Analysis of the unstable behaviour of pump-turbines in pumped-hydro energy storage plants

Reversible pump-turbine machines are the most common mechanical equipment used in the new generation of pumped-hydro energy storage plants and they are generally preferred to other technical arrangements because of their cost effectiveness. Indeed, pump storage plants have the ability to act as a battery and can support fast grid changes, thanks to their flexibility. Therefore, they are the ideal complimentary solution for intermittent renewable energies. However, to do this they require faster and more frequent changes between pumping and generating modes and more operation of the machine under off-design conditions. Even though varying the rotational speed of pump turbines has allowed increasing the continuous operating range of pump-turbines, some hydraulic instabilities at part load in both pump and turbine modes still exist.
This represents a limit for the exploitation of a more extended continuous operating range of pump-turbines.
Experimental analyses were carried out on a pump–turbine in pump mode to study the characteristics and the development of the unsteady phenomena in saddle-instabilities region. Both the pressure variation in time and frequency domains and high-speed flow visualizations were used to detect and analyze the unsteady patterns developing in the instability region from 45% to 70% of the design flow rate (Fig. 1).
In turbine mode, the unstable behavior of a pump-turbine during a load rejection scenario with servomotor was investigated by a numerical analysis of the speed-discharge characteristic up to the pump-turbine brake zone. The onset of unsteady phenomena in the pump-turbine resulted not to be a sufficient condition for giving rise to the unstable behaviour. Only when they evolved in a fully-developed rotating stall (Fig. 2) characterized by a well-defined frequency, did the head start to increase causing the S-shape, suggesting the development of proper design criteria as a possible solution to limit or eliminate the unstable behavior.

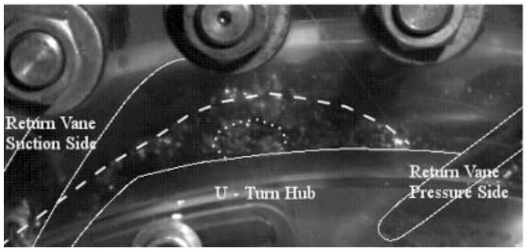

Fig. 1

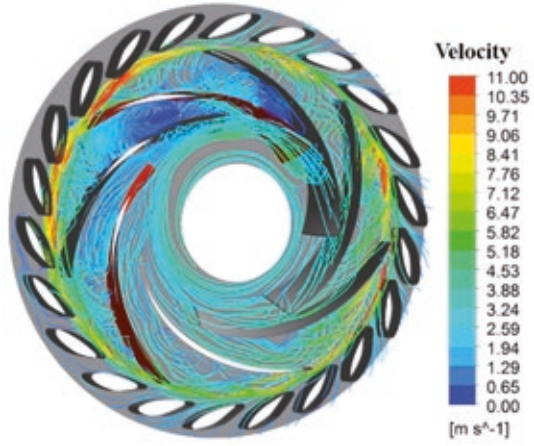

Fig. 2

Energia
Energy

DII research group
TES – Macchine a Fluido
e Sistemi Energetici

Giovanna Cavazzini
giovanna.cavazzini@unipd.it
phone: +39 0498276800

Giorgio Pavesi
giorgio.pavesi@unipd.it
phone: +39 0498276768

Guido Ardizzon
guido.ardizzon@unipd.it
phone: +39 0498276763

Assisted by
Eng. Alberto Covi
Eng. Jun Yang

www.dii.unipd.it/macchine-fluido-e-sistemi-energetici

The research project was supported by the University of Padova (No. CPDA130025/13), National Natural Science Foundation of China (Grant No. 51409123), and China Postdoctoral Science Foundation funded project (Grant No. 2014M560402).
The research project is carried out in collaboration with Alstom Power (France), University of Madrid (Spain) and Jiangtsu University (China)

Main research topics:

- Optimal design and management of hydro and pumped-hydro power plants
- Design and optimization of hydraulic and wind turbines (VAWT and HAWT)
- Cavitation, instability and pressure pulsations in turbomachines at design and off-design operation conditions
- Design and management optimization of energy systems by means of multi-criteria methods, Life Cycle Assessment (LCA)
- Gas turbines: development of numerical codes for performance prediction
- Aerodynamic optimization of rotors of helicopters and of high efficiency profiles isolated and detached