Eurovent and AMCA Industry Recommendation / Code of Good Practice

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Performance tests of very large axial fans in the context of Ecodesign requirements

First Edition

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Document history

This joint Eurovent and AMCA Industry Recommendation / Code of Good Practice supersedes all of its previous editions, which automatically become obsolete with the publication of this document.

Modifications

This publication was modified as against previous editions in the following manner:

Modifications as against	Key changes
1st edition	Present document

Preface

In a nutshell

The purpose of this document is to:

- **Explain the problem of testing large axial fans according to the standards**
- **Provide lecture analysis about the subject**
- **Provide a solution suggestion for the problem as a code of good practice**

Authors

This document was published by Eurovent and European AMCA. It was prepared in a joint effort by participants of the Product Group 'Fan Technology' (PG-FANS) and European AMCA members, which together represent a vast majority of all manufacturers of these products active on the EMEA market.

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Contents

List of abbreviations and symbols

ρ	air density (kg/m³)
v	velocity over the airfoil section (m/s)
c	blade section chord (m)
μ	dynamic viscosity of the air (kg/(m.s))
rpm	fan rotation speed in revolutions per minute

1. Introduction

Several fields in the industry require the application of very large axial fans. For example, wet cooling towers for petrochemical applications and air cooler condensers (ACCs) applied in power plants usually require fans up to 12.8 m (42 ft). Large heat exchangers for HVAC, industrial processes, data centres and power generation also require very large axial fans with diameters greater than 4.0 m (13 ft).

It is a challenge for the fan manufacturers and integrators to determine the fan performance curves for these fans using standardised airways in full compliance with the standards. Therefore, each player in the market has its testing methodology.

Considering the requirements of energy efficiency and market surveillance in the fan field, it is necessary to discuss a new criterion for testing very large axial fans that can be used for the whole industry in a feasible and standardised approach.

2. European Union regulation overview

The Commission Regulation (EU) no 327/2011 (1) was created to implement Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for fans driven by motors with an electric input power between 125 W and 500 kW. Regarding fan testing, EU 327 requires 'recognised state-of-the-art measurement methods', but no standard is mentioned. To solve this, FprEN 17166:2019 (2) was written. This standard has not been launched yet, but it provides procedures and methods to determine fan efficiency based on standards that will be better described below.

3. Fan test standards and limitations

The document (2) defines the standards that should be used to test fans in a standardised manner. There are two approaches, one for laboratory conditions (ISO 5801) and the other for in situ conditions (ISO 5802).

Although ISO 5802 (3) does not require a standardised airway, there are some constraints regarding the system upstream and downstream of the fans. These restrictions do not allow the test for large axial cooling fans.

ISO 5801 (4) provides standardised airways to test fans in several inlet/outlet configurations. All the geometries are diameter-dependent. The larger the diameter, the larger the test station dimension. For fans with a diameter greater than 4.0 m (13 ft), the dimensions of the test stations would require frame lengths that are simply not feasible.

On the other hand, ISO 13348 (5) minimises the problems referenced above by providing the opportunity to test the fans using a scaled-down model with some restrictions. The most important restriction is the Reynolds number. This standard recommends that the Reynolds number of the reduced-scale model must be at least 70% of the original value.

4. Problem discussion

The Reynolds number is a parameter used for similarity studies, especially related to viscosity. It defines a dimensionless relation between inertia and viscous forces. Considering an axial fan blade, the Reynolds number can be defined as:

$$Re = \frac{\rho . v . c}{\mu}$$

Where:

ρ is the air density (kg/m³)

v is the velocity over the airfoil section (m/s)

c is the blade section chord (m)

μ is the dynamic viscosity of the air (kg/(m.s))

Assuming air density and viscosity as constants, it is necessary to find a balance between the blade chord (or fan diameter) and air velocity (rotation speed) to meet the Reynolds number requirement when testing scaled-down fan models. If we halve the blade chord (or fan diameter), it is necessary to double the velocity (rotation speed) to maintain the same Reynolds number.

For this reason, the Reynolds equivalence, even if limited to 70%, results in other problems with difficult solutions. The rotation speed required to meet 70% of Reynolds equivalence for very large fans would result in higher Mach numbers and centrifugal loads, making it impossible to build/test scaled-down models.

5. Literature analysis

The problem above was studied by several authors, according to the next paragraphs.

The reference (6) presented a methodology to test fans in scaled conditions, concluding that *"The presented scaling method works much better than the method proposed by the ISO 13348:2007 and at the same time* **never overpredicts** *the efficiency."* They found a very good correlation in the performance measurements comparing both models, even with large diameters and Reynolds differences.

The reference (7) also studied the problem applied in large axial fans with a different approach. It studied the Reynolds number variation over the fan by changing the inlet turbulence. It concluded that *"At the scale tested in the ISO 5801 fan test facility, using the fan scaling laws on the M-fan to obtain performance characteristic data representing that of a larger scale M-fan will yield accurate results."*

The reference (8) concluded that *"Global performance measurements obtained for three rotor-only tube-axial fans, featuring equal hub-to-tip ratio but different blade load distribution, size and surface roughness, showed that both the pressure coefficient and aeraulic efficiency curves shift towards higher values of flow rates coefficient when the Reynolds number (based on tip speed and midspan chord length) increases."*

The reference (9) studied the performance similarity of a radial fan with a scaled-down model with a factor of 2,41 and a Reynolds factor of 12,4. It was concluded that *"Thus, the presented calculation* *procedure and modelling methods might be applied for the described centrifugal fans with radial blades, with sufficient correspondence with the expected real performance of the machine."*

In addition, the normative reference ISO 5801 (4) says: *"When the peripheral Reynolds number increases, the friction loss coefficients decrease. Therefore, efficiency and possibly performance may increase, compared to what is predicted according to the conversion rules provided in 15.3."*

The reference (10) AMCA 210, which is also a normative document, says: *"There is some evidence that efficiency improves with an increase in Reynolds number. (…) There is also some evidence that performance drops off with a significant decrease in Reynolds number."*

6. Proposed solution – Code of good practice

The proposed solution takes into consideration the conclusions from the references above and overcomes the limitations of the standards regarding very large axial fans. It also brings the task of testing large fans to a feasible solution with minor adjustments from the normative references recommended by the EU.

Solution roadmap:

- Axial fans greater than 4.0 m (13 ft) shall be tested as scaled-down models per ISO 13348, with the following additional requirements.
- The minimum Reynolds number requirement for these fans shall be decreased from 70% to 30%. The tested Reynolds number will be lower than the full-scale application and will, therefore, yield conservative fan efficiency results.
- To avoid compressibility problems, the Mach number shall be lower than 0,30, keeping the airflow under low subsonic conditions.
- Other large axial fans in the range of 2.5 and 4.0 m can also be tested with scaled-down models following the requirements of ISO5801 + ISO13348.

7. Conclusion

- A minor adjustment is proposed to the ISO13348 requirements, reducing the Reynolds relation from 70% to 30% when using small-scale fans to test fans with diameters greater than 4.0 m (13 ft).
- A limitation on the Mach number to 0,30 is also proposed to avoid compressibility effects during the tests.
- All other best practices in fan performance measurements can be applied in this solution, following the recommended guidelines.
- From the consulted references, including standards, it is possible to conclude that the test of scaled-down axial fans with reduced Reynolds number provides conservative performance values. Efficiency values measured on small-scale fans yield conservative results.
- Using this simple and conservative approach, it will be possible to test large axial fans to enable the implementation of the new energy efficiency guidelines into the market.

8. Literature

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