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Experimental validation of an integrated optimization design of a radial turbine for micro gas turbines

Key words: Micro radial turbine, Integrated optimization design, Bearing and shafting, Performance test

Radial turbine design

Aerodynamic design

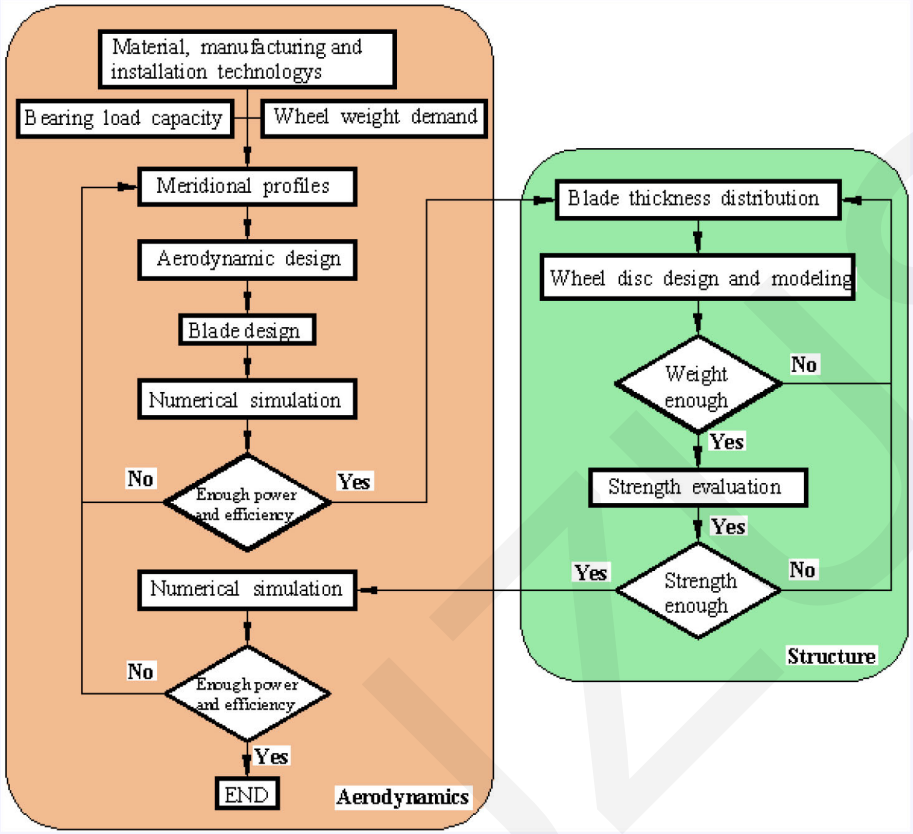
- ✓ Tan et al： a large deflection blade design method
- ✓ Zangeneh： extended to 3-D flows and applied to a radial turbine design.
- ✓ Huang：the cylinder parabolic geometrical design method.
- ✓ Ebaid et al：a unified approach for designing a radial inflow gas turbine at 60,000rpm and maximum of 60kW electrical power output.

Structural and strength design

- ✓ Watanabe et al：presented an optimization of microturbine aerodynamics using CFD, inverse design and FEM structural analysis.
- ✓ Guo： investigated blade vibration of a radial turbine wheel for microturbines.
- ✓ Xie：selected four parameters, middle inlet and outlet angle of blade, thickness in the middle of blade tip and bottom, to optimize the geometry of blade.

⇒ The research including consideration of aerodynamic performance, structural strength and turbine wheel weight is required.

