

An Experimental Investigation of Flow in a Full-scale Kaplan Turbine (PORJUS U9)

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Content

- ❖ **Porjus U9 Unit**
- ❖ **Measurement Methods**
- ❖ **Objectives of the project**
- ❖ **Fluid-structure interaction simulation and modal analysis**



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Porjus Foundation

History

- 1910-1915: The Porjus station was built.
- 1971-1980: 2 units were added with total capacity of 480 MW.
- 1998: The R&D plant with U9 unit was inaugurated.



Kaplan Turbine-U9 unit

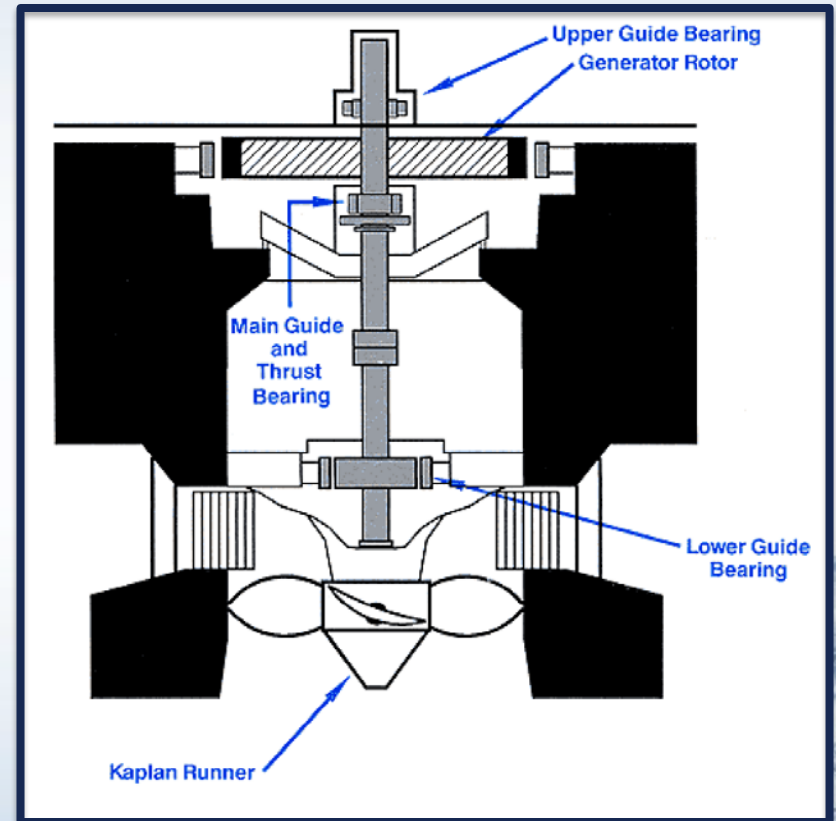
- 10 MW prototype turbine
- Runner diameter of 1.55 m
- 6 runner blades, 18 unequally distributed stay vanes, 20 guide vanes.

Problem

- Many transients due to renewable energy
- Blade bearings

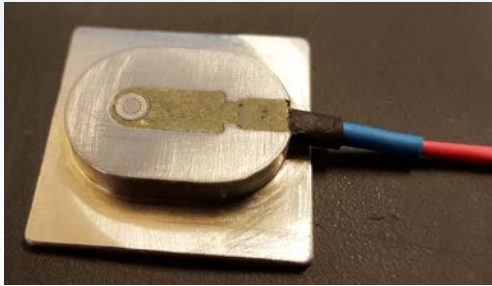
Hypothesis

- Loads on the blades during transient operation are “unclear”

