D2.3 Pedagogical Improvement of e-Learning Tools

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2 Introduction

The WP2 of the Virtual Campus Hub project (EU FP7 contract RI-283746) is devoted at the development and implementation of a series of e-learning tools to be deployed to the VCH community. These consist of three remote laboratory exercises and a database of online examination tools for automatic correction with specific emphasis on sustainable energy and turbomachinery. Together with the other elements of the VCH project, the e-learning tools are tailored to meet the needs of a rapidly expanding community of online learners by taking advantage of the last advances in the information and communication technology.

This document describes the pedagogical concept and evolution of the e-learning tools included in WP2 of the Virtual Campus Hub project (EU FP7 contract RI-283746), and the achievements obtained since the project start.
3 Objectives

The objective for the e-learning tools of the VCH is to deploy the selected tools to the VCH technology in accordance with the tasks specified in WP2 of the project DOW:

- T2.1: Development and test of remote cascade lab
- T2.2: Development and test of remote pressure measurement lab
- T2.3: Development of and test of remote flutter lab
- T2.4: Development and test of examination tools for combination of large pool of multiple answers on “simple questions”.
- T2.5: Development and test of algorithms, and a database of energy calculation exercises, for automatic correction of “minor mistakes” while allowing the students to receive credits for the parts with “correct thinking”.

From the educational point of view, the primary interest is to assess the effects that the use of these e-learning tools introduces in the learning experience of the students involved in the online courses included in the VCH pilot. The challenge here is to meet the requirements and the expectations of a cross-institutional and cross-national audience of trainers and learners. Secondly, this project aims at investigating - from a teachers’ perspective - the effectiveness of sharing consistently time and resources consuming activities such as the implementation and supervision of laboratory exercises and examination practices. Additionally, based on the experience from the large scale testing of the e-learning tools at the home university and eventually during shared activities across the different institutions, a set of best practices for teachers and educators on the use and on the possible integration of such tools in existing or ad-hoc courses will be developed and documented.
4 Remote Laboratories

In this chapter the basic concept of a remote laboratory is introduced, followed by a description of the technical and pedagogical considerations that have driven the development of the three remote laboratories included in the VCH project. After a detailed description of the remote laboratories in their current version, a summary of the trial implementation is presented along with future work and recommendations.

4.1 Basic Concept

A remote laboratory is a laboratory setup that can be controlled and observed on distance by the use of information and communication technology. Different are the classifications of laboratories and of remote laboratories used in literature, but broadly speaking while a virtual lab is regarded as a software that simulates the behaviour of the instrumentation that would be used in a laboratory activity, a remote laboratory is based on granting access and operation of the actual experimental equipment to one or several users which are located somewhere far from the laboratory facility. The instrumentation to run, control, observe and acquire data is accessible through the web, and the final user is provided with software that allows interaction and exchange of data with such devices over the internet through specific protocols. A simplified representation of how a typical remote laboratory is operated is shown in Figure 4-1: in this specific case the experiment is controlled with a computer that serves also as a web server for the camera and for hosting the graphical interface to control the instrumentation.

Remote laboratories have been developed in the last decades by several universities around the world. While the first attempts were restricted to the field of ICT, increasing interest has arisen during the years and extended to very different disciplines, even outside the engineering context (Ma & Nickerson 2006). The driving factor of this success has been the need of ensuring learners the possibility to have hands-on experience even when they were not able to physically have access to the facilities and instrumentation because of economical or geographical constrains.
4.2 The Three Remote Laboratories in VCH

For the VCH project, three remote laboratories related to turbomachinery are to be established:

1. **remote cascade lab** focusing on the characterization of the steady aerodynamic flow through a cascade of turbine blades and on the determination of the aerodynamic losses by means of probe traverse measurements. Basic knowledge in turbomachinery and in aerodynamics is required thus being suitable for integration and use in introductory courses to turbomachinery.

2. **remote pressure measurement lab** focusing on the experimental techniques used for pressure measurements in turbomachinery. Particular emphasis is on the influence of different pressure tappings on the determination of the static pressure and on the procedure used for the calibration of aerodynamic probes. The laboratory is designed for integration and use in courses related to measuring techniques in turbomachinery.

3. **remote flutter lab** focusing on the phenomenon of flutter in turbomachinery. The experimental setup allows recreating the flutter conditions over a cascade of turbine blades at specific flow conditions. A solid background in unsteady aerodynamics and aeroelasticity is required thus being it targeted mainly to specialists and researchers in the field.

4.2.1 High Engineering Content, Less Complexity

One of the main considerations in the development of the remote laboratories in VCH has been to achieve a trade-off between a high engineering content of the laboratories and an easy operation of the remote equipment. This has been motivated by the following:

- Due to the complexity of the turbomachinery phenomena investigated, knowledge about accurate and comprehensive measurements is required;

- Target users are students, PhDs, researchers and engineers in the energy sector with a strong technical background and high expectations of the capabilities of the laboratories;

- A lab is operated within a laboratory exercise with specific time constrains. The user should spend as less time as possible on learning how to use the equipment and focus instead on performing experiments, observe phenomena, acquire results of interest and analyse them;

- Users might not have experience with experimental test and not fully understand the implications of certain commands to the system, thus needing it to be self-secure;

- Users might not have access to specific resources (e.g. software licences, administrator rights to install software or plugins, etc.). This is the case for example of students wanting to use the computers at their home institutions or professionals at their work place.

The expertise in the turbomachinery field, the experience gained in the development of previous remote laboratories, and the last advances in ICT have been joined in the attempt to create an
advanced remote laboratory setup accessible from any device and operable with any level of preparation thus being suitable for a cross-institutional and diversified pool of users. This has resulted in the design of a laboratory setup built with the higher standards of the automation industry and equipped with state-of-the-art instrumentation, the same as used for research purposes. The control system has been realized with the commercial software LabView (National Instruments Corporation 2013), the standard in data acquisition and control systems. In order to allow for the remote operation of the laboratories, different technologies have been investigated such as the ThinVNC and ThinRDP (Cybele Software 2013) and other client-server protocols including ThinLinc (Cendio AB 2013), the Remote Panels technology integrated in LabView (National Instruments Corporation, 2013), SCCT (Tools for Smart Minds 2013). The optimal solution for the scope of the project has been found with the adoption of the software LabSocket (Bergmans 2013) that allows communication between the web browsers supporting the websocket technology and the LabView program controlling the laboratory equipment. The result in users that have complete control of the lab from the very first second by having access to a graphical user interface (GUI) that does not require any software installation.

