IFAS

Lecture Notes

Fundamentals of

Fluid Power

Part 2: Pneumatics

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Formula Symbols

Abbrev.	Description	Unit
τ	shear stress	N mm^{-2}
Ψ	discharge function	-
$\overline{\Psi}$	saturation level	-
A	area, piston area, flow cross section	cm^2
b	width	m
b	critical pressure ratio	-
b_{tot}	critical total pressure ratio	-
C	conductance	Nl (s bar)$^{-1}$
c_F	spring stiffness	N m^{-1}
C_{tot}	total conductance	Nl (s bar)$^{-1}$
c_{air}	spring stiffness of air	N m^{-1}
c_p	specific heat capacity at constant pressure	N m kg^{-1} K^{-1}
c_v	specific heat capacity at constant volume	N m kg^{-1} K^{-1}
D, d	diameter	m
$d_{friction}$	coefficient of Newtonian friction	Ns m^{-1}
E	bulk modulus	N m^{-2}; bar
E_a	external energy	N m
e_a	specific external energy	N m kg^{-1}
E_{air}	bulk modulus of air	N mm^{-2}
E_{oil}	bulk modulus of oil	N mm^{-2}
F	force	N
F_{spring}	spring force	N
F_{load}	load force	N
f_P	pulse frequency	Hz
$F_{friction}$	friction force	N
g	gravity acceleration	m s^{-2}
h	height	m
h	specific enthalpy	N m kg^{-1}
H	Enthalpy	N m
$I_{control}$	electric current of controller	A
l	length	m
m	mass	kg
m_{out}	exiting mass	kg
m_D	mass of steam	kg

m_{in}	incoming mass	kg
m_L	mass of air	kg
M_{load}	load torque	Nm
M_{Pnmot}	torque of pneumatic motor	Nm
n	polytropic index	-
n_{Pnmot}	rotational speed of pneumatic motor	s^{-1}
p	pressure	$N\ m^{-2}$; bar
p_0	technical standard pressure	bar
p_{out}	pressure of exiting flow	bar
$P_{exhaust}$	power of exhaust air	W
$p_{operation}$	operational pressure	bar
p_C	critical pressure	bar
p_{vap}	vapour pressure	bar
Δp_{nozzle}	pressure drop over nozzle	bar
P_{peak}	peak power	W
P_{supply}	pneumatic supply power	W
$P_{el.tot.}$	required electric performance	W
p_{air}	air pressure	bar
$p_{measure}$	measured pressure	bar
p_N	pressure at physical standard condition	bar
p_R	scaled pressure	bar
p_{ref}	reference pressure	bar
$\Delta p_{friction}$	pressure difference equivalent to friction force	bar
p_S	saturation vapour pressure	bar
P_t	technical power	W
$P_{compressor}$	provided pneumatic power of compressor	W
Δp_{he}	pressure caused by heat exchange	bar
p_{in}	pressure of incoming flow	bar
P_{cyl}	power output of cylinder	W
Q	volume flow rate	$m^3\ s^{-1}$; $l\ min^{-1}$
Q_0	volume flow rate at standard condition	$Nl\ min^{-1}$
Q_{12}	heat	J
q_{12}	specific heat	$J\ kg^{-1}$
$Q_{suction}$	sucked in volume flow rate	$l\ min^{-1}$
Q_{out}	exiting volume flow rate	$l\ min^{-1}$
$Q_{operation}$	volume flow rate of compressor at operating pressure	$l\ min^{-1}$
Q_{in}	incoming volume flow rate	$l\ min^{-1}$

$Q_{deliver}$	volume flow rate of compressor	l min^{-1}
$Q_{measure}$	measured volume flow rate	l min^{-1}
Q_N	volume flow rate at standard condition	Nl min^{-1}
Q_S	volume flow rate of supply	l min^{-1}
R	gas constant	N m kg^{-1} K^{-1}
R_0	gas constant at technical standard condition	N m kg^{-1} K^{-1}
R_D	gas constant of steam	N m kg^{-1} K^{-1}
Re	Reynolds number	-
R_L	gas constant of air	N m kg^{-1} K^{-1}
R_N	gas constant at physical standard condition	N m kg^{-1} K^{-1}
s	displacement	m
S_R	control signal	-
T	temperature	K
t	time	s
T_0	technical standard temperature	K
T_{out}	temperature of outlet flow	K
$T_{exhaust}$	exhaust air temperature	K
T_C	critical temperature	K
t_E	pulse width	s
T_{supply}	supply air temperature	K
T_{crit}	critical temperature	K
T_{cool}	inlet temperature of cooling water	K
T_{meas}	measured temperature	K
T_N	temperature at physical standard condition	K
T_P	period, cycle time	s
T_R	scaled temperature	K
T_{ref}	reference temperature	K
T_{in}	temperature of incoming mass	k
U	internal energy	J
u	flow rate	m s^{-1}
u	specific internal energy	N m kg^{-1}
U_{actual}	voltage signal of actual value	V
U_{set}	voltage signal of set value	V
v	velocity	m s^{-1}
v	specific volume	m^3 kg^{-1}
V	volume	m^3
v_0	specific volume at technical standard condition	m^3 kg^{-1}

V_0	volume at technical standard condition	m^3
v_{crit}	critical flow velocity	$m\ s^{-1}$
V_{disp}	displacement volume	cm^3
$V_{disp,p}$	displacement volume of piston motor	cm^3
$V_{disp,v,2con}$	displacement volume of vane motor	cm^3
$V_{disp,g}$	displacement volume of gear motor	cm^3
W	technical work	J
w	specific technical work	$J\ kg^{-1}$
W_a	external work	J
W_R	friction work	J
w_r	specific friction work	$J\ kg^{-1}$
W_V	volume change work	J
x	piston position	m
x_D	moisture content	-
Z	compressibility factor	-
α	angle	°
α	heat exchange coefficient	$W\ m^{-2}K^{-1}$
α_F	Flow rate coefficient	-
α_C	contraction coefficient	-
γ_{air}	coefficient for air	-
γ_{oil}	coefficient for oil	-
Δp	pressure difference	bar
η	dynamic viscosity	$Ns\ m^{-2}$
η	standard dynamic viscosity	$Ns\ m^{-2}$
η_{pm}	pneumatic-mechanical efficiency	-
$\eta_{compressor}$	efficiency factor of compressor	-
$\eta_{vol.}$	volumetric efficiency factor	-
κ	heat capacity ratio (isentropic expansion factor)	-
ν	kinematic viscosity	$m^2\ s^{-1}$
ρ	density	$kg\ m^{-3}$
ρ_0	density at technical standard condition	$kg\ m^{-3}$
ρ_K	density inside cylinder	$kg\ m^{-3}$
ρ_{air}	density of air	$kg\ m^{-3}$
ρ_N	density at physical standard condition	$kg\ m^{-3}$
φ	relative humidity	-
ω	specific power requirement	$W\ l\ min^{-1}$