

PAPER NO: TP04-04

CATEGORY: VIBRATION

COOLING TECHNOLOGY INSTITUTE

NEW FAN BLADE TIP DESIGN REDUCES STRUCTURAL VIBRATIONS – VERIFICATION IN PRACTICE

SANDER C. VENEMA
HOWDEN COOLING FANS

CHRIS B. LAZENBY
SOUTHERN COMPANY SERVICES



The studies and conclusions reported in this paper are the results of the authors own work. CTI has not investigated, and CTI expressly disclaims any duty to investigate, any product, service process, procedure, design, or the like that may be described herein. The appearance of any technical data, editorial material, or advertisement in this publication does not constitute endorsement, warranty, or guarantee by CTI of any product, service process, procedure, design, or the like. CTI does not warranty that the information in this publication is free of errors, and CTI does not necessarily agree with any statement or opinion in this publication. The user assumes the entire risk of the use of any information in this publication. Copyright 2004. All rights reserved. This paper has been reviewed by members of the Cooling Technology Institute and approved as a valuable contribution to cooling tower literature and presented by the author at the Annual Conference of CTI.

Presented at the 2004 Cooling Technology Institute Annual Conference
Houston, Texas – February 8-11, 2004

New Fan Blade Tip Design Reduces Structural Vibrations – Verification in Practice

Sander C. Venema
Product Specialist
Howden Cooling Fans
venema@howden.nl

Chris B. Lazenby
Senior Engineer
Southern Company Services
cblazenb@southernco.com

Introduction

The main purpose of this study is to understand the origin of vibration of the fan stack and to find ways to keep these vibrations within acceptable limits. Assuming that the vibration of the fan stack is not caused by resonance, then the pressure field around the fan blade tip is the cause of stack vibration. Taking a fixed position at the fan stack as a reference point, it is evident that the fan stack experiences a pulse force each time a fan blade passes by. To avoid unacceptable vibration levels, the pulse force should be kept below a critical level. The easiest way to achieve this is to restrict the aerodynamic performance per blade. In practice, this translates into a limitation of "horsepower per blade". If the maximum horsepower per blade is an aerodynamic design criterion, this will often lead to more blades per fan than is necessary to achieve the required duty point. A more challenging way to keep the pulse force below a critical level is to redesign the blade tip in such a way that the pulse force is reduced without losing aerodynamic performance. This makes it possible to apply fans with fewer blades without the risk of introducing a vibration problem.

At the 2003 CTI Annual Conference the development of a new blade tip design and its potential benefits was presented [CTI TP03-05: Vibration Control: New Fan Blade Tip Reduces Pulsation, Henk van der Spek, Howden Cooling Fans]. This paper gives the results of verification tests in a full-scale practical application.

Pressure field around the blade tip

The principle of the working of a fan blade is basically due to the difference in air velocity between either sides of the airfoil. The shape of the airfoil leads to an air velocity at the convex side of the blade, which is locally higher than at the concave side of the blade. This results in a pressure difference over the blade called lift. The lift is a useful factor because it forces the air to flow along the flow resistance of the installation. It cannot be changed without influencing the performance of the fan.

At the blade tip, there is a second factor contributing to the pressure field. Because the blade tip moves at high speed along the fan stack, an under pressure is generated in the gap between the blade tip and the fan stack. This under pressure acts on the surface area of the tip and on the part of the fan stack where the fan blade passes by at that specific moment. We call this factor the "surface velocity pressure".

Both the lift and the surface velocity pressure are illustrated in *figure 1*. *Figure 1a* shows the air velocity at both sides of the airfoil as well as the pressure components *lift* and *surface velocity pressure*. *Figure 1b* illustrates the resulting pressure distribution. This is the variation of the pressure at a fixed position on the fan stack as a fan blade passes.

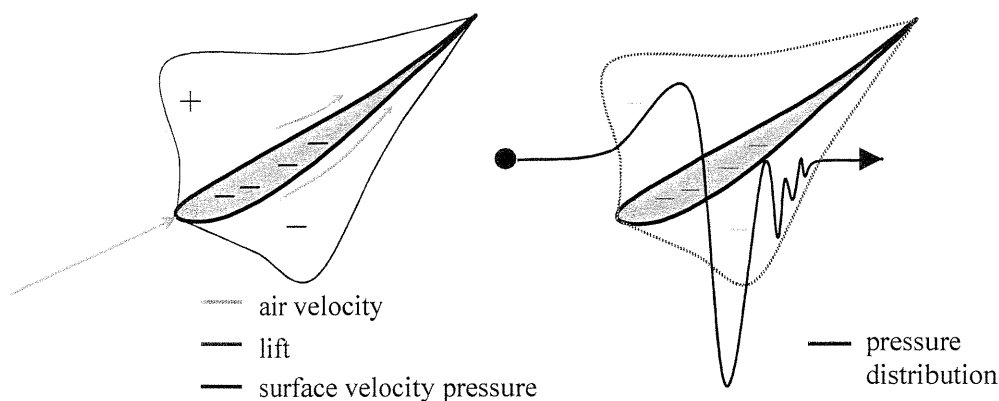


figure 1a: air velocity and pressure components around fan blade tip

figure 1b: pressure distribution around fan blade tip

Strategy for the reduction of pulsation

The lift and the surface velocity pressure both contribute to the pulse force on the fan stack. Because the lift cannot be reduced without reducing the fan performance, this study concentrated on reducing the surface velocity pressure.