4.2.2 Three laboratories, one Facility

All three laboratory exercises included in VCH are based on aerodynamic flow measurements thus needing some sort of wind tunnel to be used. In order to reduce the development time and cost of these laboratories, a modular design of the system has been used where a different experiment – ‘module’ - is mounted inside a common wind tunnel facility as shown in Figure 4-2 depending on the particular laboratory to be performed.

As a drawback to this solution is the fact that only one laboratory at the time is available. This, however, is mitigated by the short time (approx. 15 min) required to change the setup from one experiment to another one. It is also justified by the fact that each lab is used relatively little. Assuming that 1000 students would use a lab for 2 hours\(^1\), in a group of three, it would result in the use of the facility of 666 hours/lab. For the three labs this would result in a usage of 2000 hours out of the yearly available 8760 hours.

\(^1\) Duration of the exercise and of its different phases is specified in the description of lab exercise.
4.3 The “Remote Laboratory Exercise”

A remote laboratory itself cannot be regarded as a comprehensive educational tool. In this sense it is more appropriate to talk about “remote laboratory exercise” where the value-added pedagogical function is achieved by the integration of different elements – such as self-study, hands-on experience, evaluation of the intended learning outcomes – that, coupled together, ensure the achievement of the desired level of knowledge and of competence in a specific field. Therefore major importance in this project has been given to the definition of the structure of a remote laboratory exercise.

4.3.1 Structure of the Exercise

The remote laboratory exercise has been conceived as an independent learning module consisting of a series of subsequent activities, each of them corresponding to a specific learning phase. These could eventually be assigned partial scores concurring to the overall grade of the learning module considered. The structure of the remote laboratory exercise as designed for the VCH project is summarised in Figure 4-3 and a description of the different phases is here included.

Syllabus, ILO and ALO

A remote laboratory starts with an overall description of the content of the exercise, including a short demonstrative video and a list of the topics of interest treated in the laboratory. Follows a presentation of the Intended Learning Outcomes (ILO) defining what students should know, understand and be able to do as a result of their learning experience with the remote laboratory.

Self-Study of “Knowledge Material”

The next activity as presented to the student is self-study based on lecture material, lab notes and videos that, depending on the background knowledge of the target group of users, is made available online.

This activity aims at providing the theoretical knowledge of the topic of interest and of the experimental techniques used in the laboratory.

Pre-Test

As a tool to verify that an adequate level of preparation has been achieved, a self-assessment test based on multiple choice questions (MCQs) and, if appropriate, calculation exercises, is presented after the self-study. The test is a prerequisite to obtain access to the subsequent activities.

Further description on the MCQs and calculation exercises follows in Section 5.2.

Planning

In a real laboratory environment some planning is required. This includes the reservation of the laboratory resources and the definition of the experimental activity to be carried out.
For this purpose, an online scheduling tool for the remote lab is provided where users can form the lab groups and reserve the lab resources for one of the time slots available. Depending on the specific laboratory exercise, the trainer decides whether specific procedures have to be followed during the experiments or if the group is expected to plan the activity that will be carried out in the remote laboratory during the following phase.

Figure 4-3: Structure of the Remote Laboratory Exercise
Lab Execution

This represents the core activity of the exercise. During this phase the students perform the measurements, observe the phenomena of interest, and collect experimental data. The work is structured as a series of tasks of increasing complexity, each of them followed by self-study questions promoting comprehension of what just measured and motivating the tasks coming thereafter. A basic achievement of the intended learning outcomes is already expected after completion of this phase.

Data Analysis and Assessment

Once the experimental activity with the laboratory equipment is over the group is required to analyse the data acquired and summarize results and observations. This should be done in a qualitative as well as quantitative way.

This phase is aimed at deepening the knowledge and understanding on the phenomena of interest as well as training the analytical skills of the students. It is thus directly related to the ILOs of the task.

Depending on the specific exercise a manually corrected assignment and or an online test for automatic correction is included, where questions and calculation exercises focus on the outcomes from the experiments.

Online Survey

The remote laboratory exercise ends with an online survey. The primary function of it is to collect feedback on the remote laboratory and on how the exercise has been seen from a learner’s perspective. At the same time students need to self-evaluate their achievement of the intended learning outcomes as well as reflect on how they related to the laboratory activity.

A template of the survey questionnaire is here included in Appendix I – Online Survey.

4.3.2 Online Integration

As evident from the description of the laboratory exercise, different are the online tools needed for the implementation of a remote laboratory exercise such as:

- Online scheduling tool
- Online assessment tool
- Graphical user interface
- Video streaming from the cameras
- Tools for data analysis
- Online survey

To the knowledge of the authors there is no product on the market that could offer all these functionalities in one. Different LMS (Learning Management System) have been evaluated that offer online scheduling, assessment and survey tools. Only one system was found that is specifically designed for the management of remote laboratories (WeblabDeusto, 2013). This
solution, however, does not support the websocket technology used for the control of the labs nor any sort of online assessment tool.

The final deployment of the remote laboratory exercises has been achieved with the realization of a website where free tools such as Doodle for the scheduling, Google Forms for the assessment and surveys have been integrated. This has resulted in a tool for the user where all information is collected and accessible in the same place\(^2\). This solution lacks however of some of the functionalities typical of a LMS such as student tracking thus being limited from the scalability point of view.

4.3.3 The Role of the Trainer

Given a remote laboratory setup, the role of the trainer is to define the ILO to be achieved, the knowledge material and consequently decide on the tasks to be performed and on the assessment criteria to be used. Experience from the use of the remote laboratories (Chapter 4.7) has shown that different laboratory exercises can be arranged with very little modification such as to better fit with the content of the course and with the target users, thus requiring a minimum intervention from the trainer if the lab shall be used in different courses with different objectives.

4.4 Remote Cascade Lab

The remote cascade lab – shortly RCL - focuses on the determination of the aerodynamic loss coefficient of a turbine blade row by means of aerodynamic probe traverse measurements. Basic knowledge in turbomachinery and in aerodynamics is required thus being suitable for integration and use in introductory courses to turbomachinery.

