HORIZON 2020

models, EXperiments and high PERformance computing for Turbine mechanical Integrity and Structural dynamics in Europe

Reporting

Project Information

EXPERTISE

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Project website

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Ongoing project

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Coordinated by
POLITECNICO DI TORINO
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Periodic Reporting for period 1 - EXPERTISE (models, EXperiments and high PERformance computing for Turbine mechanical Integrity and Structural dynamics in Europe)

Reporting period: 2017-03-01 to 2019-02-28

Summary of the context and overall objectives of the project

Development of incremental and disruptive technologies in the areas of Energy and Mobility will have key impacts on the world's societies, and on safety, security and competitiveness of Europe.
Amongst those technologies, turbines will play a major role:
- recovery of shale gas depends decisively on compressors;

- recovery of shale gas depends decisively on compressors;
- modern gas supplied power plants are bridging towards the age of renewable energies;
- aero-engines are to undergo the most massive changes in their history with the advent of composite materials, gear boxes, and turbine-electric concepts separating generation of power and thrust.

A technological commonality of the upcoming challenges is the need for full model based development and computer system simulation to address the societal needs of Quality and affordability and Safety, while reducing the development time of new products.
The structural dynamics and vibration questions are at present far from being addressed adequately. There are two main reasons for this:

- the physics of mechanical joining technologies that dominate the damping behavior of the large-scale structures are not yet fully understood;
- high performance computing (HPC) capabilities are not fully exploited in nonlinear structural dynamics.

Thus, we proposed a European contribution through the Marie Curie Integrated Training Network EXPERTISE, whose ultimate research objective is to develop advanced tools for the dynamics analysis of large-scale models of turbine components to pave the way towards the virtual testing of the entire machine (i.e. whole engine simulations).

EXPERTISE will address some of the challenges on the way to a fully validated nonlinear dynamic model of turbo-machinery components, by bringing together world leading institutions and companies from across Europe in a multidisciplinary project with the following scientific goals:
- improving the understanding of the physics of friction contacts in order to develop, identify and validate advanced models for dynamic simulations of turbomachinery models;
- developing efficient and accurate analysis tools for the nonlinear dynamics of turbomachinery components, based on two different and complimentary approaches: Reduced Order Models (ROMs) and Domain Decomposition Methods (DDMs);
- taking advantage of High Performance Computing (HPC) with the objective of increasing the productivity of applications developers, by extracting sufficient parallelism from the application, and doing I/O in an efficient manner.

Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far

In the first reporting period, the WP1 activity focused on stationary frictional contacts typical of turbomachinery applications with the development of analytical solutions to determine the stress state. In order to improve the current contact modeling techniques, the equations that characterize interface discontinuity accounting for friction, wear and thermal effects were developed with a special focus on the third body concept. In parallel, a software for the nonlinear forced response of structures with localized nonlinearities was developed, embedding the Archard wear model and closed-form solutions to calculate normal and tangential contact stiffnesses in case of rectangular contact areas. From the experimental side, experiments have been conducted on the existing 1D Friction rig at Imperial College London to improve the understanding of the rig itself and to generate reliable and accurate measurements.

measurements.

In WP2, different interface identification techniques have been compared and it was concluded that the state of art in decoupling methods is at a level that linear joint identification can be done if a suitable interface is defined. FRF decoupling technique was also initially applied to a linear bolted connection by using a FE dynamic model of two bolted beams, whose response was used as simulated experimental values and will be used to identify the properties of the simplified joint element.

In WP3, on one side, the research activity has been focussed on the identification of contact parameters at joints by substructuring method by the method of Lagrange multiplier frequency based substructuring (LM-FBS).
In parallel, the development of massively parallel simulation models for the different systems in a water turbine started and focused on (i) Development of a numerical model (ii) topology optimization by different algorithms; (iii) Reading and parsing of mesh data using parallel programming. A python library ContPy, was developed in order to easily integrate Finite Element modules with Continuation Techniques and Alternate-Frequency-Time (AFT). A Dual Cyclic Symmetry was formulated in order to take advantage of similarities among sectors and a set of Matlab codes for 3D structures with geometrical nonlinearity was developed to run harmonic balance method with continuation algorithms. Finally, different modelling and solution techniques used in the mathematical modelling of rotors, were implemented together with FETI methods as a first step towards highly parallel solvers for contact problems with friction.

