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Numerical and Experimental Evaluation of the Intake Manifold Layout on Cooling Capacity

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ABSTRACT

Improving cooling capacity of reciprocating compressors and reducing power losses at the suction valve by properly designing the length of the intake manifold is a topic greatly investigated over the past few years. A numerical approach has been chosen to investigate a number of layouts and to evaluate most sensible parameters performing a role in affecting COP. A one–dimensional simulation code resolving Navier-Stokes equations using the Discontinous Galerkin method has been used to investigate the compressor behavior. The interaction between suction valve structure and refrigerant flow has been taken into account as well as the discharge valve one. An experimental verification is done which confirms numerical results. Suction valve motion, pressures within the cylinder and along the suction track have been measured and compared. Suction valve lifts for suction stroke likewise cooling capacity have been confirmed depending on the length of the internal ducts of the intake manifold.
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1. INTRODUCTION

Commonly studies pointing out forecasting skills of numerical codes are presented which are focused on comparing numerical and experimental values of a physical fluid flow property (i.e. pressure) versus time or crank angle in a selected point of refrigerant internal path (Deschamps *et al*., 2002, An *et al.*, 2002, Yoshimura et *al*., 2002).

In this study the feature of the simulation code proposed by Bassi *et al*. (2000) in solving so called incompletely parabolic problems has been verified and has been made the most of it to investigate the behavior of pressure waves within the intake manifold. The incompletely parabolic character comes from the fact that the information concerning fluid properties can travel spatially upstream as well as downstream and only forward in time.

The above mentioned code solves a model describing the whole compressor pump group as a set of volumes and one-dimensional variable-area ducts taking into account also the interaction between the unsteady real gas flow and the automatic valves. Just this feature plays a relevant role being pressure waves in the suction line originated from the motion of the suction valve and then affecting its behavior in such a manner that it is not possible carry out significant results without coping with fluid-structure interaction.

Trying to bring into an household hermetic compressor what is done on automotive engines assigning the suction duct length in order to improve the sucked charge it is not easy because of the size of the appliance and because of the speed of sound. This leads to excessive length for the suction muffler internal duct. It has been judged not worthwhile looking for a beneficial effect of the pressure waves originated during a suction stroke onto the following one. Each single suction valve lift has been regarded instead as a suction stroke then the time between two subsequent valves lifts are sharply reduced. This leads to the feasibility of encase the optimized design within the space usually available within the compressor shell.

2. ANALYSIS METHOD

First a numerical model has been built taking into account the geometry of the whole compressor, the refrigerant inlet and discharge pressure as well as the wall temperature. The refrigerant circuit is reduced as summarized in Figure 2-1 where volumes are denoted with symbols V and ducts with symbols T respectively. Initially the model has been designed to describe the current situation of a datum compressor.

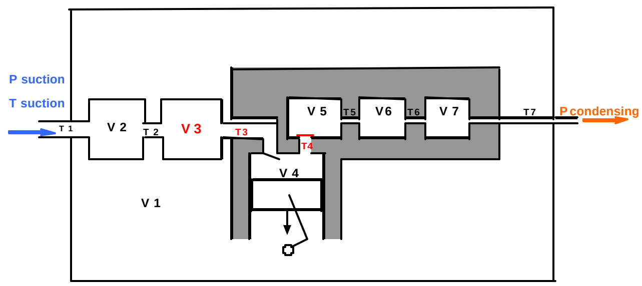

Figure 2-1: Geometrical scheme of the compressor

Numerical results have been compared with experimental results from a set up equipped with pressure transducers, thermocouples and a system to reveal the opening of suction and discharge valve versus the crank angle.

