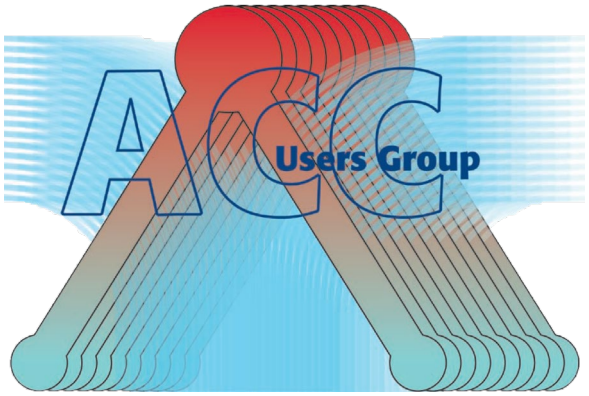

2023 Annual conference

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COFIMCO

AXIAL FANS FOR THE WORLD

FRP-Carbon twin shaft for axial fan blades and validation on Cofimco's 38ft test rig

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Introduction

Nowadays, large axial fans are employed on Air-Cooled Condensers and Cooling Towers.

Extensive research and lab tests pointed out in the development of an improved shaft to connect the blade airfoils to the hub: the pultruded FRP-Carbon twin shaft.

Scope of the present study is to show how the twin shaft design is capable to improve the blade load capacity on large fan sizes and the results achieved on 38ft test rig.

Summary

1. Background: rigid blade connection and FRP-Carbon shaft
2. Cofimco 35FD: FRP-Carbon twin shaft for axial fan blades
3. Validation on 38ft test rig
4. Structural comparison: test results
5. Conclusions

Background:
rigid blade connection and FRP-Carbon shaft

Background (1)

The goal of a fan is to generate air flow through obstacles present in the heat exchanger overcoming the resulting pressure losses. From an aerodynamic point of view, it means:

1. **A lift has to be generated for each blade.**
2. **Lift is not constant but varies cyclically due to aerodynamic disturbances.**

In evaluating shaft design and strength, particular attention must be paid to point 2.

Background (2)

Main causes of aerodynamic disturbances:

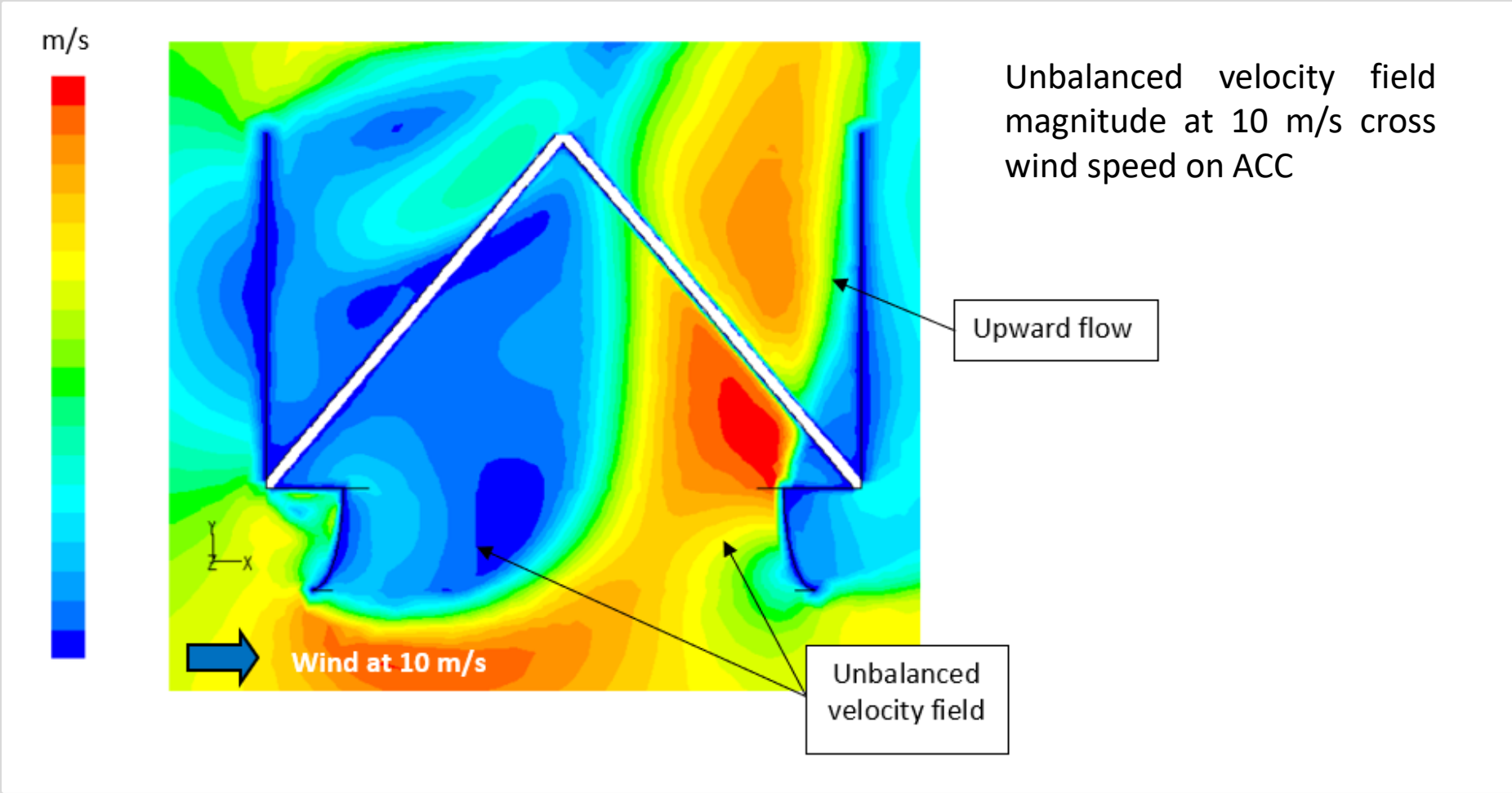
- **Mechanical obstacles to the flow: supporting structures, drive shafts, walkways.**

