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Experimental study of blade thickness effects on the overall and local performances of a Controlled Vortex Designed axial-flow fan

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ABSTRACT

The purpose of this work is to study the effects of blade thickness on the performances of an axial-flow fan. Two fans that differ only in the thickness of their blades were studied. The first fan was designed to be part of the cooling system of an automotive vehicle power unit and has very thin blades. The second fan has much thicker blades compatible with the rotomoulding conception process. The overall performances of the fans were measured in a test bench designed according to the ISO-5801 standard. The curve of aerodynamics characteristics (pressure head versus flow-rate) is slightly steeper for the fan with thick blades, and the nominal point is shifted towards lower flow-rates. The efficiency of the thick blades fan is lower than the efficiency of the fan with thin blades but remains high on a wider flow-rate range. The mean velocity fields downstream of the rotors are very similar at nominal points with less centrifugation for the thick blades fan. Moreover, the thick blades fan maintains an axial exit-flow on a wider range of flow-rates. The main differences concern local properties of the flow: phase-averaged velocities and wall pressure fluctuations strongly differ at the nominal flow-rates. The total level of fluctuations is lower for the thick blades fan that for the thin blades fan and the spectral decomposition of the wall fluctuations and velocity signals reveal more harmonics for the thick blades fan, with less correlation between the different signals. For this kind of turbomachinery, the use of thick blades could lead to a good compromise between aerodynamic and acoustic performances, on a wider operating range.

1. Introduction

The low-speed axial-flow fans, used for instance in the cooling system of automotive vehicles power units, have very complex three-dimensional geometries that can affect both their overall and acoustical performances. An example of one parameter that dramatically modifies the performances is for instance the blade sweep [1–4]. A second parameter that should affect the performances is the blade thickness. Low-speed axial-flow fans usually have conventional thin blades. However, following motivations such as active control of the blade shape or the use of the rotomoulding process [5,6], the designers would have now to face profiles with thicker blades. The control of blade shape may help to reduce the radiated noise or to extend the operating range and the need for actuators then implies thicker blades. The rotomoulding process—previously tested for wind turbine blades—leads to thick hollow blades and may be more economic because of material gain. The blades can have more stiffness with greater inertia moment. Complex shapes with blade recovering are moreover easier to manufacture than with traditional plastic injection methods, and the blades can be filled for instance with noise-absorbing foam.

In aeronautics and in the automotive industry, changing the blade thickness has been used for many years as an efficient way to modify the lift and drag characteristics and the boundary layers detachment process [7,8]. Applied to low-speed axial-flow fans, one could *a priori* think that the extra thickness may increase the dissipation of energy in the von Kármán street behind the blades so that the performances of the fan decrease and the pressure fluctuations in its wake increase. The effects of blade thickness on the overall performances are not so well known [9–12] and to the best of our knowledge the influence on the dynamics remains an open question.

Therefore this study intends to compare the aerodynamical performances of two axial-flow fans that only differ in the thickness of their blades. The geometry of the fans and the experimental setup are presented in Section 2. The results on the mean features are presented and discussed in Section 3: the overall characteristics of the two fans are presented in Section 3.1; the mean velocity fields downstream of the fans are compared in Section 3.2 and these results are briefly discussed in Section 3.3. Some results on local fluctuating quantities are presented and discussed in Section 4: measurements of the wall pressure fluctuations that are an

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