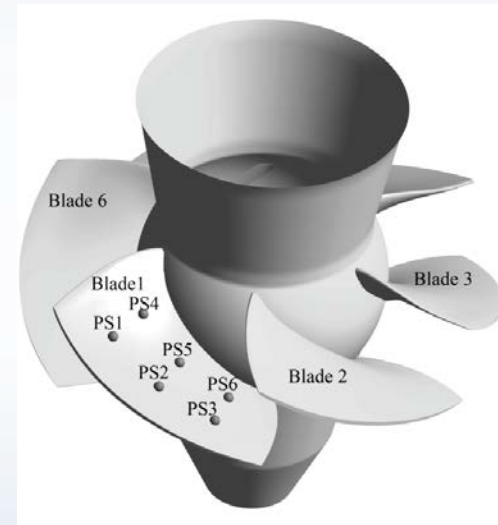
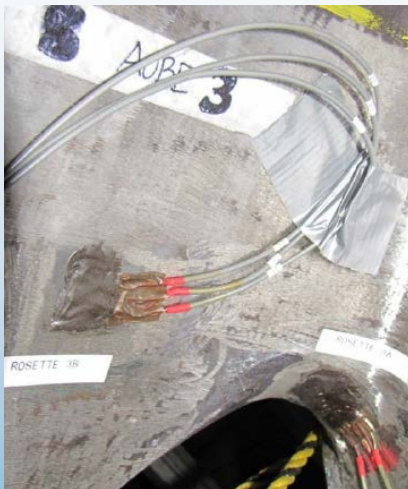


Methods

- Pressure measurement on the blades



- Strain Gauges on the shaft and runner blade
(Torque, Axial force, Bending moment)



Methods

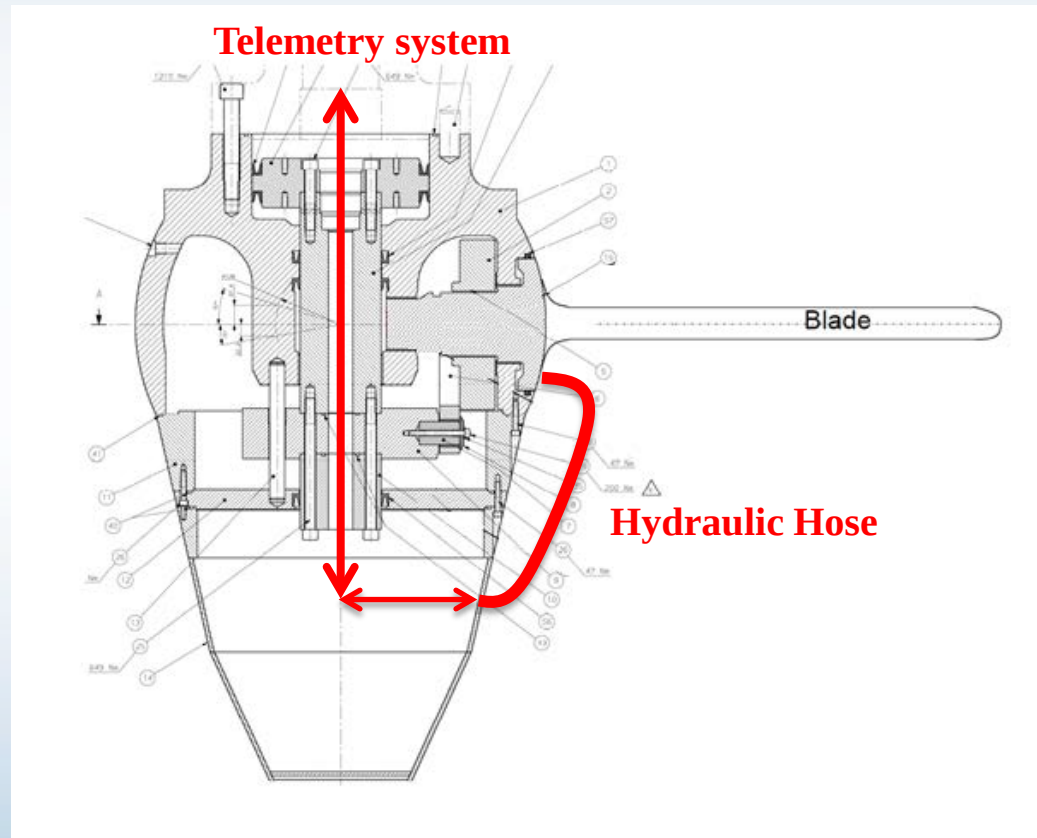
- Velocity measurement - LDA



- Accelerometer



DAQ system



Objectives

Pressure measurement

- ☐ Pressure measurements on the runner during steady and transient operation.
- ☐ Use the prototype and model results to study scale-up effects
- ☐ Providing a data-base for U9 prototype numerical simulation



