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Replacement of Steel Blade by Composite Blade for Flutter Measurements

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ABSTRACT

This work summarizes FEM simulations which were made to evaluate performance of a steel blade which is currently used in the facility for flutter measurements. These simulations are also used for an initial design of a CFRP based blade which could replace the original steel blade and therefore allow measurement in the wider range of frequencies.

INTRODUCTION

The blades of turbines are made longer and slender to enhance its efficiency. These long and slender blades, which are operated at supersonic speeds, are prone to the blade flutter. The flutter can cause fatigue failure of the blade. The problem of blade fatigue failures has not yet been fully resolved due to lack of experimental data.

New test facility is under development to solve this problem. The new experimental setup allows investigation of high subsonic flow in a five-blade cascade, where the middle blade undergoes forced sinusoidal oscillation about its centre of gravity. Operation of middle blade at high frequencies is restricted by stresses induced by inertial forces due to oscillations. For advancement of the measurements it would be convenient to increase frequency of forced oscillations.

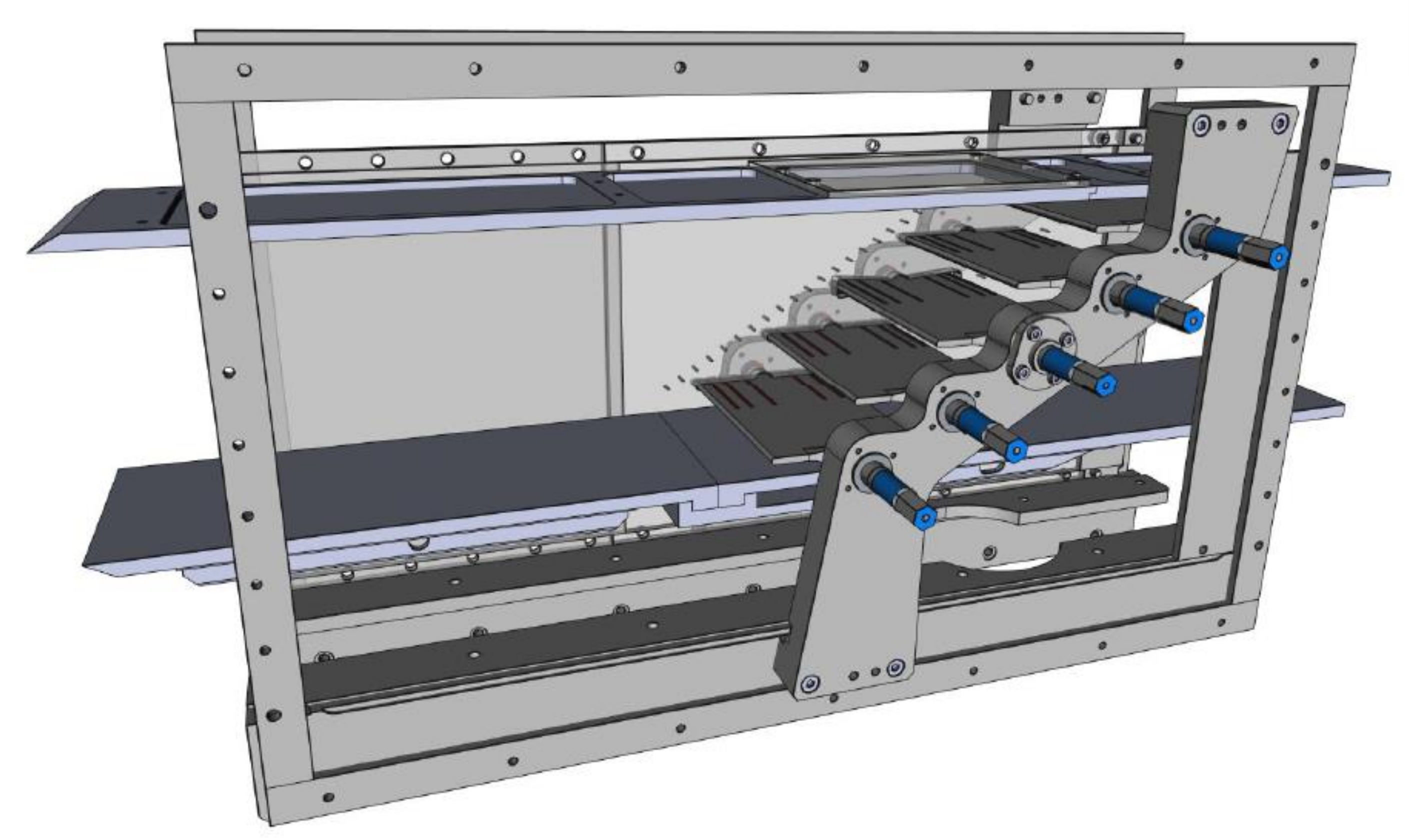

Fig. 1: Experimental facility.

The idea is to improve the performance of the middle blade by replacement of current steel blade by design based on the CFRP (Carbon Fibre Reinforced Polymer) due to its strength to weight ratio.

ANALYSIS OF INERTIAL FORCES

Loading conditions are necessary input for the simulations. The angular acceleration was derived from rotational angle of the blade:

$$\varphi(t) = \varphi_0 sin(2\pi f t)$$
$$\alpha_{\max} = \varphi_0 (2\pi f)^2$$

SIMULATIONS

Several simulations were performed in FEM software Ansys 2021 R1

- Quasistatic analysis
- Transient analysis
- Modal analysis
- Computational fluid dynamics

Firstly, the steel blade was analyzed. Subsequently, the simulations were used for the design of the composite blade.

