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Ideal Specific Work of Rotary Compressors: A New Approach

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Abstract

The paper deals with the analysis of the compression stroke in rotary displacement compressors, following an innovative approach. Both a theoretical study and an experimental activity have been carried out to achieve the results.

The rotary compressors are positive displacement machines in which compression and displacement are affected by the positive action of rotating elements. Currently, these machines are successfully employed in many applications, such as refrigeration, heat pumps and supercharged automotive engines. The first step of the activity presented in this paper has been the analysis (also in terms of bibliographical research) of the well-known theory behind the operation of the rotary compressors, in order to clarify the correct ideal working process. The main finding has been the evaluation that the use of the classical "*pV* representation" to calculate the ideal specific work leads to a numerical error in the result. In order to overcome the miscalculation, the authors have proposed a different representation of the process, introducing a new approach and a consistent model. Starting from the new pV representation, a more detailed equation has been achieved to calculate a more exact value of the ideal specific work. After the theoretical analysis, a test bench has been set up, in order to compare the developed model with experimental data: particularly, the machine object of test has been a scroll compressor. The specific work has been evaluated for the scroll compressor, tested under different working conditions, (for example, at different compression ratios): the values have been successfully compared with the theoretical ones, previously calculated by the new equation.

An optimistic conclusion is represented by the good agreement of the new proposed model with the experimental data, while it is still simple, adaptable, and theoretically strict.

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Keywords: Displacement machines, rotary compressor, scroll compressor, ideal specific work

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Nomenclature

p	Pressure [Pa]	V_c	Inlet volume [cm^3]
T	Temperature [K]	V'_c	Last closed cell volume [cm^3]
h	Specific enthalpy [kJ/kg]	V_m	Discharge volume [cm^3]
V	Volume [m^3]	μ	V_c'/V_m
v	Specific volume [m^3/kg]	M_c	Inlet air mass [kg]
W	Work [kJ]	M_m	Mass inside discharge volume [kg]
w	Specific work [kJ/kg]	k	Isoentropic index
0	Inlet state point	m	Generic politropic index
1	End of internal compression state point	ρ_i	Internal volumetric compression ratio
X	End of iso-choric compression state point	R	Gas constant [kJ/kgK]
2	End of global compression state point	c_p	Iso-baric specific heat capacity [kJ/kgK]
β	Total compression ratio p_2/p_0	c_v	Iso-choric specific heat capacity [kJ/kgK]
β_i	Internal compression ratio p_1/p_0	Cu	Real specific work/Ideal specific work
β_{X2}	p_2/p_X		

1. Introduction

The rotary displacement machines include both rotary types, such as the compressor lobe (roots), employed since the beginning of the Industrial Revolution, and more recently introduced machines, such as the rotary vane compressor, the screw compressor and the orbiting compressor (scroll).

Currently the rotary machines are successfully employed in several fields of mechanics, above all thanks to the research activity, expressed in the following branches:

- Interpretation of machine working [1,2,3,4];
- Study on geometrical issues or on the design of rotor profiles and losses models [5,6,7,8,9];
- Study on the machine behaviour into thermodynamics cycles [10,11,12,13];
- Performance enhancement by cooling the compressor [14,15,16].

All the different rotary machines are characterized by the same distribution system: the rotors discover and intercept ports carved in the stator. So, they all have a design pressure ratio β_i generated by the internal volume reduction (for roots compressors β_i=1).

The compression ratio, required by the application β, may overlap or not with the compression ratio β_i, that the machine is able to build in itself, due to volume change of cells. Some authors [1] show the convenience to operate in the field $\beta \geq \beta_i$, because the compression efficiency decays more slowly than in the field below the nominal compression ratio.

Therefore, the following discussion will refer only to the case $\beta > \beta_i$. In this case, there is a series of three compressions, as it is shown in Fig.1.

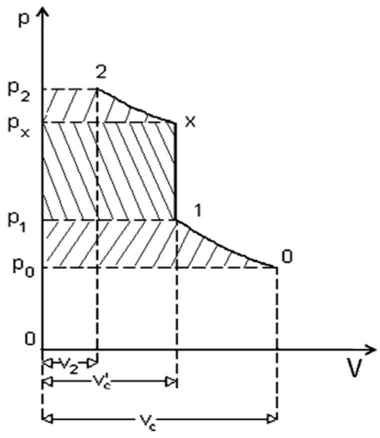

Figure 1

Referring to Fig. 1, in these machines there is a first internal compression (0-1) due to volume reduction. Then, at the opening of the