Objectives

Strain gauge measurement on the runner and shaft

- ❑ Evaluate steady and unsteady stresses on the runner and shaft during steady and transient operation.
 - ❑ Find the critical regions subjected to higher stresses during the steady and transient operating condition
- ❑ Using both measurements on the runner and shaft to provide a procedure in order to calculate the stresses on runner by means of indirect measurements (on the shaft)
- ❑ Providing a data-base for fluid-structure interaction analysis of U9 prototype

Objectives

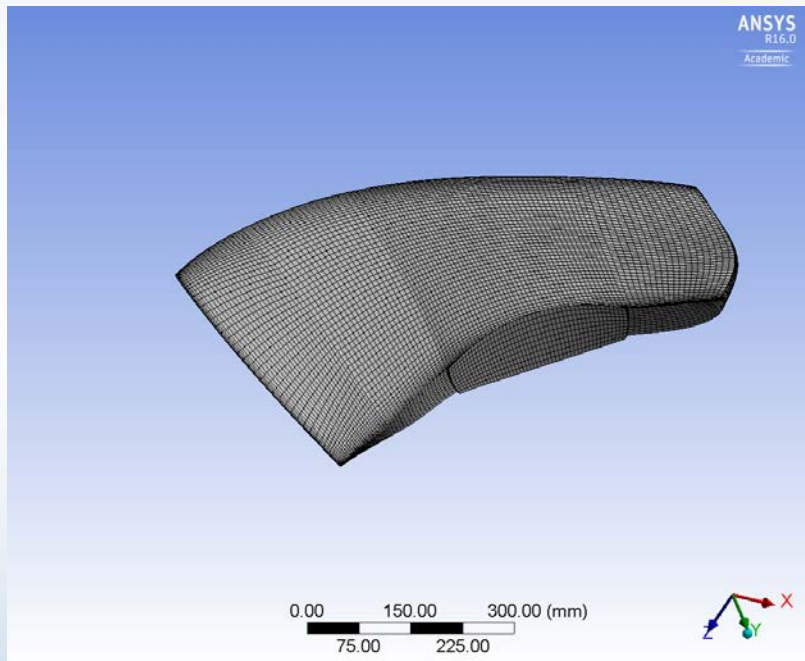
Velocity and vibration measurement

- ❑ Velocity measurement within and after the runner
 - ❑ Capturing various phenomena during different operating conditions
 - ❑ Comparing results of prototype with model
- ❑ Vibration measurement with accelerometers on the runner and bearings
- ❑ Providing a data-base for U9 prototype numerical simulation