ACC: Walkway

CT: panels to hybridize

Background (3)

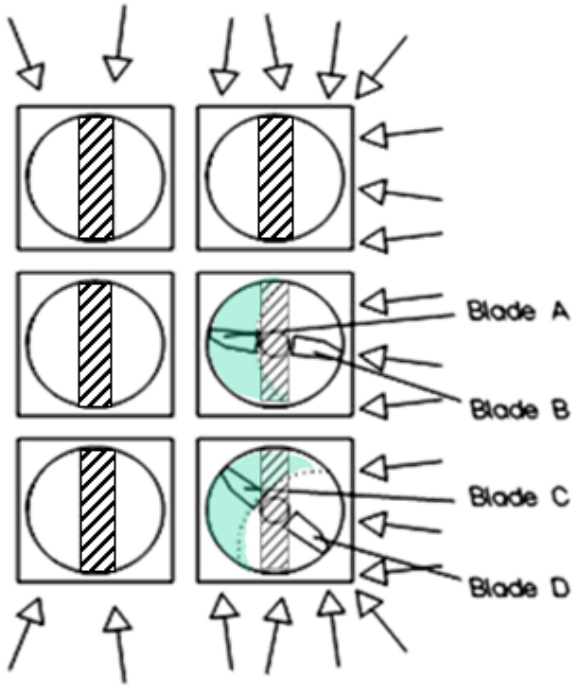
- **Wind gusts and asymmetric flow pattern.**



Unbalanced velocity field magnitude at 10 m/s cross wind speed on ACC

Background (4)

- Asymmetric flow pattern due to different fan location in CT or ACC equipped with many cells.



Background (4)

Consequences from a mechanical point of view:

1. **High bending moment by aerodynamic lift is generated at the blade shaft.**
2. **Bending moment and lift are transferred to the hub, drive system and to the structure.**
3. **Any abrupt and/or cyclical loads that excite fan blades are transferred to the drive system and to the structure.**

Background (5)

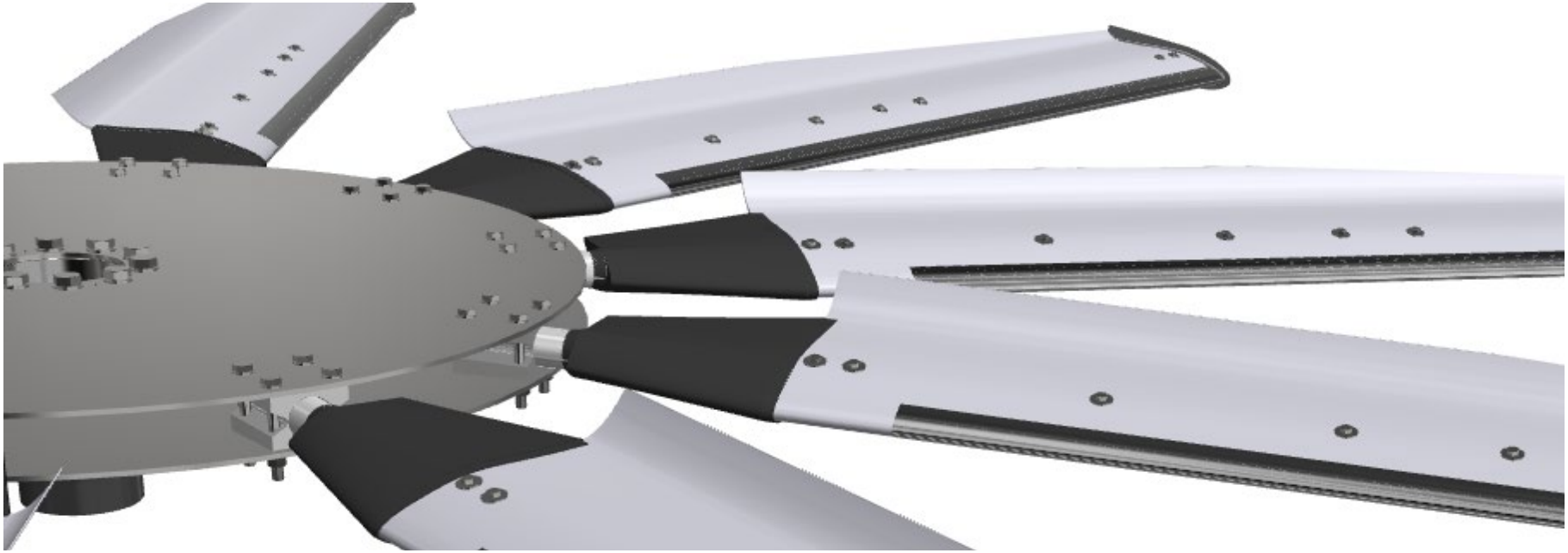
Therefore, the blade connection to the hub must be strong enough to withstand high loads generated at the shaft.