4.4.1 Intended Learning Outcomes

After completion of the Remote Cascade Lab exercise the learner should be able to:

- perform experimental testing of turbine blade rows based on probe traverse measurements
- determine the aerodynamic loss coefficient of a turbine cascade based on experimental data
- analyse the influence of the flow parameters (inlet angle, Mach number) and of the blade surface roughness on the downstream distribution of flow quantities and on the aerodynamic losses of a turbine cascade
- evaluate the observed phenomena and relate them to what taught during lectures and/or contained in the knowledge material

4.4.1 Experimental Setup

The RCL consists of the aerodynamic test facility - in other words a wind tunnel - for turbomachinery applications shown in Figure 4-4.
In the test section, a set of low pressure turbine blades is arranged such to form a linear cascade. The airflow comes from the inlet pipe and is discharged in atmosphere after passing through the cascade. The flow rate can be settled to different levels, as well as the cascade can be rotated to achieve different inflow angles. The measurement system consists primarily of aerodynamic probes for determination of pressures and velocities. The probes are mounted on the automatized positioning system shown in Figure 4-4 such as to determine complete spatial distributions. Further information in (Monaco et al. 2013).

4.4.2 Remote Control of the Lab

All the functionalities mentioned before can be used on distance. The user has control of the experiment through an online graphical user interface (GUI) where to set parameters such as inlet angle, flow speed and positioning of the probes. The experiment is monitored by having online access to the cameras installed in the test facility. The cameras have zoom and rotation functionality and the users can also select among different pre-set views focusing on the locations of most interest. The GUI and an example of a pre-set view pointing at the cascade of blades are shown in Figure 4-5.

![Figure 4-5: RCL – a. Graphical User Interface; b. network camera (right)](image)

The data acquired during the measurements are shown real time and send automatically at the specified email address.

4.4.3 The Laboratory Exercise: “Loss Measurements in a Turbine Cascade”

The remote cascade lab is arranged following the structure presented in Section 4.3.1 and presented to the students as composed of different tasks (lab reservation, self-study, online test, measurements, data analysis, survey), each of them with an estimated time of execution. The measurements are also organized as a series of tasks of increasing difficulty being the first to start up the wind tunnel. An example of task is here included, showing also the self-study questions aimed at promoting comprehension of the experiment:
Task 4 - Influence of blade surface roughness

In order to investigate the effect of modified blade surface roughness, a 1D traverse measurement at midspan over 5 pitches (3 baseline blades and 2 blades with modified surface) is performed with the parameters specified in Table 4. This corresponds to the probe traverse shown in Figure 2.

<table>
<thead>
<tr>
<th></th>
<th>Start Position</th>
<th>End Position</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pitchwise traverse</td>
<td>80 mm</td>
<td>90 mm</td>
<td>8</td>
</tr>
<tr>
<td>Spanwise traverse</td>
<td>50 %</td>
<td>60 %</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 4: 1D traverse measurement, measurement over 5 pitches.

Self-study Questions

- Do you notice any big difference in the distribution of p4 with respect to the previous measurement?
- Are the pressure dips in correspondence of the two additional blades deeper and/or wider with respect to the baseline blades? If so, do you think this is due to increased or reduced blade surface roughness?
- How do you think these differences affect the aerodynamic loss coefficient?

Figure 4-6: RCL – Example of task during the measurements

Optional tasks are proposed, depending on the time left and on the interest of the group in a specific aspect of the lab. The laboratory includes also an interactive tool for the analysis of the data. This can be used, for example, to visualize 2D distributions of the flow quantities and to compare some of the results as shown in Figure 4-7.

Figure 4-7: RCL – Interactive tool for data analysis.
4.5 Remote Pressure Measurement Lab

The remote pressure measurement lab – shortly RPML - focuses on the experimental techniques used for pressure measurements in turbomachinery. Particular emphasis is on the influence of different pressure tappings on the determination of the static pressure and on the procedure used for the calibration of aerodynamic probes. The laboratory is designed for integration and use in courses related to measuring techniques in turbomachinery.

4.5.1 Intended Learning Outcomes

After completion of the remote pressure measurement lab exercise the learner should be able to:

- have comprehensive knowledge and experience in pressure measurement techniques;
- determine the effect of different pressure tappings on the steady pressure readings;
- execute a simplified probe calibration and determine the probe calibration coefficients;
- analyse the influence and limitations of the data acquisition system and measuring techniques used on the results;
- evaluate the observed phenomena and relate them to what taught during lectures or contained in the knowledge material.

4.5.2 Experimental Setup

The remote pressure measurement lab is developed on the same aerodynamic test facility used for the RCL. In this case, the module shown in Figure 4-8 is positioned in the test section. The internal surface of the module, exposed to the flow, has a pattern of static pressure tappings of different shape, dimension and orientation.

*Figure 4-8: RPML – a. Module with pressure taps; b. detail of the pressure tappings; c. aerodynamic three-hole wedge probe used for calibration*
For the simplified calibration procedure included in the laboratory exercise the aerodynamic three-hole wedge probe also shown in Figure 4-8 is placed at different yaw angles using the same probe positioning unit as for the RCL.

4.5.3 Remote Control of the Lab

The GUI\(^3\) for the control of the RPML laboratory is shown in Figure 4-9 along with the view from the network camera pointing at the probe during an aerodynamic probe calibration.

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\(^3\) GUI realized using the ‘Remote Panels Technology’ of LabView.
4.5.4 The Laboratory Exercise

The remote pressure measurement laboratory exercise is arranged following the structure presented in Section 4.3\(^4\).

The measurement part is divided into two main tasks:

- check the influence of the shape of the pressure taps for three different Mach numbers
- perform the probe calibration for a range of different yaw angles, from -25 degrees to +25 degrees, at three different Mach numbers

For both tasks the parameters to be used are specifically assigned. Follow data analysis and reporting where specific instructions are given along with self-study questions. As for the remote cascade lab, students are asked to fill out an evaluation form that includes, among other, questions related to the achieved learning outcomes.

\(^4\) In this case, however, an additional task is required: the lab group needs to download and install the software necessary for the remote control of the laboratory (being the GUI deployed with the ‘Remote Panels Technology’ instead of with LabSocket). A demo GUI is then being used to verify the successful installation of the software. This task does evidently not add any educational benefit to the lab and it will be removed as soon as the GUI will be reprogrammed using the LabSocket technology.
4.6 Remote Flutter Lab

The remote flutter lab – shortly RFL – focuses on the unsteady aerodynamic behaviour of a cascade of low pressure turbine blades and on the phenomenon of flutter in turbomachinery.