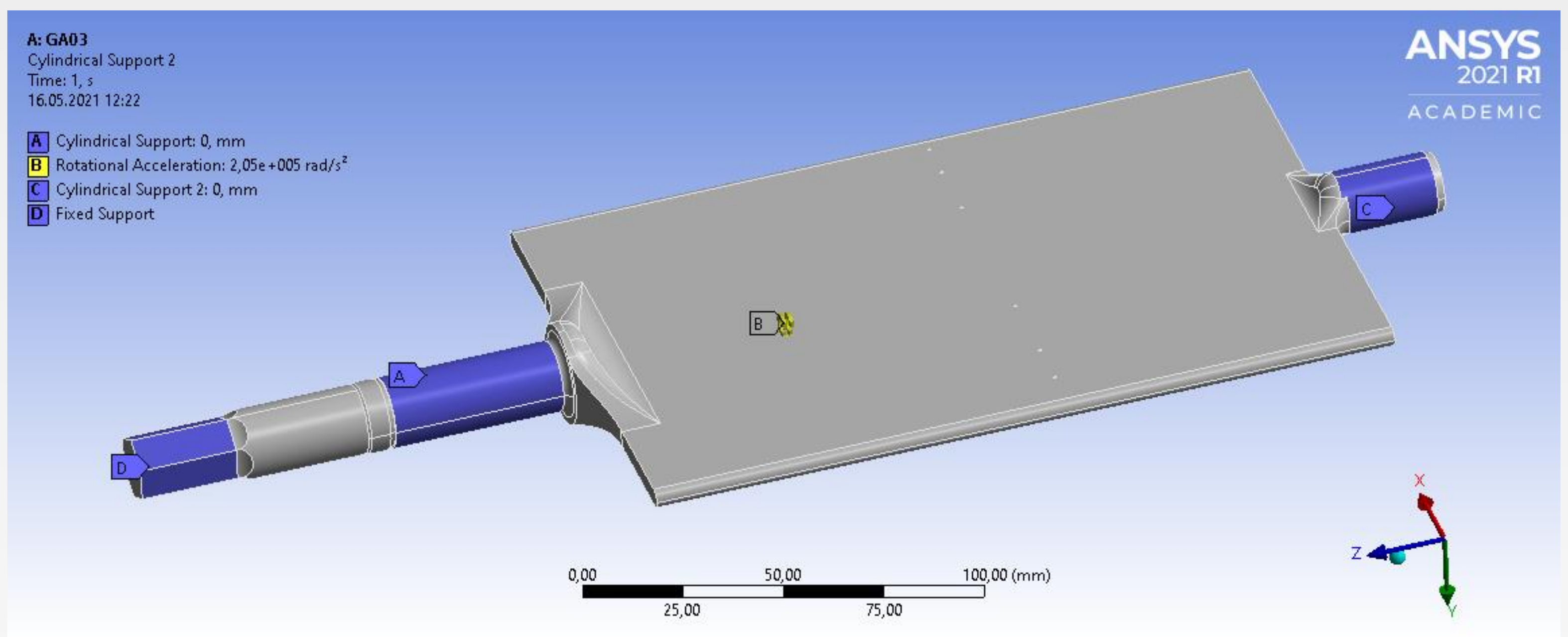

Fig. 2: Boundary conditions for the quasistatic analysis.