Rigid solutions using either steel shafts or hand laminated FRP blades, transmit any loads to the supporting structure, and generally show blade natural frequencies quite near to common fan forcing frequencies. As a result, vibrations can be high.

Using pultruded FRP-Carbon shafts gives to the blade a suitable flexibility, resulting in a noticeable reduction of the vibration level; simultaneously, high strength of carbon rovings limits blade deflection.

Background (6)

However, for large fan applications (i.e. larger than 10 meters) and/or heavy-duty points (i.e. in presence of high wind), many blades in FRP-Carbon shafts are still required.



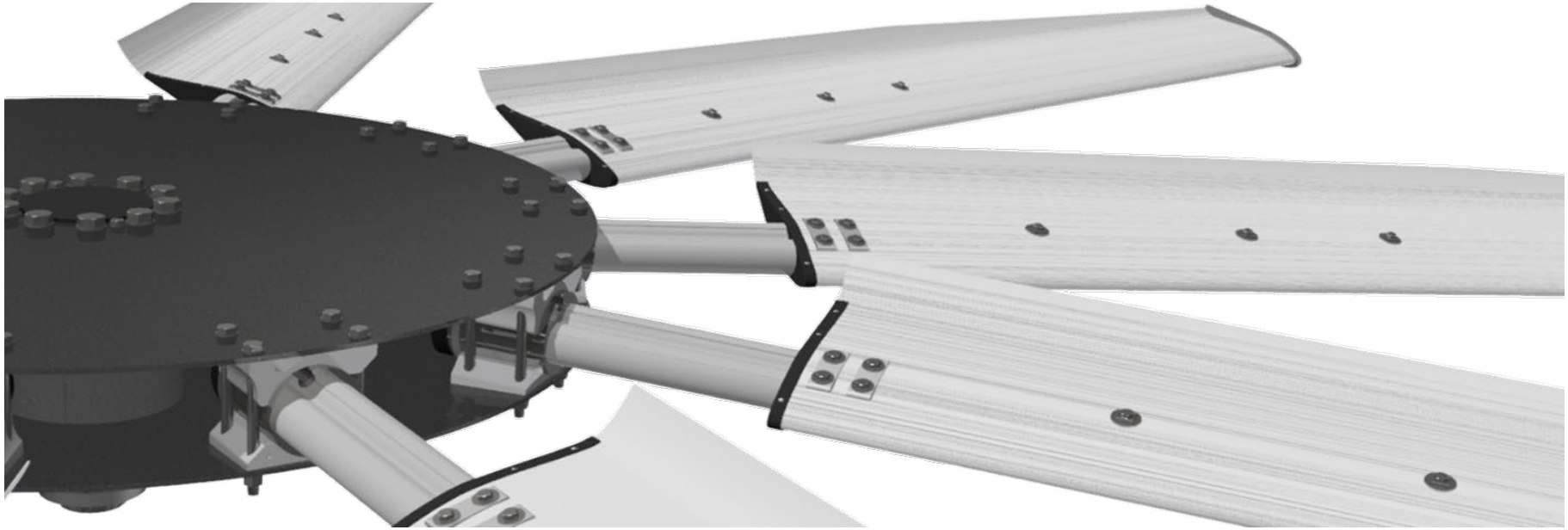
Cofimco 35FD:

FRP-Carbon twin shaft for axial fan blades

FRP-Carbon twin shaft (1)

The improved connection design, extend the use of FRP-Carbon shafts to very large fans thanks to:

- **A peculiar binocular shape, hence the name twin shaft;**
- **Use of pultrusion technology and FRP-Carbon material.**



FRP-Carbon twin shaft (2)

The main strengths of the new twin shaft design are:

1. **Limited blade deformation and/or fluctuations along with stress for large fans without increasing the airfoil size.**
2. **Adequate flexibility.**
3. **Blade natural frequency far from the typical fan forcing frequencies.**