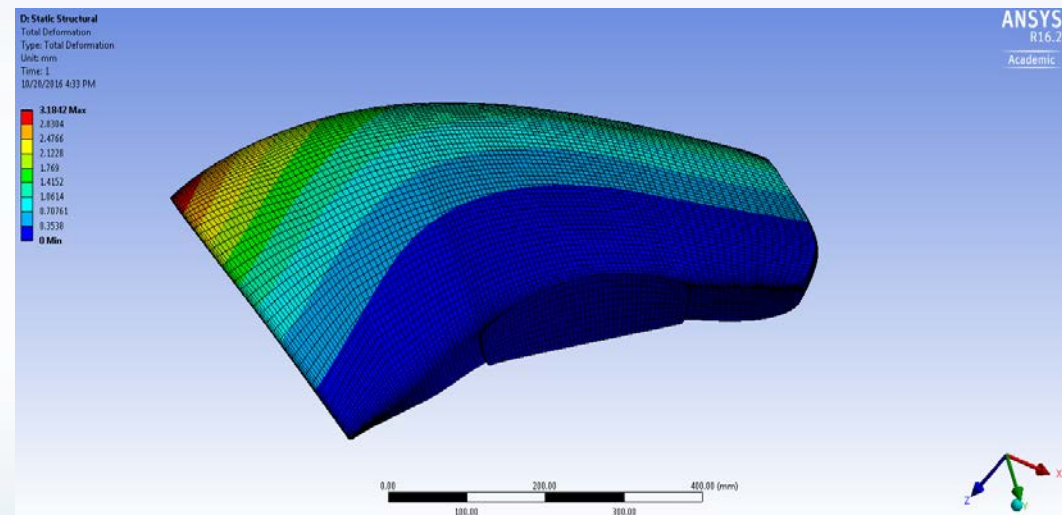


Strain gauge locations

□ Fluid-Structure Interaction of the U9 runner

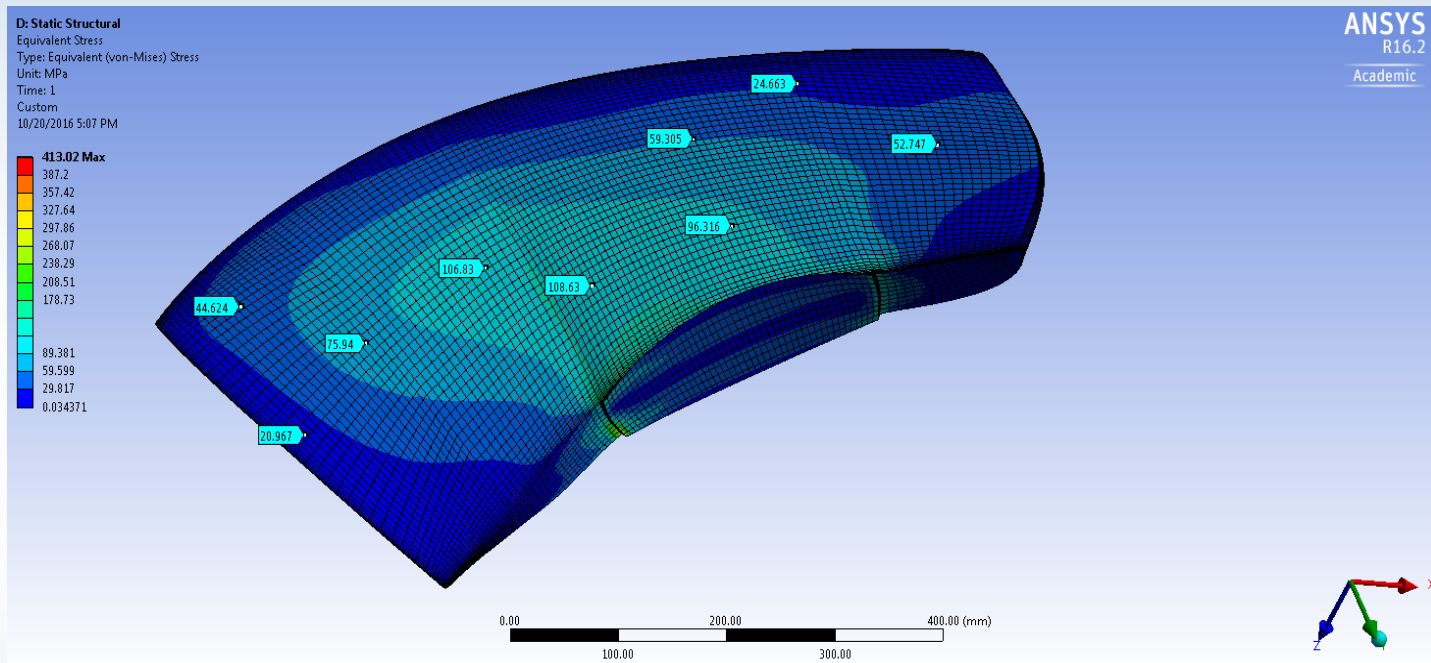


The structured mesh of the individual U9 prototype blade



Total deformation of the U9 runner blade – One-way FSI





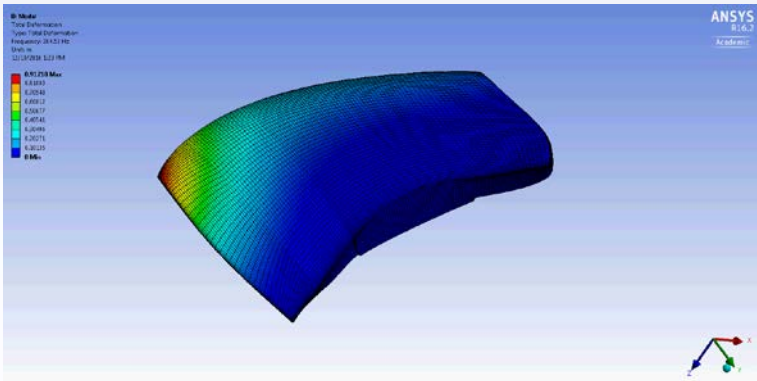
The equivalent (von-Mises) stress of the runner blade