Due to the complexity of the phenomenon, this laboratory exercise is mainly targeted to students, researchers and experts in the field of unsteady aerodynamics and aeroelasticity.

4.6.1 Intended Learning Outcomes

After completion of the remote flutter lab the learner should be able to:

- acquire steady and unsteady blade loading data
- identify which are the critical conditions leading to the phenomenon of flutter
- determine the critical reduced frequency and inter-blade phase angle of the travelling wave mode during a free flutter condition based on experimental data
- additional intended learning outcomes are to be defined

4.6.2 Experimental Setup

The remote flutter lab consists of an aeroelastically unstable turbine blade row that will exhibit self-excited and self-sustained flutter at specific operating conditions. The blades are free to oscillate in a torsional rigid body mode where the center of rotation is placed such as to achieve self-sustained vibrations. The blade support includes variable torsional stiffness which enables to study the concept of critical reduced frequency. The instrumented blades, the system for the variation of the torsional stiffness and the unsteady data acquisition system are integrated in the flutter module shown in Figure 4-11.

*Figure 4-11: RFL – Module with the oscillating blades and the instrumentation for unsteady pressure and motion data acquisition*
4.6.3 Remote Control of the Lab

The remote operation of the flutter lab is achieved using the GUI shown in Figure 4-12 and the network cameras installed in the facility. The GUI allows setting the flow conditions (inlet angle, flow speed) and the stiffness of the blades and shows real-time the pressure and displacement data from the five instrumented blades.

![Figure 4-12: RFL – GUI (left); view from the downstream camera facing the suction side of the oscillating and instrumented blades (right)](image)

4.6.4 The Laboratory Exercise

The remote flutter lab is not yet been regarded a laboratory exercise as defined in Section 4.3. Given the uniqueness of the setup and of the instrumentation adopted, the remote flutter lab is presently being used as a test case for research activities in the field of aeroelasticity (among other a research publication is planned for the upcoming ASME TurboExpo 2014) and evaluated by a group of Thrust alumni now working in industry and in academia. The outcomes of these activities are giving visibility and relevance to the remote flutter lab in the research community and leading to the definition of the laboratory exercise for full integration in the Thermal Turbomachinery course included as a test case in the VCH project.
4.7 Deployment and Assessment of the Remote Laboratories in VCH

This section summarises the steps followed and the outcomes from the test and implementation of the remote laboratory exercises in VCH.

4.7.1 First Round of Test – Courses at KTH

The conceptual and technical development of the three remote laboratory exercises included in VCH has primarily been driven by the requirements of the turbomachinery courses offered at KTH. The first and most natural implementation of the remote laboratories has consequently interested the following existing courses at KTH:

- MJ2429 Turbomachinery
- MJ2241 Jet Propulsion Engines – General Course
- MJ2240 Measuring Techniques

This activity has overall involved more than 150 participants (99 for RCL, 85 for RPML) during the autumn semester 2012 and detailed results are documented in D3.2 “Trial Implementation and Test of Two e-learning Tools” delivered in December 2012.

The outcome of the test is overall positive and encouraging, though it shows that improvements on both the educational as well as technical side had to be established. On the technical side the main limitation was represented by the difficulties encountered in the installation of the software required for the operation of the GUI. Secondly the fact that though very advanced, the remote laboratory did not transmit the same feeling as if being standing inside the lab room. On the pedagogical side two were the main challenges encountered: the achievement of the intended learning outcomes (average of 3,5 on a scale of 1 to 5) and the definition of whether the absence of a physical instructor hindered in performing the laboratory exercise. While the former was evenly distributed among the different laboratories and courses, the latter revealed to be very much dependent on the instructions given for the execution of the measurement and for the analysis of the data: the more freedom in the planning of the activity, the harder to finish the experiments on time and achieve the intended learning outcomes.

4.7.2 Improvement of the Labs

Based on the first round of test of the remote laboratory exercises, some changes have been introduced to the original solution in order to improve the weak points highlighted above.

Three have been the main actions taken:

- implementation of a GUI that does not require any software installation and that can be operated from any device to improve accessibility and ease of use
- change in the exercise structure such as to improve the achievement rate of the intended learning outcomes

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5 Students that have logged-in at least once the self-assessment
installation of an additional camera to increase the perception of reality of the lab

As introduced briefly in Section 4.2.1, the LabSocket software package has been used to develop a GUI based on the new websocket and html5 technologies. On the one hand the process of implementation of the system has been rather straightforward. On the other hand, the LabSocket has shown limited support of functionalities such as sliders, knobs, graphs. This has played a significant role against the goal of enhancing the pedagogical perception of the GUI. A graphical comparison between the original GUI and the new one based on LabSocket is shown in Figure 4-13 and is representative of the different level of information that is possible to exchange with the user. The careful process of selection of the essential elements has had the consequence of moving part of the information (such has the graphical representation of the blades and of the positioning of the probes) from the GUI to the laboratory instructions.

Figure 4-13: RCL – Original GUI deployed with the ‘Remote Panels Technology’ (top); new GUI deployed with the LabSocket system (bottom).
The design process of the new GUI has also taken into consideration the fact that the GUI would now be accessible from any laptop, tablet and smartphone. The result is a GUI of 1024x768 pixels where indicators can easily be seen and commands entered from the touchscreen of a common smartphone contributing significantly to the ease of use.

With respect to the structure of the remote laboratory exercise, changes have interested only the measurement and data analysis phases. The task of planning the experiments to be performed has been removed and substituted with a precise definition of a series of subtasks to be accomplished with only part of these relying on the students’ own initiative. An example of this is included in Figure 4-6. The same applies for the phase of data analysis. This modification constitutes also a typical example of how a more “analysing” ILO would fit into the 3rd cycle of higher education.

Last, an additional camera has been installed in the laboratory facility in order to increase the perception of reality of the laboratory. The camera allows very close monitoring of the probe during its positioning as shown in Figure 4-14.