Integrated Optimization Design



Flow chart of integrated optimization design

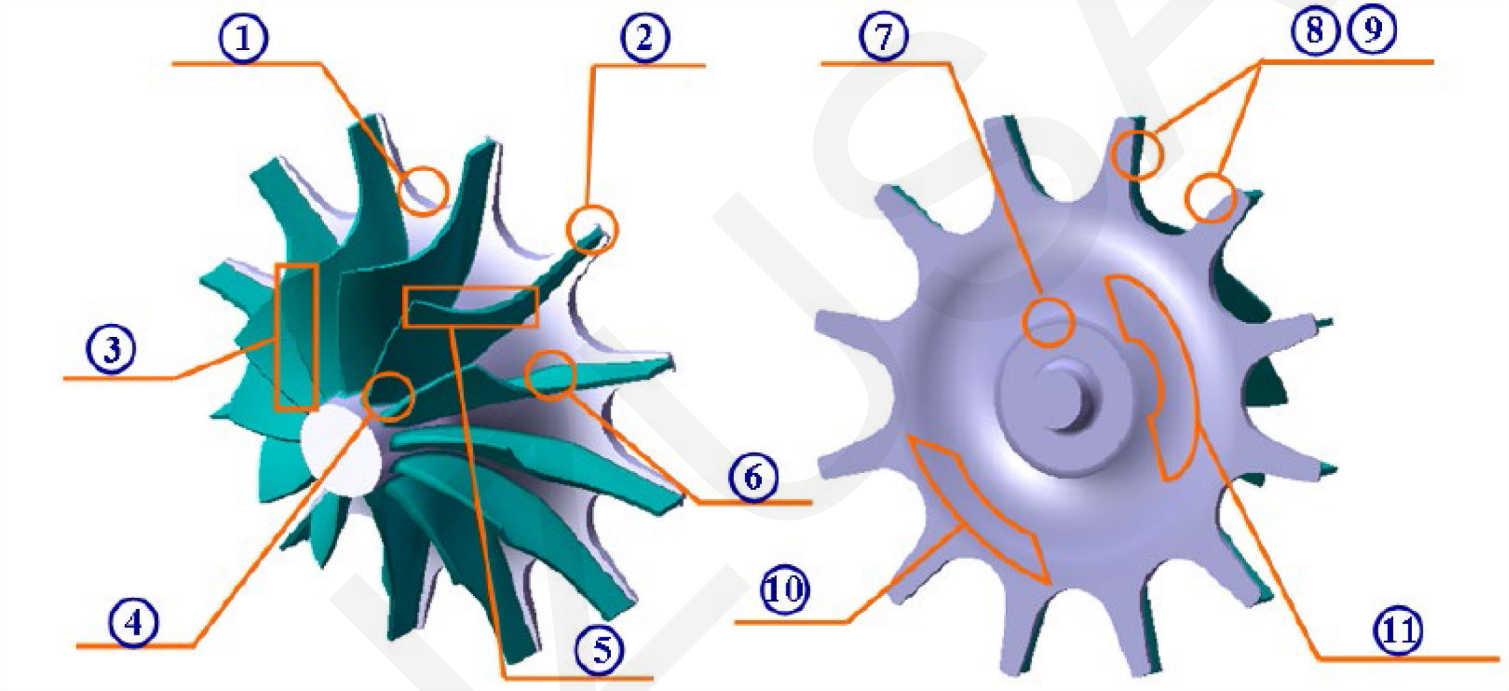
1) This method is nonlinear but an iterative and repeat process with trade-off considerations among three aspects.

2) Core steps of this optimization design method are meridional design in the aerodynamics process and blade thickness distribution in the structure modeling process.

3) The iteration design is stopped until the new turbine wheel meets aerodynamic and strength requirements with acceptable weight synchronously.