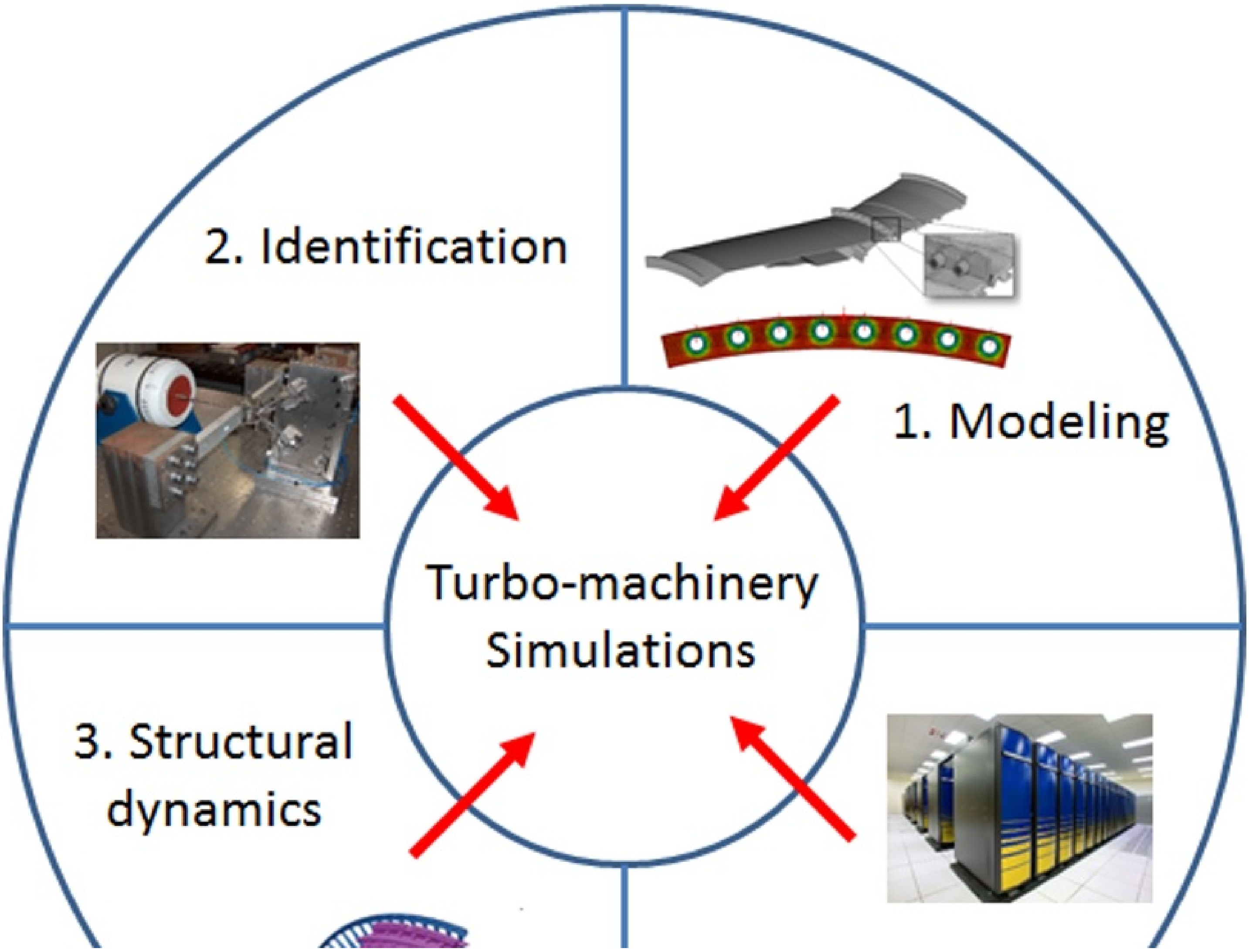
In WP4, the activity was focused on I/O and task-based programming models, by developing small benchmarks to test the performance of different file formats. The activity also focused on the needs of the data structures used by applications used for dynamics analysis of large-scale models of turbines focusing on the FETI-DP domain decomposition method. A mechanism inside dataClay was developed to enable application programmers to define the consistency mechanisms. The characterization of I/O performance on HPC systems was also performed and a set of I/O benchmarks was used to measure the impact of parameters of the parallel filesystem. Synthetic I/O benchmarks was designed to implement typical I/O tasks of HPC applications. Finally, both state-of-the-art and emerging memory technologies were investigated, as well as the in-memory layouts and the optimizations, that can be exploited using some popular layout schemes, addressing the computation of memory slices to exchange when communicating between remotes processes.

Progress beyond the state of the art and expected potential impact (including the socio-economic impact and the wider societal implications of the project so far)

The EXPERTISE project aims at answering to two complementary needs:
- the need for mechanical engineers of the challenges related to the employment of high performance computers in mechanical design;
- the need for computer science engineers aware of the possible applications of HPC in the field of structural dynamics and mechanical design.

More accurate and numerically efficient simulations will enable system level predictions and reduce the number of experiments necessary for the product certification. Therefore, in the short and medium time, EXPERTISEN will contribute to reducing the development times and costs of turbines, while in the medium and long time it will contribute to answering to the societal needs for more efficient, less pollutant and more reliable gas turbines for applications related to energy generation, water-turbines, oil & gas extraction and aeronautics. Specifically in aeronautics, the ETN addresses the problems of safety of air transport and of time and cost efficiencies of air transport, included among the priorities for the European Aerospace Industry in the ACARE 2020 vision and in the ACARE Strategic Research Agenda.

Although the focus of EXPERTISE is on turbine, the technical contents and the results of EXPERTISE will be of interest to a broader set of industries (e.g. automotive, rail, aerospace and wind energy sectors).



The final target and the four pillars of the EXPERTISE project.

Mid Term Meeting in Barcelona - Group picture

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