**Figure 4-14: RCL – View from the additional camera installed in the facility**

### 4.7.3 Second Round of Test – Courses at KTH

In the attempt to establish the effectiveness of the changes made to the remote laboratory exercises, a second round of tests has been carried out with the integration of the remote cascade lab in the following courses:

- MJ2430 Thermal Turbomachinery
- MJ2244 Airbreathing Propulsion II

This activity has overall interested more than 60 course participants during the spring term 2013.
It can be stated that the changes introduced have significantly affected the remote laboratories as confirmed by the numbers in Figure 4-15 and Figure 4-16. This picture is of course not exhaustive, but representative of the fact that the perception of the participants with respect to the remote laboratory experience and with respect to the achieved learning outcomes has significantly improved. From a trainers perspective two are the main evidences:

- the way the remote laboratory exercise is structured (e.g. precise tasks rather than independent planning) is of paramount importance for the learning experience of the students, independently from the technical capabilities of the remote laboratory setup. This is reflected in both the ability of the users to operate the equipment as well as to achieve the intended learning outcomes
- the transition to a GUI that does not require any software installation for the user and that is operable from any device enhances the accessibility and scalability of the lab.

4.7.4 Test with VCH Partners

Last but not least, the test of the remote laboratories has interested participants from the VCH partners and community. In this case the project partners were required to provide a number (at least three) of candidates to perform one of the remote laboratory exercises. The remote cascade lab has been taken as the reference for this test for two reasons:

- general knowledge in turbomachinery and in aerodynamics is required thus being relatively simple to find test people and to confine the exercise to a one-time activity (no need to follow lectures, courses, read books, etc.)
- is the laboratory exercise that has been tested more extensively and for which more information (such as participants’ survey) is available for comparison

This activity has for the time being interested 7 participants during May 2013. Further tests will be carried out and documented during the remaining months before the project end.

With respect to the existing lab structure, additional modifications have been introduced in order to allow people outside of KTH to perform the laboratory. This has been the natural consequence of the process of integration and deployment of the laboratories to the VCH. Modifications have mainly consisted in:

- transition from the use of online tools accessible to KTH users only (e.g. online test on the local LMS) to tools that could be used by users outside of KTH
- complete independence of the laboratory exercise from any learning material available to KTH students only (books, lecture notes, etc.)
- additional network camera installed in the lab facility.

As shown in Figure 4-15 in Figure 4-16 respectively, the test with people from outside of KTH confirms the overall performance of the remote lab as an e-learning tool. This is to be regarded

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6 Participants from TUe will execute the test during June 2013; additional users are expected as the result of the promotional campaign at the ASME TurboExpo 2013 conference (June 3-7, 2013)
both in terms of remote experience of the lab as well as with respect to the achievement of the intended learning outcomes.

![Figure 4-15: RCL - Rating of the remote laboratory experience. Scale: 1 = bad; 5 = excellent.](image)

**Figure 4-15: RCL - Rating of the remote laboratory experience. Scale: 1 = bad; 5 = excellent.**

![Figure 4-16: RCL - Achievement of the intended learning outcomes. Scale: 1 = bad; 5 = excellent.](image)

**Figure 4-16: RCL - Achievement of the intended learning outcomes. Scale: 1 = bad; 5 = excellent.**

From a trainer’s perspective, the most interesting aspects are the level of confidence of the participants in the use of the remote lab and their ability to qualitatively interpret the results though their different level of knowledge in the turbomachinery field. At the same time the achievement of the intended learning outcomes is questionable, having some candidates not being able to fully complete the laboratory exercise and obtain analytical results on the top of the qualitative ones.
4.8 Final Remarks, Future Work and Recommendations

The lab exercises have been set up such that they can be used for different study levels. Presently the Intended Learning Outcomes are directed towards the 2nd cycle of higher education (MSc level). But the equipment is usable also for other levels. It will without problems be possible to raise the level of the ILO for the Remote Cascade and the Remote Flutter facilities such that it can be adopted for the 3rd cycle (i.e. PhD level). Similarly the Measurement Lab and the Cascade Lab can be adapter, with another set of ILO, to the vocational training level. This will of course mean a substantial work to redefine the ILOs and ALOs to correspond to knowledge and skills corresponding to these levels, but the experimental facilities are deliberately set up for this and can as such have a much wider spread than “only” the MSc level as has been the objective of the VCH project.

The outcome from the test and implementation of the remote laboratory exercises is so far very positive and encouraging and some aspects of importance can be highlighted:

- reliability of the laboratory setup and of the remote equipment
- overall very good student perception of the remote laboratory and of the achieved learning outcomes

4.8.1 Future Work

Few are the months left to the end of the VCH project and many the achievements obtained since the project start with the remote laboratories. Some of the important steps yet to be realized are:

- full integration of the VCH technology such as to allow for federated authentication. This goes in parallel with the work included in WP5 – “Virtual Campus Hub Technology”
- give result to and extend the audience of users of the remote laboratories within the VCH community. This goes along with the process of creation of a VCH community being carried out by the VCH partners
- continuous technical and pedagogical improvement of the remote laboratories. This includes e.g. the implementation of the last release of the LabSocket with increased functionality, the deployment of the GUI of the RPML with the LabSocket system, the definition of the remote flutter lab as a plug-and-play laboratory exercise.

4.8.2 Recommendations

If some recommendations were to be given for the development of new remote laboratories, here are the most important ones:

- Pedagogical
  
  o importance of conceiving a ‘remote laboratory exercise’ as a whole starting from the design phase
importance of clearly state the intended learning outcomes, define precise tasks to be accomplished and offer self-study questions such as to overcome the absence of a physical instructor

- Technical

  reliability of the experimental setup and of the remote operation is a necessary but not sufficient condition of technical success

  increased accessibility and ease of use can be improved with the adoption of recent web technologies

  economical and technical effectiveness of a modular design allows reuse of expensive equipment while minimizing the time-to-operation of a specific remote laboratory. A picture representative of the modular design for the case of the three laboratories included in VCH is shown in Figure 4-17.

Figure 4-17 Modular design – three laboratories, one test facility
5 Continuous Examination Tools

The present chapter focuses on the pedagogical development and test of the continuous examination tools for automatic correction. These constitute tasks T2.4 and T2.5 of the Virtual Campus Hub project.

5.1 Introduction

A database of energy calculation exercises for automatic correction and a large pool of multiple choice questions (MCQs) have been developed within a series of courses at the Heat and Power Technology Division, KTH. These exercises have been created in Bilda\(^7\) - the online learning management system (LMS) in use at KTH - with some dedicated JavaScript programming and are integrated in online self-assessments, exams and home assignments. What follows in this chapter is based on the work performed by a team of PhD students and senior staff at the HPT Division at KTH and that constitutes part of a publication planned to be submitted at the ASME TurboExpo 2014 Conference (Noor et al. 2013).

