PhD in Mechanical Engineering

Research Title:
Digitalized Virtual Engineering and Testing of Lean Rotating Systems

Funded by	DIMEAS

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Contact	This activity is a joint activity of the three research groups in: a) http://www.dimeas.polito.it/en/research/research_groups/design_of_powertrain_and_engine_components_materials_testing_and_simulation (Proff. Delprete, Rosso) b) http://www.dimeas.polito.it/en/research/research_groups/design_of_rotating_machines_and_mechatronic_systems_mechatronic_laboratory (Proff.Tonoli, Amati) c) http://www.dimeas.polito.it/en/research/research_groups/design_and_experimentation_of_industrial_and_railway_systems_and_microsystems/research_topics/research_topics_industrial_systems (Prof.Brusa)

Context of the research activity	The challenging targets of the Sustainable Development Goals (www.aics.gov.it) impose even to rotating systems engineering and design to pursue a strong effort to decrease the environmental impact of industrial machines and rotors, in terms of noise, power consumption, risk for operators, and waste of materials. Those goals motivate to improve the rotor safety, continuous monitoring, reliability, maintainability, and availability, by resorting to some new enabling and innovative technologies, as those included within the frame of the Industry 4.0 strategic initiative (MISE - www.sviluppoeconomico.gov.it), but not only. They even aim to make leaner the system as an industrial product of newest generation. New rotating industrial systems must fulfil stringent

	requirements with respect to Safety, Noise, Vibration, Harshness and weight reduction. Nevertheless, reaching those targets looks rather difficult, since some of those goals are often mutually conflicting. The weight reduction combined with a higher angular speed very often leads to an increasing level of noise and to a reduced endurance. Moreover, at higher spin speed shafts, gears, bearings behave more as flexible systems, and thus vibrations might be larger, especially as the influence of gyroscopic effect on the dynamic behavior of rotor increases. Those targets require the development of three issues of the rotor design as: • The straight implementation of the digitalized system engineering, from the customer needs to service to allow a consistent requirements management and system integration (http://www.dimeas.polito.it/en/research/research_groups/design_and_experimentation_of_industrial_and_railway_systems_and_microsystems/research_topics/research_topics_industrial_systems); • The numerical simulation of the whole system dynamics, including all the tools allowing the representation of the 3D virtual mock-up of the system (http://www.dimeas.polito.it/en/research/research_groups/design_of_powertrain_and_engine_components_materials_testing_and_simulation/research_lines); • The enhancement of testing facilities, aimed to precisely monitoring the system safety and damage occurrence in destructive tests (as in the spin test facility) and the smart monitoring of structural health in service, through an instrumented test rig allowing a complete retrieving of main service parameters (as in a remotely controlled rotor test facility equipped with smart bearings). Those goals motivate to develop a research activity based on a real and industrial test case, to be fully designed, which implements the Model Based Systems Engineering (MBSE, https://aise-incose-italia.it/). Practically speaking some challenging issues of that activity include: • Analyzing the rotor as a system, since the beginning of design, by resorting to the tools of MBSE, i.e. by tracing customer needs and requirements, allocating them to system functions and architecture components; • Simulating the rotor system behavior, by even performing a trade-off activity between proposed solutions, strictly based on the 3D modelling of the rotor system. It is known that many components of the rotor system (aircraft gearbox, electric car gearbox, high production machinery gearbox) cannot be easily studied through some 1D and 2D models, but they need a full 3D model to investigate the coupling effects between in-plane

	and out-of-plane modes of disks, flywheels and other accessories. At present the available commercial software (Ansys and Samcef) only partially cover the need for a 3D virtual engineering of rotor. The proposed Ph.D. aims to detect and overcome those limitations, through some innovative modelling approaches of the rotor structural dynamics. • Testing the rotor prototype by resorting to a new facility, aimed to be suitably equipped with digitalized in situ and remote monitoring systems, aimed at identifying the rotor behavior, its current structural health and predicting residual life.

Objectives	1. Defining a systematic approach to develop the lean rotor product, with specific attention to energy saving, cost reduction and low noise emission, based on the digitalized MBSE processes. 2. Developing some new modelling approaches to simulate the structural dynamic behavior of the rotor test case, by resorting to a full 3D representation for a straight detection of the gyroscopic effects and coupled phenomena. 3. Testing the built system by a new facility specifically conceived to allow prompt condition monitoring, structural health diagnosis and system failure prevention.

Skills and competencies for the development of the activity	The candidate should know: Structural Dynamics, Finite Element Method and Fundamentals of Machine and System Design.