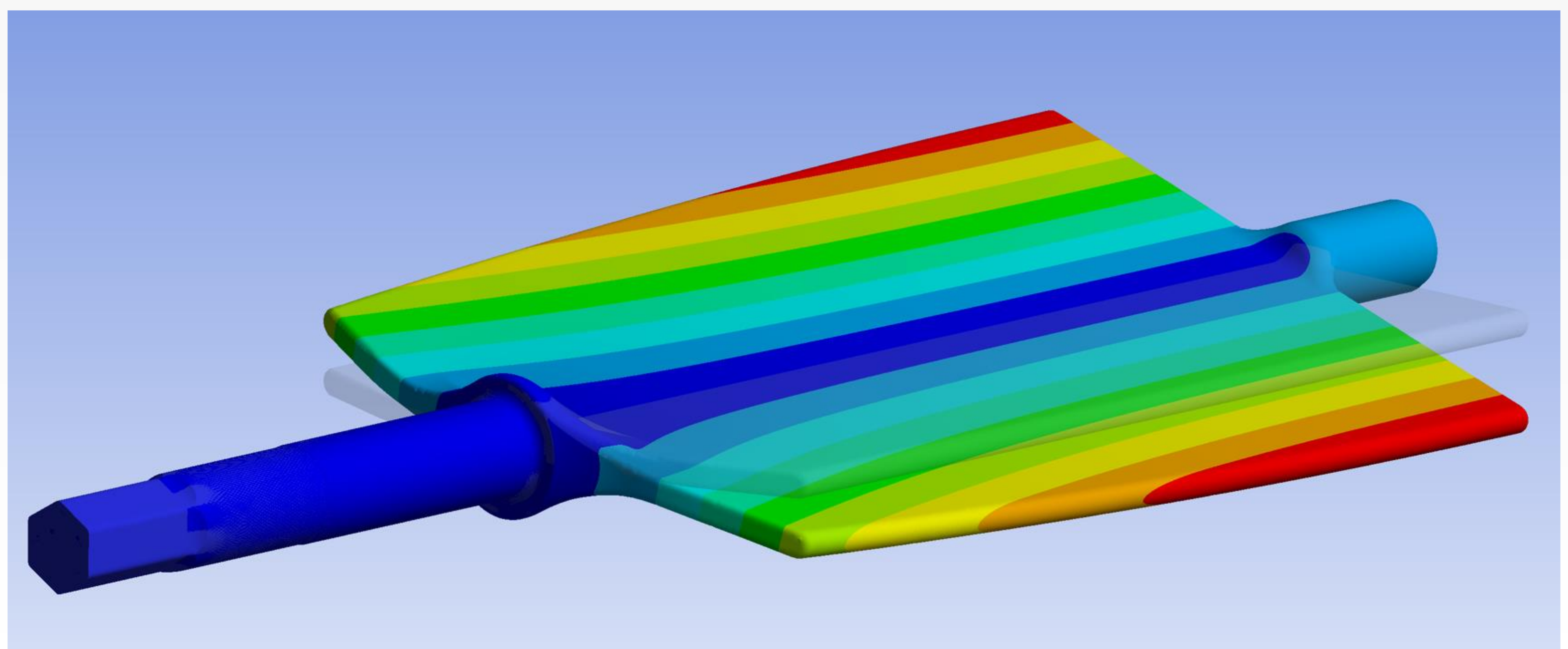

Fig. 3: Deformed shape of the blade.