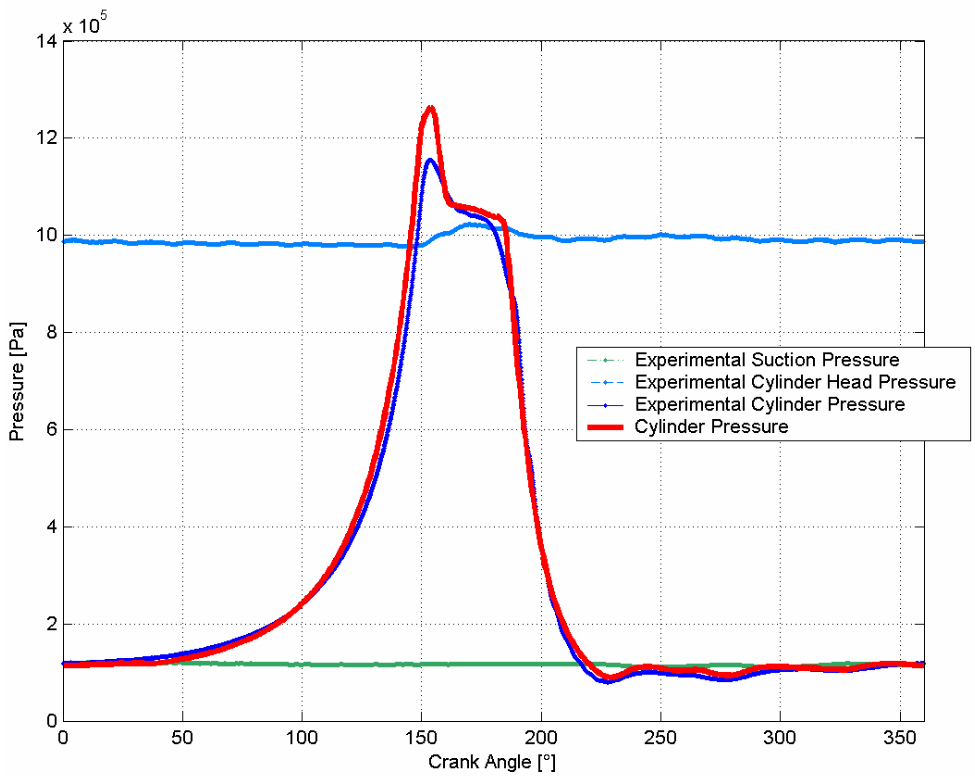

Figure 2-2: Experimental pressures compared to numerical cylinder pressure

The numerical model has demonstrated to be reliable in describing the compressor behavior as shown in Figure 2-2 and 2-3..

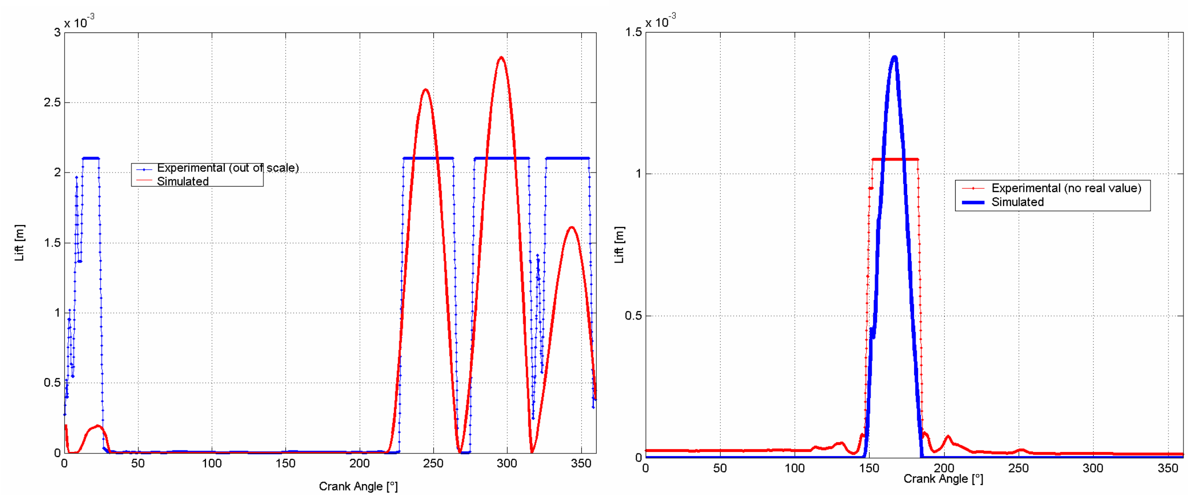

Figure 2-3: Case 1: suction valve motion (left) and discharge valve motion (right)

A numerical optimization has been performed acting on the length of the duct denoted by the symbol T3 in Figure 2-1. For each selected length the analysis of the pressures in various points along that duct has shown the motion of a peak of pressure going upstream and originated at the moment the suction valve closes. As the peak reaches the volume denoted as V2 in the above mentioned figure it 'bounces back' and comes back toward the cylinder then affecting the suction valve dynamics

Varying the length of the T3 duct has shown to cause a variation of the number of suction valve lifts keeping constant all the other parameters. In such a way it can induce a detrimental backflow if not well assigned..