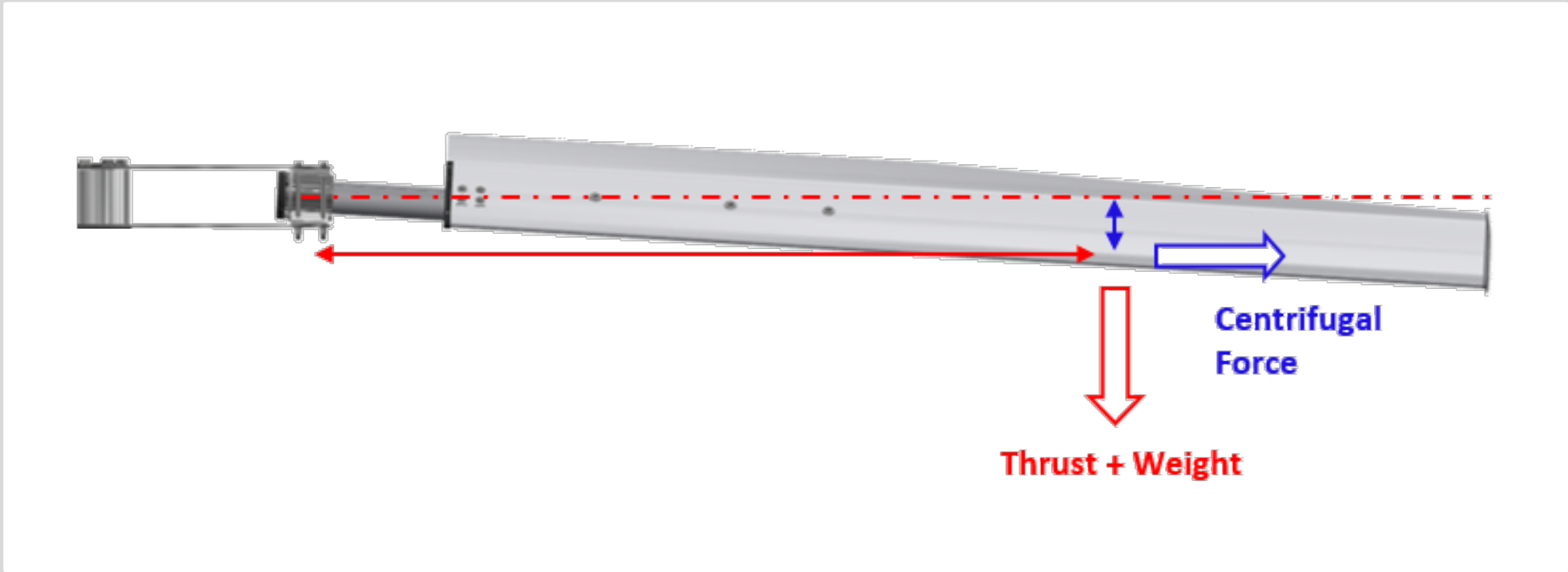
FRP-Carbon twin shaft (3)

- **Thanks to the peculiar binocular shape of twin shaft, where two pultruded FRP-Carbon shafts are merged in one single component, blade deformation and/or fluctuation are limited along with stress without increasing the airfoil size.**

35F **35FD**

FRP-Carbon twin shaft (4)

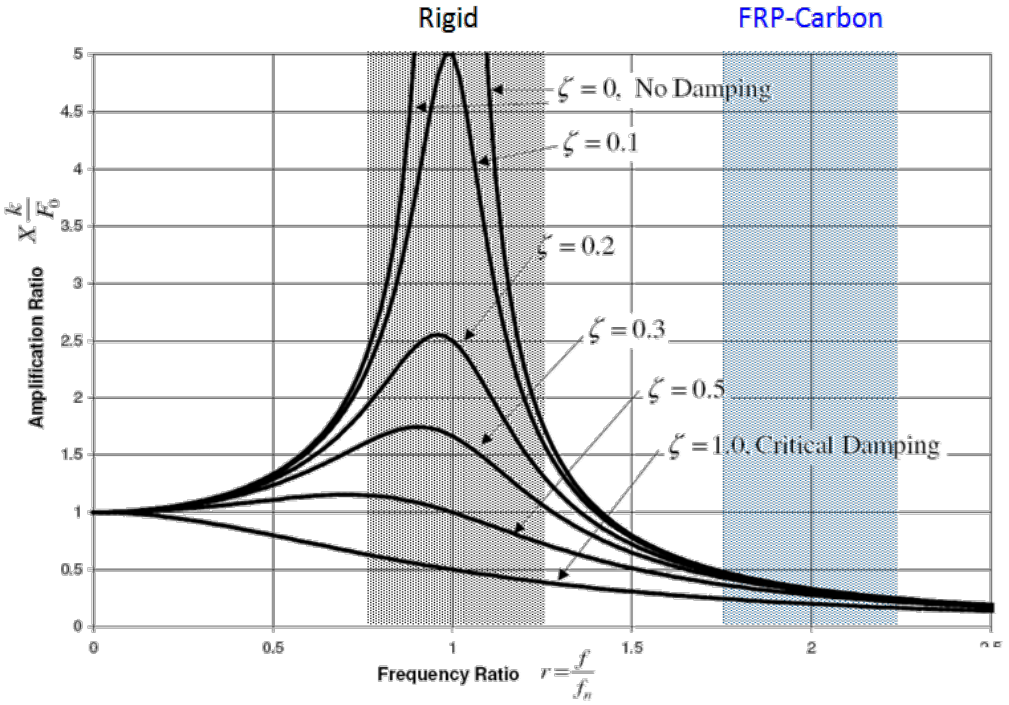
- **The mechanical properties, shape and size of the shaft result in an adequate flexibility. As a result, the blade recognizes a beneficial bending moment given by the centrifugal force as opposed to the bending moment given by weight and thrust.**



FRP-Carbon twin shaft (5)

- **The new FRP-Carbon design results in a blade natural frequency (BNF) far from the common fan forcing frequencies. Considering the high dampening factor of shaft material, vibrations are greatly reduced.**

The BNF together with twin shaft shape and material, allows the fans operated by VFD generally with no speed to skip.