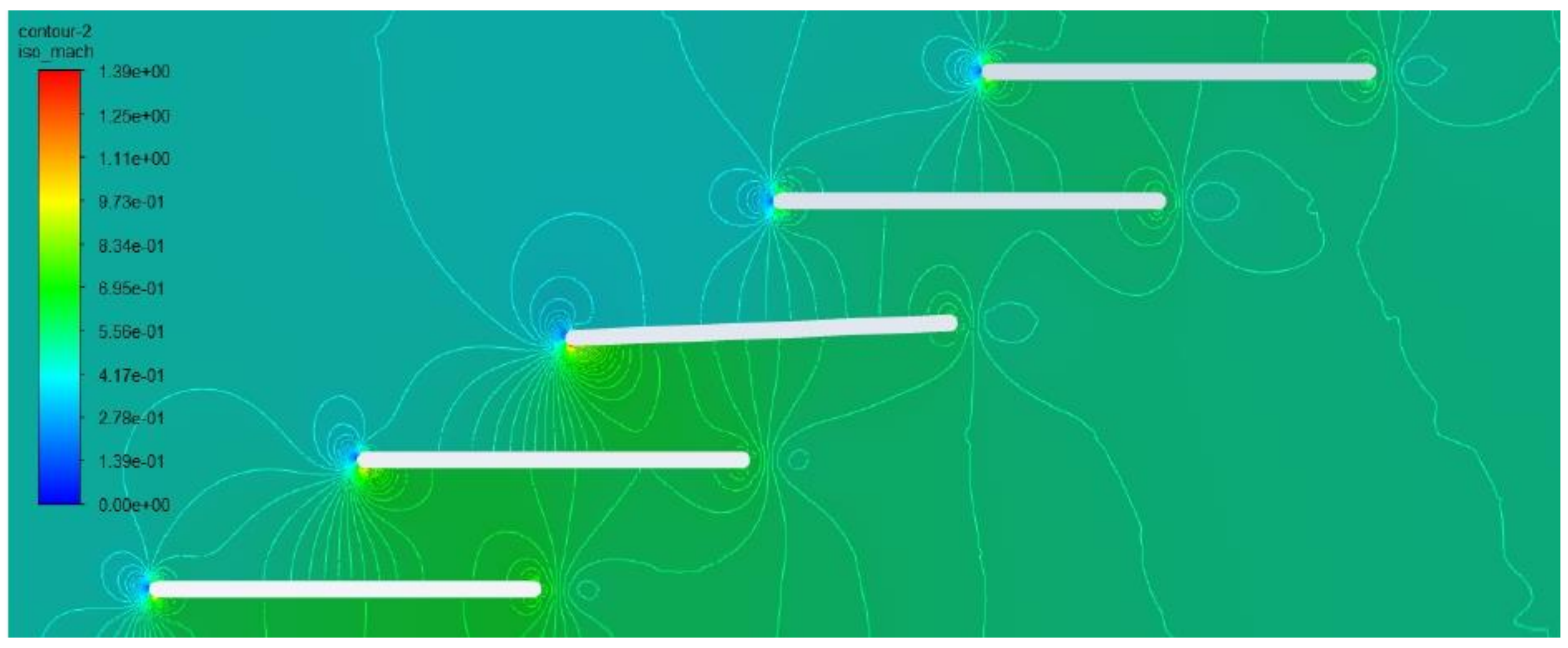

Fig. 4: CFD analysis of aerodynamic moments.

CONCLUSION

Several structural and CFD analysis were made for evaluation of performance of the steel blade and for design of the CFRP blade. The simulations show that the replacement of steel blade by CFRP blade is convenient and feasible.

	Steel	CFRP
Vertical displacement [mm]	1,93	1,15
First eigenfrequency [Hz]	287	357

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