Integrated Optimization Design

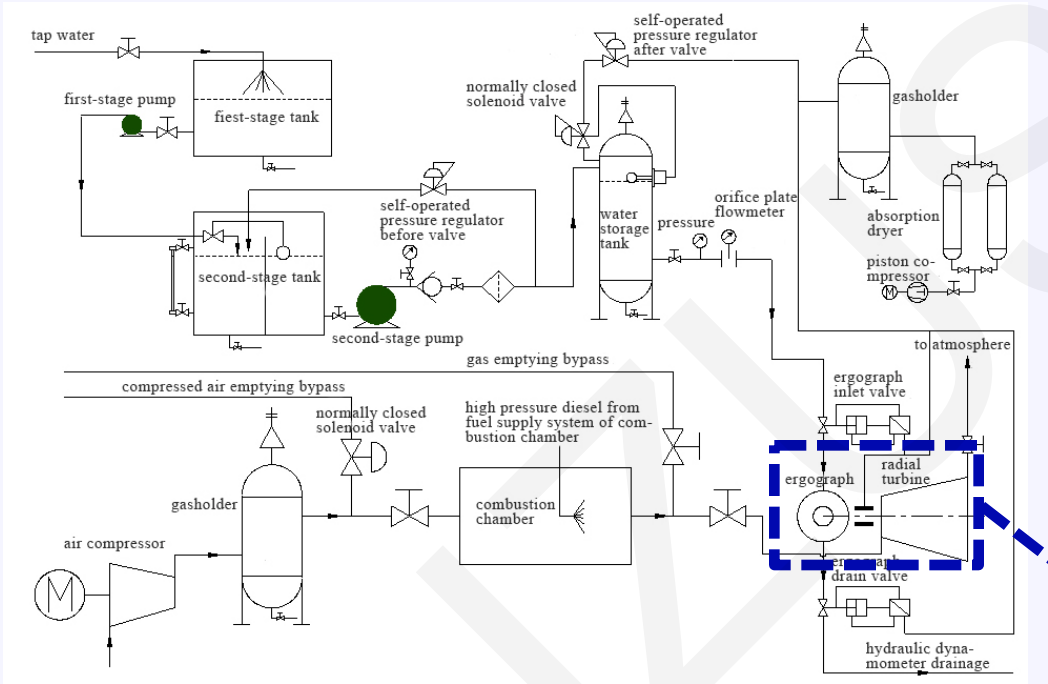
Design results : 11 modifications and optimizations