Validation on Cofimco 38ft test rig

Validation on 38ft test rig (1)

For validating and determining the benefits given by twin shaft, extensive tests have been performed on Cofimco's 38ft test rig in the most severe operating conditions.

The 38ft Cofimco test rig has been designed to operate fans at different duty points and check related performance and noise along with deformation and stress acting on fan blades.

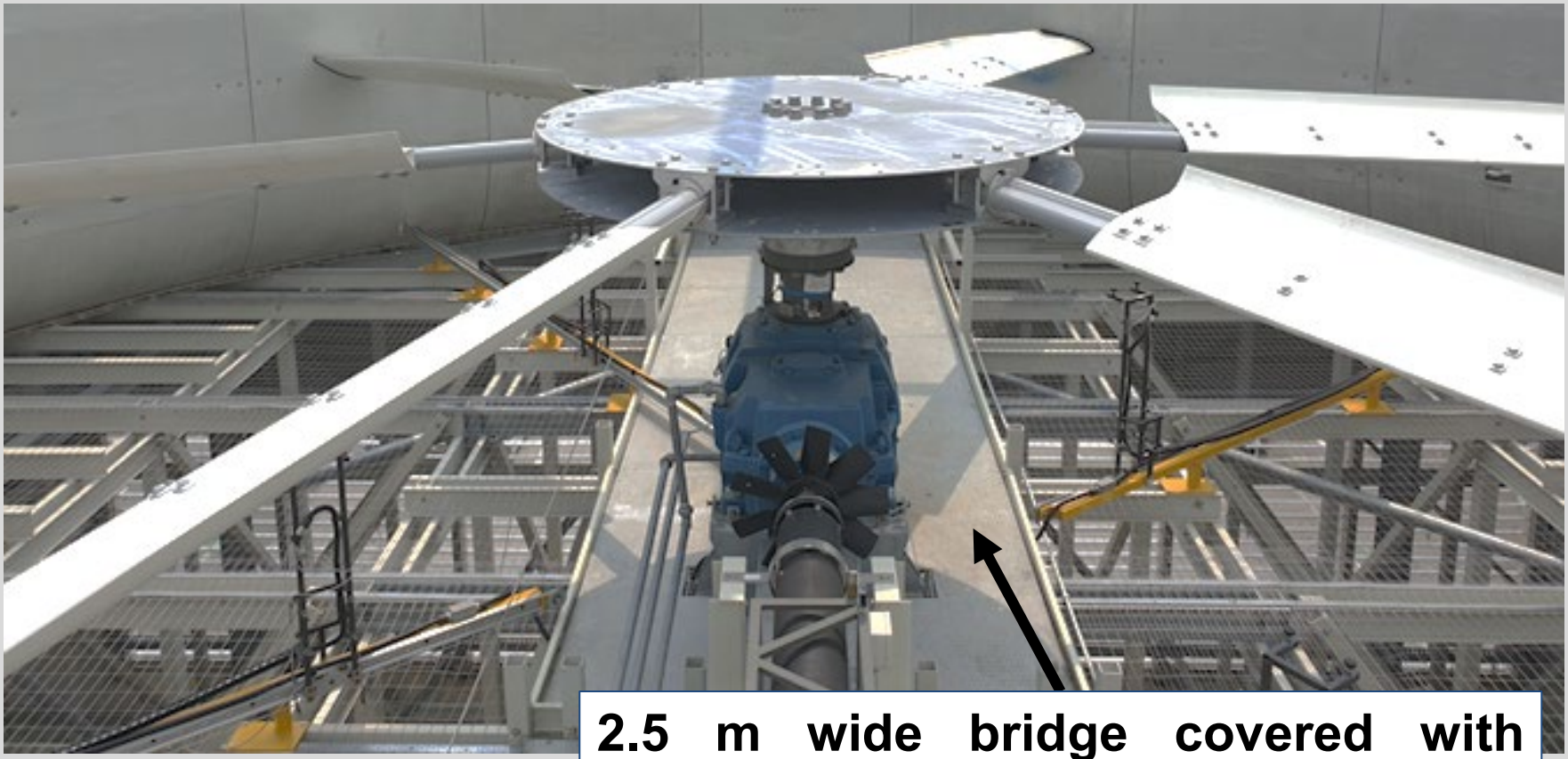
By the way, the fan supporting structure can be equipped with different types of obstacles to simulate typical fan arrangements.

Validation on 38ft test rig (2)

Fan is driven by a 250 kW electrical motor through GB and VFD system. A louvers system allows to change the static pressure and test different duty points.

Validation on 38ft test rig (3)

For structural comparison, the fan supporting structure of Cofimco's 38ft test rig is <u>set as a typical ACC forced bridge</u>.



2.5 m wide bridge covered with panels to improve cyclic loads

Validation on 38ft test rig (4)

The structural comparison between different fan solutions is performed by measuring the deformation and stress acting on a sample blade for each fan in operation through strain gauge sensors, connected a telemetric system.