As mentioned before, the surface velocity pressure acts on the surface area of the blade tip. The thought, then, was that minimizing the surface area of the tip using a plate airfoil might help reduce this velocity pressure. However, to be considered properly designed this airfoil would have to maintain the same fan performance. A new design (patent pending), named 'Aerotip' (*figure 2*), was developed and tested in both scale model versions and ultimately in a full size 32-foot diameter fan laboratory facility. The results, as follows, were encouraging.

- For a fan whose blades were equipped with the 'Aerotips', the vibration level of the fan stack was 30% lower than a fan with standard blade tips (*figure 3*).
- The 'Aerotips' resulted in an increased maximum pressure of up to 10%, and an increased fan efficiency of up to 5% (*figure 4*).

These results indicate that it is possible to reduce the pulse forces on the fan stack without suffering a reduction of fan performance. On the contrary, the 'Aerotip' seemed to increase the fan performance slightly.

Details of the tip design and test set-up are given in TP03-05.

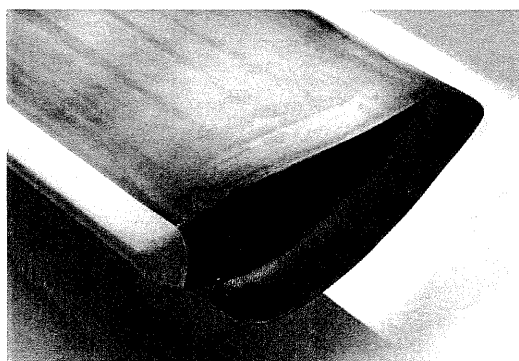


figure 2: 'Aerotip'

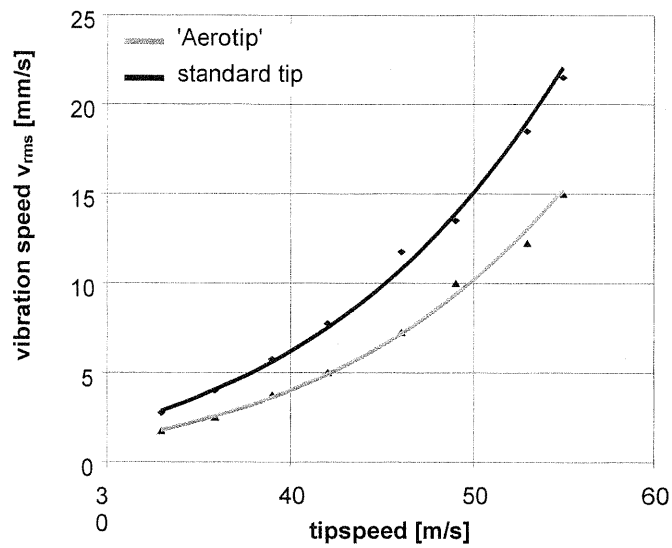


figure 3: Vibration level on the fan stack as a function of the fan rotation speed

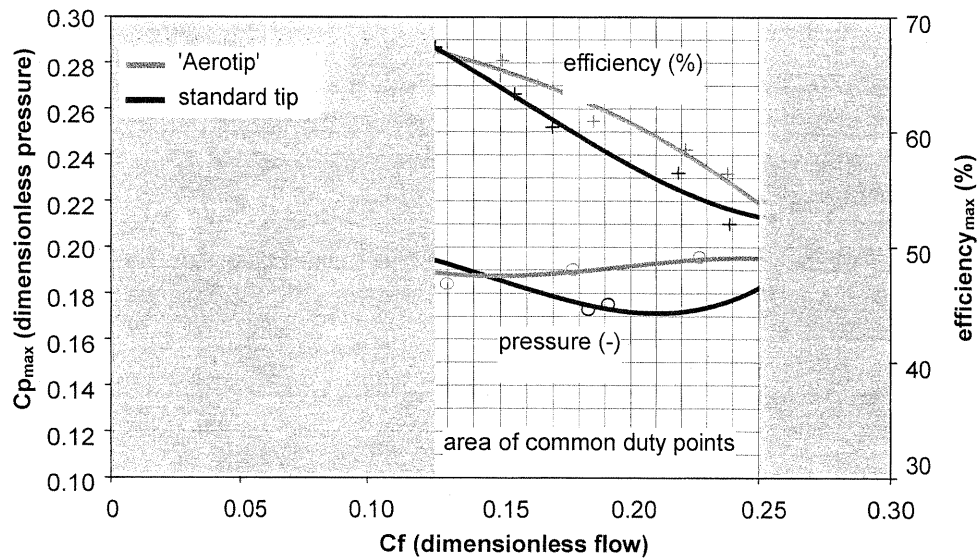


figure 4: Comparative performance of fan pressure and fan efficiency versus airflow for conventional fans and fans equipped with the 'Aerotips'