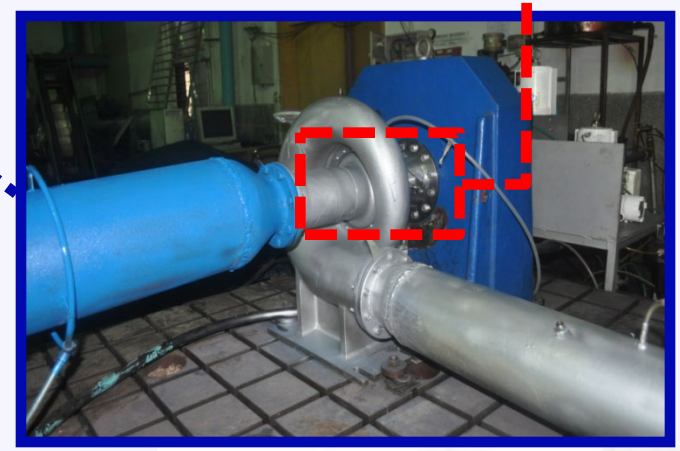


Different optimization regions of the turbine wheel

Experiments on the aerodynamic characteristics

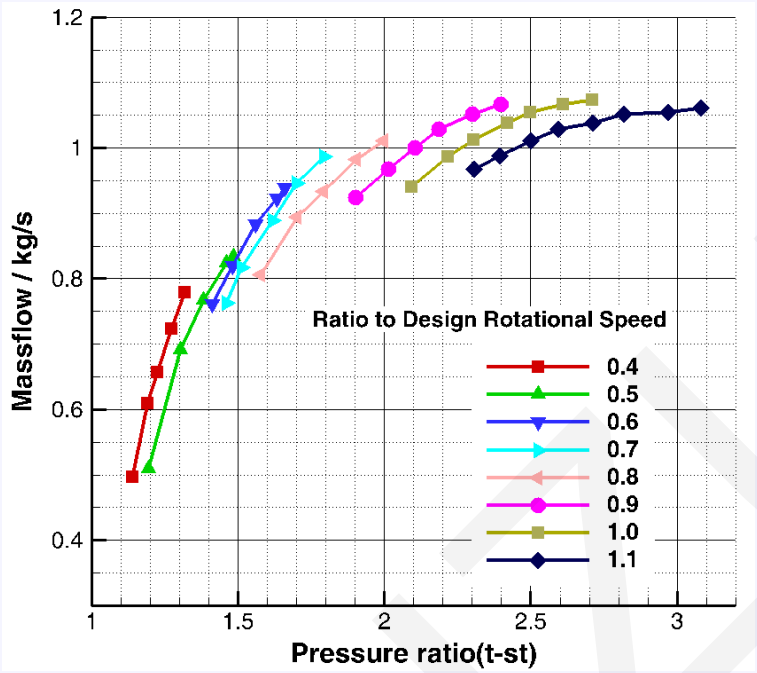
Experimental setup:



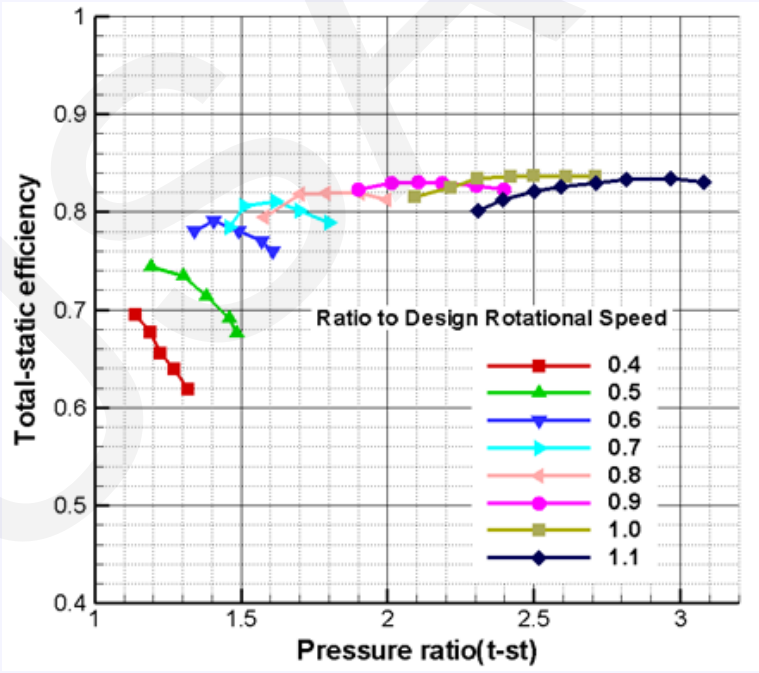


Experiments on the aerodynamic characteristics

Results:



(a) Corrected flow



(b) Total- static efficiency

The overall performance of radial turbine vs. the Pressure ratio

Conclusions

- At the design speed, the total-static efficiency of the radial turbine reaches up to 84.3%. The experimental results show that under the premise of material strength and weight reduction, the aerodynamic performance of the micro radial turbine is good enough to meet the requirements for engineering applications.
- The experiment has validated the reliability of the integrated optimization design method of radial turbines, which is to some extent a significant progress in the aerodynamic design and comprehensive design of micro radial turbines.

More details for design method of micro radial turbine:

(1) Fu L., Shi Y., Deng Q. H., et al. , 2012. Integrated Optimization Design for a Radial Turbine Wheel of a 100kW-Class Microturbine. ASME Journal of Engineering for Gas Turbines and Power, 134(1):012301-1/8.

(2) Fu L., Shi Y., Deng Q. H., et al. , 2010. Aerodynamic Design and Numerical Investigation on Overall Performance of a Micro Radial Turbine With Millimeter-Scale. ASME Journal of Engineering for Gas Turbines and Power, 132(3):032301-1/8.