Structural comparison: test results

Test results (1)

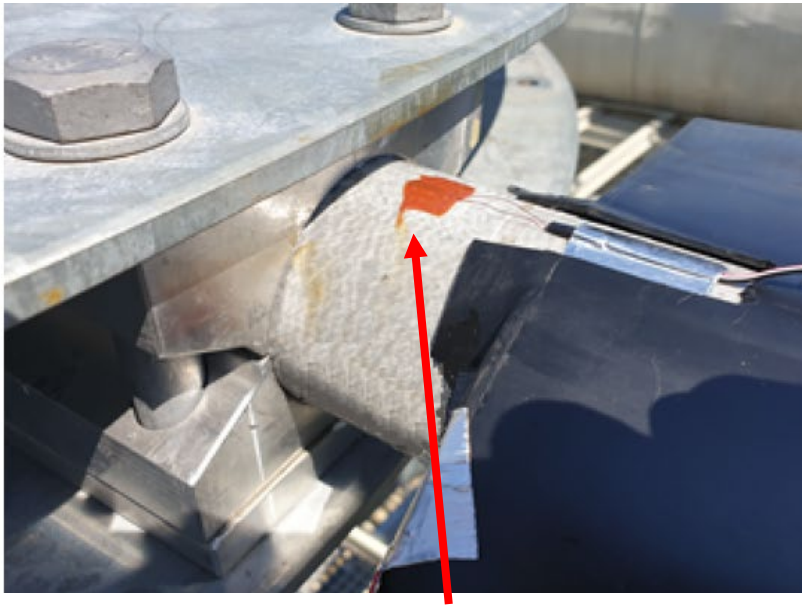
The stress and vibrations transmitted to the drive system by a 35FD fan with FRP-carbon twin shafts and then with 35F FRP-Carbon shafts are compared in the most severe duty points as per above mentioned 38ft test rig setting.

Comparative tests

- **same N° blades**
- **same airfoil**
- **same performances**
- **vibration probes on GB**

Test results (2)

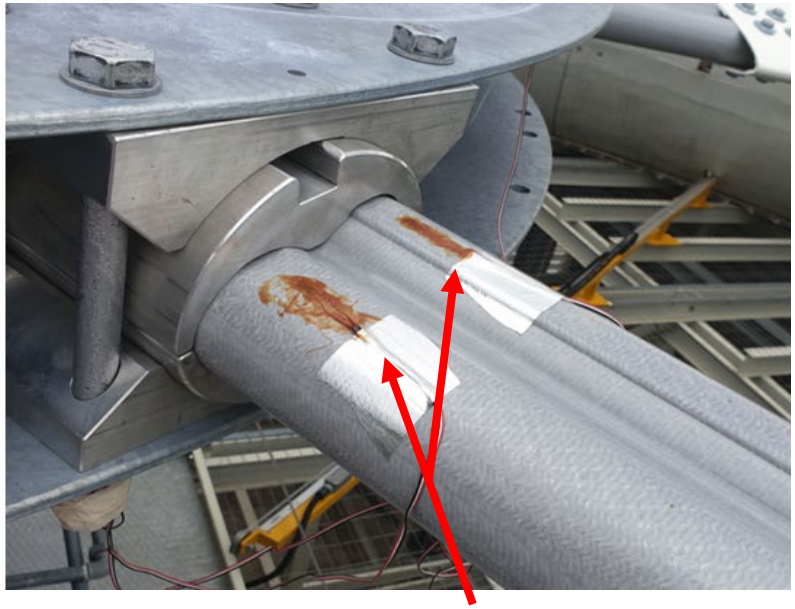
Stress and vibrations have been measured on a sample 35F-6 blades fan with FRP-Carbon shafts at different pitch angles, louver settings and speeds.



A strain gauges, has been installed on a sample blade shaft.

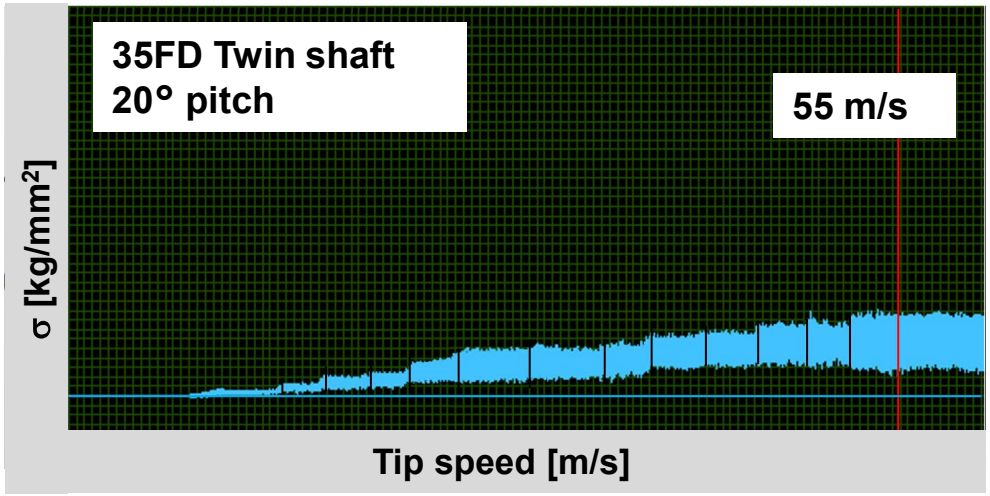
Test results (3)