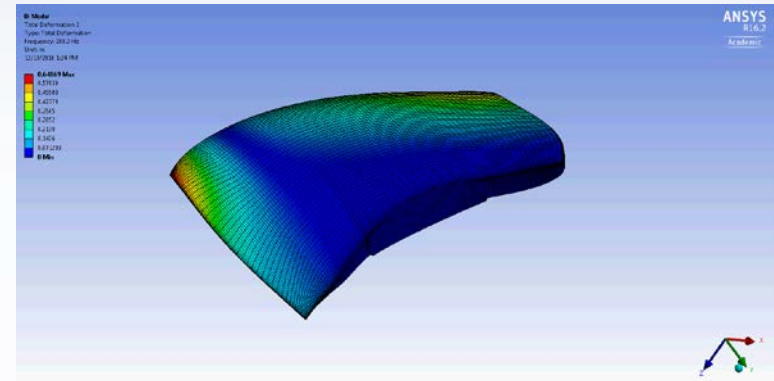
Porjus U9 measurement design

□ Modal analysis of the runner

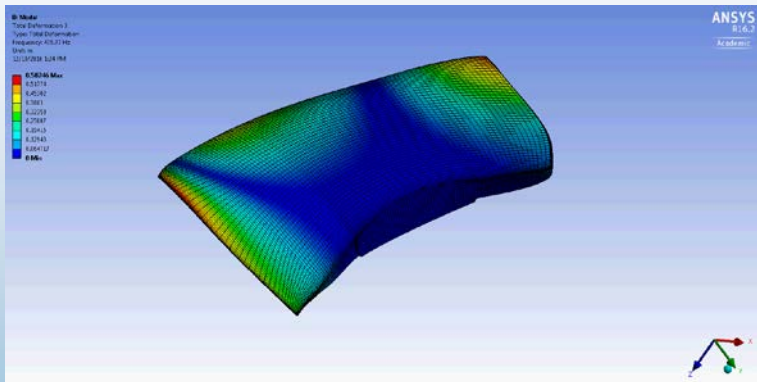
Bending Mode



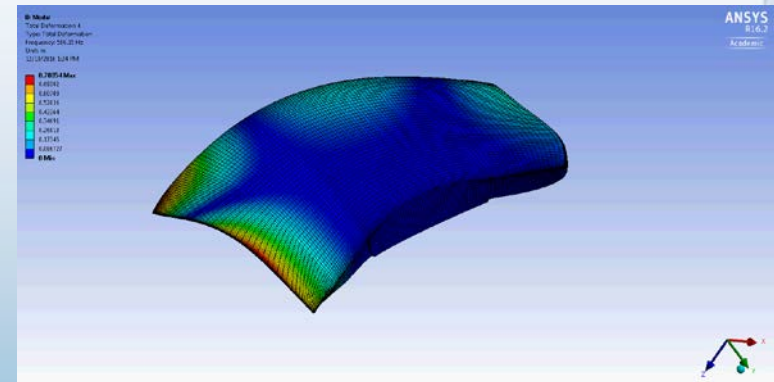
First Nodal Diameter



Second Nodal Diameter

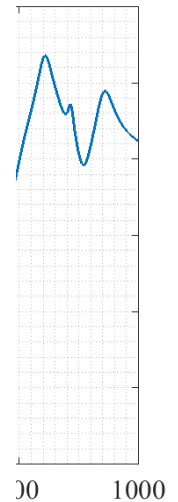