5.2 Motivation for the Use of the Continuous Examination Tools

Tests and exams are a vital part for the universities and institutions to access in general the academic learning, teaching and evaluation process. Due to the increasing number of self-assessments, quizzes, control tests, mid-term and final exams, the Heat and Power Technology division, KTH, has started to switch paper-based exams, quizzes, self-assessments and home assignments with computer-based where there is a possibility of automatic corrections.

There have been several main objectives that are behind the idea of introducing the continuous examination tools for automatic correction, such as:

- Switching from a “teacher-centered” to a “student-centered” educational system
- To introduce more clearly the ILO-concept identifying the ALO and the existing knowledge material needed to reach the skills expected from the education.
- Providing an efficient way for teachers and students both; for teachers as it may reduce correction time and for students as it reduces the waiting time for results and solutions.
- To avoid the possibility of a rather subjective assessment of the student’s answers when correcting exams scripts manually; since it may involves personal (human) judgment.
- To reduce in general the work load on the teachers and course assistants to perform the manual checking of the hand written exam papers. To reduce the paper need, this will turn out to be a unique step towards minimizing environmental issues.

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\(^7\) Bilda is developed by PingPong AB.
With regard to the computer based automatically corrected exams there can be some doubts that need to be addressed and resolved; such as the sub-tasks provided for the exercise should not guide the students towards the solution. Second most important issue is that in an approach towards adopting automatically corrected questions, multiple choice type questions are preferred while avoiding open ended questions and this may limit the possibility for teachers to see the written script from the student which may not give teacher a direct possibility to judge the students concepts.

5.3 Multiple Choice Questions Type Exercises

A multiple choice question is generally defined as a form of assessment in which the respondent is presented with a question and a list of statements and he/she is required to pick one (or more) of the statements that better responds to the question.

The Multiple Choice Question (MCQs) developed in this project are of two main types. One type consists of simple questions without using Java Script, with a number of correct and incorrect alternatives per question (which are the multiple alternatives or, multiple choices). The other type is the type which uses JavaScript programming in order to randomly select a specified total number of multiple correct and incorrect alternatives (for e.g. 5) from a pool consisting of generally 10 alternatives, of around 5 correct and 5 incorrect.

5.3.1 Development

MCQs have been formed in two main steps; firstly by transforming the open-ended kind of questions to MCQs, and secondly by programming the MCQs into the online platform which is used for students to perform online exams and home assignments. First step was done with the help of teacher assistants in the supervision of the subject and expert teachers with strict considerations on quality check of the developed questions. A strict consideration has been also given to the fact that the MCQs are more conceptual i.e. to test students developed concept. However, there are still many questions that are of memorizing nature and these needs to be taken care of. Furthermore it has been considered to categorize the different kinds of MCQs, such as in the internal database for MCQs, each question has been considered to be categorized into either understanding nature or memorizing nature. An example of two such questions is shown in Figure 5-1. It should be pointed out that to develop good MCQ is a considerable task and it requires significant work by the teacher.

5.3.2 Outlook

A typical MCQs type exercise has instructions page containing the necessary instructions and general information about the exam. The questions are usually made to appear on the next page to the instructions page.

When programming the MCQs, the type of script developed has been aimed to be such that multiple kinds of alternatives appear to the student for one-single question as can be seen in Figure 5-2. When preparing an online exam, the teacher can choose from each pool a unique question but when it appears to students the same question will be randomly choosing different
alternatives. Furthermore an effort has been made to make it possible for different students to receive different questions.

Figure 5-1: Comparison between memorizing nature and understanding nature type questions
Figure 5-2: Different alternatives for one single question
5.4 Calculation Type Exercises

A calculation type exercise is commonly regarded as a form of assessment in which the respondent is required to calculate the value of a quantity based on a set of input data and, if needed, assumptions using formula(s) of his/her knowledge or provided in the exercise.

5.4.1 Development

A calculation type exercise as conceived in this project is developed in such a way that the procedure followed by the student to get to the result can be evaluated regardless of the numerical value being correct or wrong thus granting partial credits in relation to a “correct thinking”. This means that in an exercise consisting of multiple parts (e.g. two parts) where the first part has to be used to calculate the answer for the second part, even if the ‘first part’ answer is wrong, the student can proceed on to solve the ‘second part’ and if he/she uses the correct procedure for that part of the problem he/she will get partial credits for that. How? This is possible by having the calculation exercise programmed into two parallel steps. First the student’s answers to the ‘second part’ is checked against a correct value within a pre-defined tolerance range. If this value is found to be outside the tolerance window defined by the program, then the program takes a step forward and starts a parallel calculation routine where the student’s (wrong) answer to the ‘first part’ is used as an input for the calculation of the value in the ‘second part’ with the correct procedure and equations. If the student’s answer to the ‘second part’ corresponds – within the tolerance range - to the value calculated by the parallel process this means that the student has followed the correct procedure for the ‘second part’ and will receive credits for that. This is named as “Twin-Tracking”. It is important to note that “No matter how the individual parameters behind the sub-tasks are depending on each other, the individual mark received on one sub-task is independent of the other”. As an example, if the student inputs a wrong value in sub-task 3 and if the parameter in sub-task 3 is used for calculating the parameter in sub-task 1, as long as the student uses the correct equation to calculate sub-task 1, he/she receives full points on sub-task 1 regardless of the numerically wrong value used for sub-task 3” (Noor et al. 2013). On the top of the “Twin-Tracking” method a data randomization routine makes it possible to provide each student with a different set of input data for a similar numerical problem.

5.4.2 Outlook

A typical calculation type exercise is presented in a webpage consists of two sections. The first section of the page contains the necessary information with all the given input values and the major tasks. In the second section the user shall fill in the blanks for multiple sub-tasks (as derived from the major sub-tasks) with indicated points to be received. These sub-tasks are preceded by notes that contain specific instructions to students as to what they need to consider while putting their answers in the spaces provided for each sub-task. An example of a sub-task input pattern as it appears to the student is shown in Figure 5-3.
Note: The decimal point is a point (.), not a comma (,). The use of the wrong decimal separation will be interpreted as wrong dimensions and the result will be wrong. It is sufficient to input a number at an accuracy of three decimal places (e.g., 250.361).