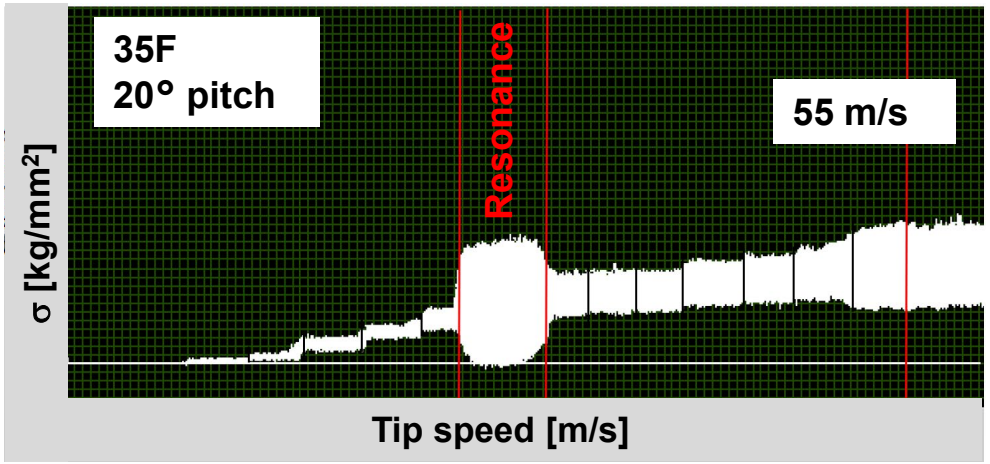
Stress and vibrations have been measured on a sample 35FD-6 blades fan with FRP-Carbon twin shafts at different pitch angles, louver settings, and speed.



Two strain gauges have been installed on a sample blade shaft, on its two convex sides.

Test results (4)





Stress comparison

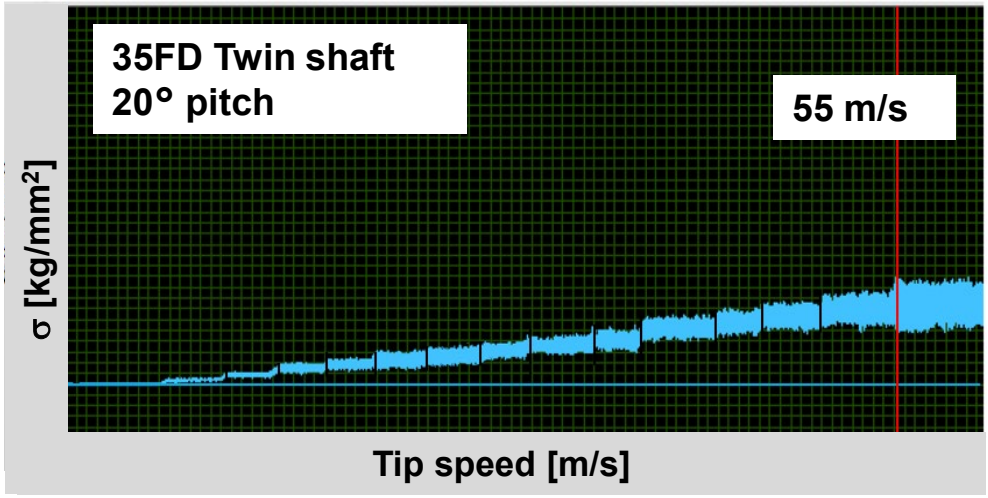
<u>Open louvers configuration:</u>

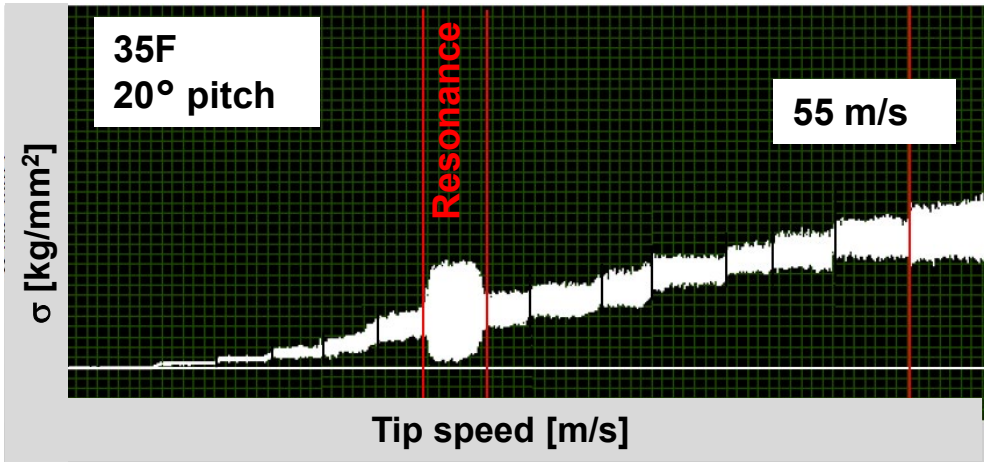
Max delivered airflow

Max cyclic load

Stress on twin shaft almost halved & no speed to skip

Test results (5)





