in an air scroll compressor, as a case study, shows that the developed model can describe the compression process and predicate the volumetric efficiency and compression efficiency of the scroll mechanism well.

Un modèle de procédé de compression avec équations intégrales pour le mécanisme de spirale dans un compresseur du même nom

Mots clés : Compresseur à spirale ; Procédé ; Energie ; Modéle

1. Introduction

Nowadays, scroll machines have been widely used as the compressors in various applications such as air compression, air conditioning, refrigeration, vacuum equipment, and heat pump. Among the inherent characteristics of a scroll compressor, its high efficiency is attracting more interest from researchers. The efficiency study of the scroll compressor is based on the compression process and various losses.

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Nomenclature

c_{gp}	Specific heat of working gas at constant pressure ($J\cdot(g\ K)^{-1}$)
c_{ov}	Specific heat of lubricating oil at constant volume ($J\cdot(g\cdot K)^{-1}$)
f_p	Ideal pressure function under adiabatic compression process
f_T	Ideal temperature function under adiabatic compression process
F_τ	Tangential gas force (N)
H	Height of scroll wrap (mm)
k_c	Coefficient of compression chamber pairs for the scroll mechanism
k_l	Gas leakage coefficient
k_T	Modification coefficient of temperature
L_{fr}	Distances from the tangential force's action point to the centers of the fixed scroll (mm)
L_{or}	Distances from the tangential force's action point to the centers of the orbiting scroll (mm)
L_r	Length of the line segment between two apexes of the scroll compression chamber (mm)
m_{cg}	Mass of the working gas in the scroll chamber (g)
m_{co}	Mass of lubricating oil in the scroll chamber (g)
m_g	Gas mass in suction chamber (g)
m_{gs}	Suction gas mass of suction scroll chamber (g)
$m_{in,cg}$	Gas mass leakage in scroll chamber (g)
$m_{lr,in}$	Mass of radial leakage in scroll chamber (g)
$m_{lr,out}$	Mass of radial leakage out scroll chamber (g)
$m_{l\tau,in}$	Mass of tangential leakage in scroll chamber (g)
$m_{l\tau,out}$	Mass of tangential leakage out scroll chamber (g)
m_o	Suction oil mass of the scroll chamber (g)
$m_{out,cg}$	Gas mass leakage out scroll chamber (g)
m_s	Fluid mass in suction scroll chamber (g)
m_{sl}	Leakage gas mass (g)
M_{dW}	Theoretical driving moment of scroll mechanism ($N\cdot mm$)
$M_{\tau do}$	Equivalent driving moment of the orbiting scroll ($N\cdot mm$)
n	Adiabatic exponent of air
N	Number of living scroll compression chamber pairs
n_w	Speed of the scroll compressor ($r\cdot min^{-1}$)
p_{cg}	Gas pressure of scroll chamber (MPa)
p_{cid}	Ideal pressure of scroll chamber (MPa)
p_d	Discharge pressure of compressor (MPa)
p_{did}	Ideal discharge pressure of compressor (MPa)
p_{down}	Pressure of downstream scroll chamber (MPa)
P_{dW}	Theoretical driving power of the scroll mechanism (Kw)
p_{in}	Pressure of inner profile of scroll chamber (MPa)
p_{out}	Pressure of outer profile of scroll chamber (MPa)
p_s	Suction pressure of compressor (MPa)
P_{sc}	Power obtained by the working gas (Kw)
P_{scd}	Theoretical input power of the scroll mechanism (Kw)
p_{up}	Pressure of upstream scroll chamber (MPa)
q_{gv}	Mean volume rate of suction gas ($L\cdot min^{-1}$)
q_{ov}	Volume flow rate of lubricating oil ($L\cdot min^{-1}$)
R_b	Radius of base circle (mm)
R_d	Radius of modification arc for the inner profile (mm)
R_{or}	Orbiting radius of the orbiting scroll (mm)
R_s	Radius of modification arc for the outer profile (mm)
$S_{inv,in}$	Area enclosed by the base circle and inner involute profile (mm^2)
$S_{inv,out}$	Area enclosed by the base circle and outer involute profile (mm^2)
t_ω	Working period of the scroll mechanism (s)
t, t^*	Time (s)
t_c	Working period of a scroll chamber (s)
T_{cg}	Gas temperature in scroll chamber (K)
T_{cid}	Ideal gas temperature in scroll chamber (K)
T_d	Discharge temperature of compressor (K)
t_M	Starting time that the modification profile form a scroll chamber (s)
T_o	Temperature of lubricating oil (K)
T_{od}	Discharge temperature of lubricating oil (K)
T_{os}	Suction temperature of lubricating oil (K)
T_s	Suction temperature of compressor (K)
V_c	Volume of the scroll compression chamber (mm^3)
V_{cg}	Gas volume of the scroll compression chamber (mm^3)
V_g	Suction gas volume of scroll mechanism (mm^3)
V_{gs}	Suction gas volume of suction chamber (mm^3)
V_o	Suction oil volume of suction chamber (mm^3)
V_s	Suction chamber volume of scroll mechanism (mm^3)
V_{sl}	Gas volume leakage in suction chamber (mm^3)
$W_{\Sigma dw}$	Total work done by the scroll mechanism (J)
$W_{\Sigma g}$	Total working gas energy variation in the scroll mechanism (J)
$W_{\Sigma h}$	Total work loss in the scroll mechanism (J)
$W_{\Sigma o}$	Total lubricating oil energy variation in the scroll mechanism (J)
W_{dW}	Work of a scroll chamber done by the scroll mechanism (J)
W_l	Energy loss of a scroll chamber (J)
ΔW_{cg}	Energy variation of working gas of a scroll chamber (J)
ΔW_o	Energy variation of lubricating oil of a scroll chamber (J)

Greek letters

β	Modification involute angle of scroll wrap (rad)
ϕ	Involute angle of scroll profile (rad)
ϕ_E	Ending involute-angle of scroll profile (rad)
ϕ_M	Modification involute-angle of scroll profile (rad)
ϕ_{s0}	Initial involute-angle of scroll profile (rad)
η_{scm}	Compression efficiency
η_{sv}	Volumetric efficiency
λ	Center angle of modification arc (rad)
ρ_g	Density of the working gas ($g\cdot mm^{-3}$)
ρ_o	Density of the lubricating oil ($g\cdot mm^{-3}$)
φ	Normal angle of scroll profile (rad)