Note: Do not type units, texts, spaces in the blank spaces provided. Only numbers without spaces in between are acceptable.

Note: SI-units should be used. If you use any other units the solution will be considered wrong.

Note: in the extremely unlikely event that you do not come up with a reasonable result for one of these values you will receive 0 point on that task but you can still continue the exam by using the value given in the parenthesis and in italic next to the respective parameters.

Note: The individual scores that can be achieved for each sub-task is indicated in blue text beside each sub-task.

Type your values in the spaces provided below and give your answers to three decimal places:

- The correct picture number = (type a number corresponding to the correct picture: e.g., 1.2 or 3) 1 point

- High pressure level steam enthalpy $h_{HP} =$ kJ/kg ($h_{HP}=3300$ kJ/kg) 0.5 points

- Medium pressure level steam enthalpy $h_{MP} =$ kJ/kg ($h_{MP}=3000$ kJ/kg) 0.5 points

- Low pressure level steam enthalpy $h_{LP} =$ kJ/kg ($h_{LP}=2700$ kJ/kg) 0.5 points

- Steam enthalpy at the steam turbine exit $h_{exit\_ST} =$ kJ/kg ($h_{exit\_ST}=2100$ kJ/kg) 0.5 points

- Total steam mass flow rate = kg/s (mdot$_{st}=18$ kg/s) 1.5 point

- High pressure steam mass flow rate = kg/s (mdot$_{HP}=5$ kg/s) 1 point

- Steam turbine electrical power output = MW (Pst$_{el}=10$ MW) 1.5 point

- Fuel consumption without supplementary firing = MW ($100$ MW) 1 point

- Fuel consumption due to supplementary firing = MW ($9$ MW) 1 point

- Electrical efficiency of the combined cycle = % (El. efficiency = 33 %) 1 point

- Total steam mass flow rate = kg/s (mdot$_{st}=18$ kg/s) 1.5 point

- High pressure steam mass flow rate = kg/s (mdot$_{HP}=5$ kg/s) 1 points

- Medium pressure steam mass flow rate = kg/s (mdot$_{MP}=5$ kg/s) 1 points

- Low pressure steam mass flow rate = kg/s (mdot$_{LP}=10$ kg/s) 1 points

Figure 5-3: Sub-tasks input pattern for calculation type exercises
5.5 Combining MCQs with Calculation Type Exercises

A question that has arisen during the development of the calculation type exercises is how the diagrams, flow charts and schematic drawing knowledge of students may be checked through this kind of automatic corrections. To solve the matter a strategy of introducing Multiple Choice Questions (MCQs) with multiple right and wrong schematics, flowcharts or other drawings shall be given to the student to test his knowledge on what he/she considers as correct. These MCQs can be added as subtasks after posing the exercise question. See Figure 5-4 and Figure 5-5 for examples on this.

What is CORRECT about the colored lines drawn along the labels (A, B, C, D and E) on the following diagram?

- [ ] Stream A represents combustion fuel
- [ ] Process A-B represents water to steam conversion process
- [ ] Stream B represents flue gas
- [ ] Stream C represents water vapor formation
- [ ] Stream E represents pressurized hot steam

*Figure 5-4: Example of MCQ asking the student to identify the correct process in the plant layout*
5.6 Use of the Continuous Examination Tools

The MCQs and calculation exercises can be used for different purposes and in different forms along the duration of the course:

- As to train or verify the knowledge of the theory and the ability to solve calculation problems
- In the form of exercises (not concurring to the final grade of the course), assignments (concurring to the final grade) and exams

Here follows a brief nomenclature of the continuous examination tools as they are presented to the students in the courses at the HPT division at KTH:

- “Self-assessment”: made available on a regular basis (usually every week), it consists of a series of MCQs dealing with the topics treated during the past lectures. It can contribute to the final grade of the course and in such case a single attempt is usually allowed
- “Home Assignment”, “Problem of the week”: it consists of a calculation type exercise to be solved within a relatively long time (in the order of one or few weeks). It can contribute to the final grade of the course
- “Online Exam”: it is usually a combination of MCQs and of calculation exercises. It is used in both intermediate (if applicable to the course) and final exams in the course.
5.7 Deployment and Assessment of the Continuous Examination Tools

5.7.1 Integration into Courses at KTH

Calculation type and MCQ type exercises for automatic correction have been introduced in a number of courses at the HPT division at KTH where the Bilda system was already used. Some statistics about the use of the continuous examination tools in the last edition of these courses is summarized in Table 5-1.

<table>
<thead>
<tr>
<th>Courses</th>
<th>MCQs</th>
<th>Calculation Type</th>
<th>Year</th>
<th>Students active in the course</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exercises</td>
<td>Assignments</td>
<td>Exam</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exercises</td>
<td>Assignments</td>
<td>Exam</td>
<td></td>
</tr>
<tr>
<td>Sustainable Power Generation</td>
<td>√</td>
<td></td>
<td>V</td>
<td>2012</td>
</tr>
<tr>
<td>Combustion Theory</td>
<td>√</td>
<td>√</td>
<td>V</td>
<td>2012</td>
</tr>
<tr>
<td>Applied Heat and Power Technology</td>
<td>√</td>
<td>√</td>
<td>V</td>
<td>2012</td>
</tr>
<tr>
<td>Renewable Energy Technology</td>
<td>√</td>
<td>√</td>
<td>V</td>
<td>2012</td>
</tr>
<tr>
<td>Turbomachinery</td>
<td>√</td>
<td>√</td>
<td>V</td>
<td>2012</td>
</tr>
<tr>
<td>Thermal Turbomachinery</td>
<td>√</td>
<td>√</td>
<td>V</td>
<td>2013</td>
</tr>
<tr>
<td>Jet Propulsion Engines</td>
<td>√</td>
<td>√</td>
<td>V</td>
<td>2012</td>
</tr>
<tr>
<td>Airbreathing Propulsion II</td>
<td>√</td>
<td>√</td>
<td>V</td>
<td>2013</td>
</tr>
<tr>
<td>Rocket propulsion</td>
<td>√</td>
<td>√</td>
<td>V</td>
<td>2013</td>
</tr>
</tbody>
</table>

Table 5-1: Statistics of automatically corrected assessments at HPT

5.7.2 Sharing of the Assessment Tools with the VCH Partners

A demonstrative portfolio of the assessment tools used in the aforementioned courses – both of the MCQs type and of the calculation type exercises – has been made available to the VCH partners through guest accounts to the Bilda system. It is to be observed that the content developed – in particular the database of MCQs - is much wider but it has not been possible to
share it entirely with the public due to the fact that the material is reused in future editions of the courses as part of assessments and examinations.