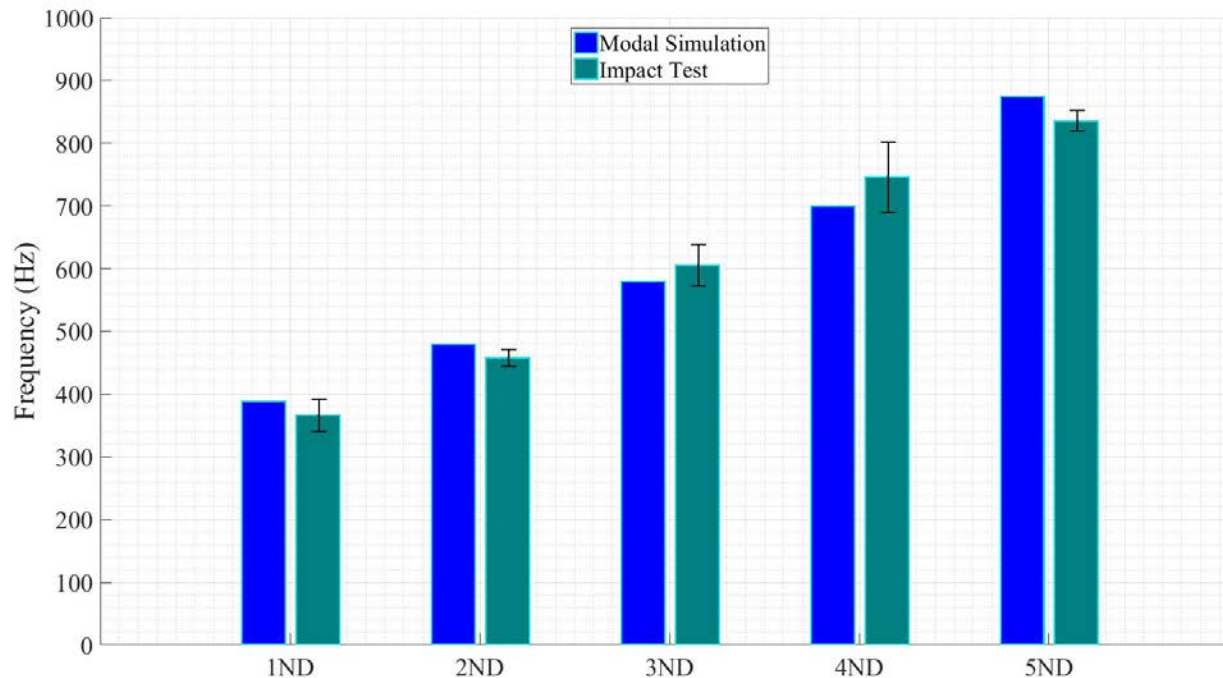
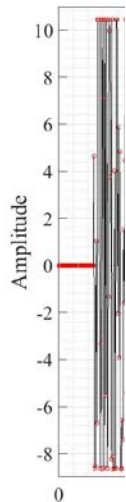


Third Nodal Diameter



Porjus U9 measurement design

- Impact test – U9 prototype runner



Impact test

The frequencies of nodal diameters

~~im~~ **impossible.**

Thank You