Stress comparison
<u>45° louvers configuration:</u>
reduced delivered airflow
reduced cyclic load

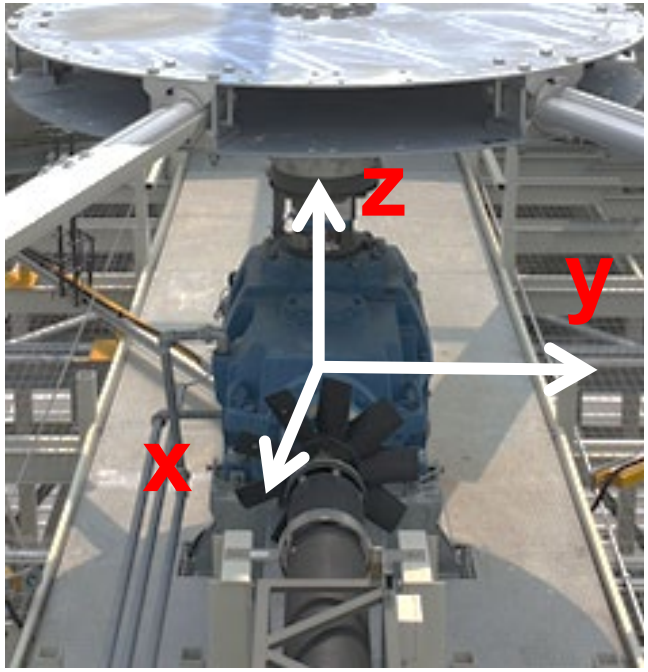
Stress on twin shaft almost halved & no speed to skip

Test results (6)

55 m/s 20° Pitch	Vibration mm/s RMS		
	Direction		
	X	Y	Z
35FD: Twin shafts	2.4	2.5	2.5
35F: FRP-Carbon shafts	1.9	2.6	2.1

Resonance 20° Pitch	Vibration mm/s RMS		
	Direction		
	X	Y	Z
35FD: Twin shafts	2.6	2.5	2.7
35F: FRP-Carbon shafts	3.1	3.5	**7.5**

Vibration measurement
<u>Open louvers configuration:</u>
Max delivered airflow
Max cyclic load

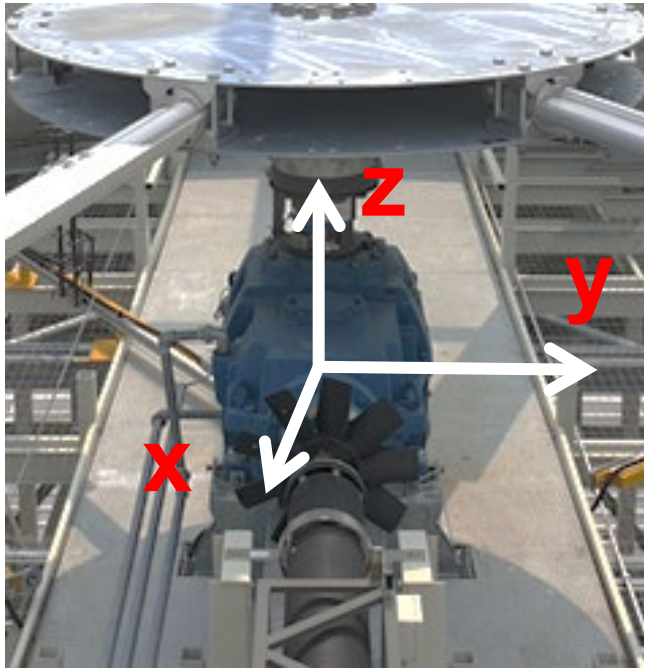


Test results (7)

55 m/s 20° Pitch	Vibration mm/s RMS		
	Direction		
	X	Y	Z
35FD: Twin shafts	2.2	2.6	2.1
35F: FRP-Carbon shafts	1.7	2.6	1.8

Resonance 20° Pitch	Vibration mm/s RMS		
	Direction		
	X	Y	Z
35FD: Twin shafts	2.5	2.7	3.0
35F: FRP-Carbon shafts	2.9	3.3	**6.4**

Vibration measurement
<u>45° louvers configuration:</u>
reduced delivered airflow
reduced cyclic load



Test results (8)

For the long term and fatigue life evaluation, twin shaft 35FD blades have been also validated on fatigue machines that simulate the typical cyclic loads present on fan applications.

Machines have been set based on the highest stress measured on the 38ft test rig further increased to create very meaningful safety margins.

Conclusions

Conclusions

The new FRP-Carbon material and improved shaft design used in 35FD fan blades, represent a great development in the strength and performance of axial fans.

1. **The blades of large fans can withstand severe duty points and manage the high abrupt loads as the ones given by wind and wind gusts.**
2. **The blades can be generally operated from 0 to 100 % speed without any range to skip when the fan is driven by VFD.**
3. **The vibration and loads introduced in the structure are greatly reduced.**

THANK YOU FOR YOUR ATTENTION

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