5.7.3 Evaluation Process and General Outcome

A detailed description of a large scale test conducted for the qualitative assessment of the continuous examination tools is documented in D3.2 “Trial Implementation and Test of Two e-learning Tools” delivered in December 2012. The report examines the e-learning tools both from a students’ as well as teachers perspective in both the technical and pedagogical aspects. A more extensive analysis, that includes quantitative evidences from testing of the continuous examination tools in a wide umbrella of courses offered at the HPT division at KTH is documented in (Noor et al. 2013).

As a general outcome in most of the courses the computer-based automatically corrected exams have proven to be very convenient and effective in helping teachers in their evaluation tasks. This is particularly relevant in courses with large number of students that justify the additional time and effort required in programming the MCQs and calculation exercises.

From a student’s perspective the most interesting aspect in the use of the continuous assessment tools is the possibility of learning by doing: by having the chance to do self-assessments throughout the course period and receiving feedback immediately helps in assimilating the content of the course week by week. With respect to the online exam students like the fact that results are available shortly after the exam.

Many are still the concerns and limitations in the use of the continuous examination tools. The quality and standard of automatically corrected exams is the main concern for the teachers and it mostly depends on the difficulty in the formulation of questions: exams based on MCQs are observed to be easier compared to open-ended questions based on the fact that the MCQs provide the students with ready-made answers instead of forcing the students to use their own words as well as calculation exercises might guide the students to the solution. From a students’ perspective the main disadvantage regards mainly the difficulty to show real understanding of the course content. For the calculation exercises this is thought to largely depend upon the fact that students are not always aware of the procedure followed in grading the exercises that takes into account of a “correct thinking” as explained in Chapter 5.4.1.

Another important aspect that has arisen from the assessment of the continuous examination tools is the difficulty in comparing the level of achievement of the intended learning outcomes in an online exam with respect to a traditional paper-based exam. The work included in D3.2 makes aware of the fact that misleading conclusions can be drawn if a one-to-one (i.e. comparison within two consecutive editions of the same course, one with and one without the use of the continuous examination tools) comparison of the exam grades is made. A larger population of cases should be considered to have evidences of significance. These should disregard the student’s results from the specific formulation required in the development of the MCQs and of the calculation exercises (with the introduction of the sub-tasks) with respect to the corresponding open-ended questions and traditional calculation exercises.
6 Bibliography


Appendix I – Online Survey

Welcome to the Evaluation Form of the Remote Laboratories!

The present evaluation form is used to get the feedback from you having performed the following remote laboratory exercise: *Remote Cascade Lab*

Your answers will be used for assessing the quality of the laboratory and to make improvements where necessary. All your comments are highly appreciated. Thank you in advance!

**Section 1**

Please rate the below questions using the following scale:

1 = bad  
2 = weak  
3 = OK  
4 = good  
5 = excellent

1. How do you rate the online performance of the experiment (in terms of technical performance, i.e. having the equipment doing what you want it to do)?

   1  2  3  4  5  
   0  0  0  0  0

2. How well did you have control over the laboratory equipment (in terms of you knowing what to control and how to do this)?

   1  2  3  4  5  
   0  0  0  0  0

3. How well did the laboratory preparatory material (lab notes, videos, tutorial, etc.) prepare you for doing this laboratory exercise?

   1  2  3  4  5  
   0  0  0  0  0

4. How well were your interactions aligned with the laboratory objectives?

   1  2  3  4  5  
   0  0  0  0  0

5. How do you rate the quality of the experimental data obtained?

   1  2  3  4  5  
   0  0  0  0  0
6. How good understanding of the topic treated did you get from performing this laboratory exercise?

1 2 3 4 5
0 0 0 0 0

7. How do you rate the usefulness of performing such a remote lab exercise over theoretical work only?

1 2 3 4 5
0 0 0 0 0

8. How well did remote cameras (including audio) transmit the lab experience?

1 2 3 4 5
0 0 0 0 0

Section 2
The below questions are to be answered by yes / no / can't say.

1. Did you read the laboratory instructions prior to performing the laboratory exercise?

   Yes  No  Can’t say
   O   O   O

2. Could you perform the laboratory exercise smoothly, i.e. without interruptions?

   Yes  No  Can’t say
   O   O   O

3. Could you measure and analyse the data successfully?

   Yes  No  Can’t say
   O   O   O

4. Did you understand what you were doing during the laboratory exercise?

   Yes  No  Can’t say
   O   O   O

5. Did the absence of a physical lab instructor hinder you in performing the laboratory exercise?

   Yes  No  Can’t say
   O   O   O

6. Would you like to perform a similar laboratory exercise again?
7. Do you think that performing experiments through virtual labs was more challenging than real experiments?

Yes  No  Can’t say
O    O    O

Section 3

Your comments

1. Describe three interesting aspects of the present laboratory exercise.

2. Specify three problems / difficulties that you experienced prior to or while performing the laboratory exercise.

3. How did you find the user interface? Is there any control, option, graph or other that you think should be improved and how?

4. Are there any suggestion that you would like to give to us?

Section 4

Almost done. Just a few questions left!
1. Pick one or more statements below that you agree with!
   O It would be beneficial to integrate such laboratory exercises during lectures to highlight and discuss practical aspects.
   O No thanks. Laboratory exercises shall be conducted by students, not by teachers.
   O If I had access to such laboratory exercises from a smartphone (or surf pad), I would happily use it for getting real test data measured by myself.
   O No thanks. Better to have no lab experience at all than a remote lab.
   O I could imagine having such a lab exercise as part of an exam and using real test data in calculation problems.
   O No thanks. Having remote lab exercises in an exam would just confuse me.
   O If there was an app for performing such a lab exercise, I surely would use it.
   O If there was an app for performing such a lab exercise, I would hate it.
   O I would give the students some extra points if they fill in the survey.

2. For those being in favour of such remote lab exercises, what phenomenon or machine (in the field of turbomachinery) would you like to be able to test in a virtual manner?

Last question: tell us from which location you did the lab
   O KTH
   O DTU
   O TU/e
   O PoliTo
   O Other