Inlet manifold layouts yielded from numerical models have been experimentally verified. The former experimental set-up has been modified two new intake manifold have been built according to numerical results, one having the best length the other with a longer T3 duct with a length that numerically exhibited a worsening in performances .

Two pressure transducers have been placed along the duct: one close to the suction valve, the other close to the V2 volume to compare what has been foreseen by the simulation code.

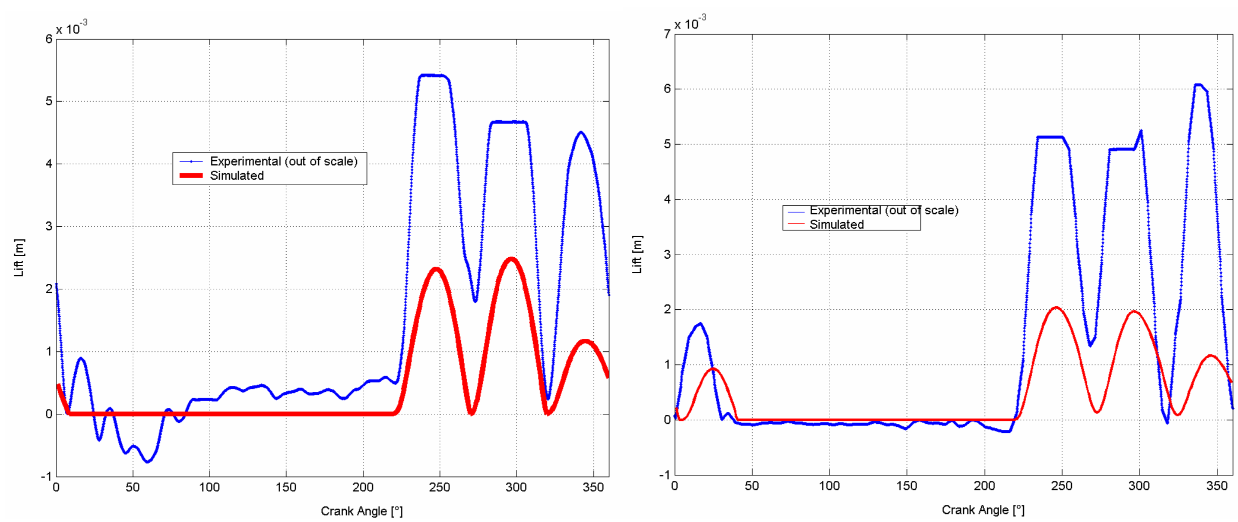

Figure 2-4: Suction valve motion for T3 duct length Case 2 (left) and Case 3 (right)

As shown Figure 2-4 there is a good agreement between foreseen valve motion and that experimental one. Also cooling capacity matches experimental values as can be recognized from the data collected in Table 2-1:

Tabel 2-1: Comparison among intake manifold layouts

	T3 Duct Length [m/m]	Computed Cooling Capacity [w/w]	Measured Cooling Capacity [w/w]	Variation %
Case 1 (Original Intake Manifold)	0.5	0.95	0.94	-1.1
Case 2	1	1	0.98	-2
Case 3	1.3	0.98	0.97	-1.1

Tabel 2-2: Improvement in cooling capacity

	Measured Cooling Capacity (Case 1 = 1)
Case 2	1.042
Case 3	1.031

6. CONCLUSIONS

A simulation model has been assembled and validated. It has been used to investigate the unsteady flow pulsations within the suction muffler with the aim to design a new intake manifold improving the cooling capacity. Gas interaction with suction and discharge valve have been taken into account. The model demonstrate to be able to provide with good agreement the investigated properties.
Used as a tool to get a better comprehension of the phenomena internal to the suction muffler and to design new optimized versions it has demonstrated its potentialities confirmed by experimental results.
Refrigerant flow pressure pulsations in the region close to the suction valve are strictly correlated to mechanical properties of the valve structure and to the geometry of the suction duct closest to the cylinder. Both flow and structure must be investigated in a coupled way to design an optimal configuration.

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