TECHNISCHE UNIVERSITÄT DRESDEN

Fakultät Bauingenieurwesen Institut für Statik und Dynamik der Tragwerke

Scientific report

Short Term Scientific Mission

COST: IE0601
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Host: Sandie Le Conte, Musée de la Musique, Paris
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At the beginning of 2009, a project on statical structural analyses of historical keyboard instruments was started at the Institute for Structural Analysis at Dresden University of Technology in collaboration with Händelhaus Halle. The aim of the project, funded by the German Federal Cultural Foundation, is to analyse the structural behaviour of such instruments using modern computational methods (Finite-Element-Method). Considering two reference objects, one pianoforte made by Johann Schmidt in 1786 (MS-28) and one pianoforte made by Conrad Graf in 1835 (MS-44), the statical characteristics of the different basic systems are to be analysed and the influences of existing damages and climatic changes (temperature, moisture) on the load bearing behaviour should be identified. The conclusions drawn out of this fundamental research will be applied during the restoration of a pianoforte made by Späth and Schmahl (MS-30).

At Paris Musée de la Musique first experience in using FEM for musical instruments already exists. Within the scope of the restoration of an harpsichord made by Couchet, FEM was applied for the statical and dynamical analysis of corpus and soundboard (LE CONTE et al., 2007a). The prime goal of the Short Time Scientific Mission was getting knowledge about the methods and the approach adopted in this project to benefit from the experience within the own work. Furthermore, the first results achieved during the initial period of the own project were discussed with researchers from Musée de la Musique and Paris University. It was assessed that the approaches chosen for the simulation of the structural behaviour are different in some ways. In LE CONTE et al. (2007a), shell elements, in the own project brick elements are used. LE CONTE et al. (2007a) describe the complex behaviour of wooden materials by means of an elastic orthotropic material model. In addition to the string-loads, effects out of moisture-changes are taken into account using a simplified, uncoupled model. The simulation was performed time-independent, without consideration of creep, damping and visco-elasticity, using the code CAST3M. At the Institute for Structural Analysis, a FE-Code was developed that allows the consideration of anisotropic, elastic-plastic material behaviour (SCHMIDT und KALISKE, 2009). Besides, the simulation of temperature- and moisture-transfer is under development. The common point of both approaches is the use of displacement elements. The main focus lies on the deformation of the structure.
Due to the short working duration within the own project, no results for the entire structure of a historical keyboard instrument are available yet. The steps of simulation (digitalisation of the geometry,

meshing, computing) were initially tested at a detail of the structure so that it is not possible yet to directly compare the results of both projects.

Another important workscope within the STSM was the formulation and systematisation of typical damages of the considered instruments and the identification of sensitive parts of the structure. At this, the possibility was offered to discuss with curators, piano makers and other specialists. Although the specific damages depend significantly on the design of each instrument, and with it on year and method of construction, typical damages can be detected. Due to the loading by the strings, the whole structure sustains heavy deformations. The back region of the pianoforte is lifted (tail piece) whereas the cheek is lowered. This loading can lead to the failure of the glued joint between bent side and cheek. Another sensitive part of the structure is the soundboard. It frequently shows heavy losses in terms of long cracks. The study of numerous historical keyboard instruments makes clear that the damages of the pianofortes considered in the own project are typical for instruments of this time and construction.
The described damages are mainly to be reasoned by the high loading caused by the tensioned strings. An additional increase of the string-tension was caused by the exchange of historical strings by new ones and the adjustment of tuning to modern performance practice. Nevertheless, the influence of long-term-effects and climatic fluctuations on load bearing behaviour, appearing deformations and cracking may not be neglected. In this respect, the change of moisture is the principal criterion. Furthermore, it appears that the influence of climatic changes strongly depends on the stress level inside the structure. This time-dependent behaviour, mechano-sorptive creep, clarifies that a coupled material model is useful and necessary for the realistic description of the structural behaviour of historical pianofortes.

In making of musical instruments many different types of wood, frequently hardwood, are used. The material parameters needed as input for the FE-computation are difficult to identify for most of those wood-species. The amount of literature available concerning this topic is limited and the contained data is often inaccurate. Moreover, it is not known to what extend the material parameters are consistent with those of wood used in the special case. Le Conte et al. (2007a) compensated this deficit by calibration and verification of the numerical model using deformation-measurements of the object. In the own project, too, it is one next important step to open up adequate measurements and experiments to verify the model. Since the Institute for Structural Analysis does not possess own experimental equipment, knowledge about tests that are possible and adopted at Musée de la Musique is of large importance. At the laboratory of the museum for example, the evaluation of elastic and viscoelastic (Le Conte et al., 2007b) properties is possible using small test-specimens. To conserve to original substance, naturally only non-destructive test procedures are acceptable, for example the modal analysis to determine the acoustic properties of the structure. For the verification of the numerical model of the Couchet-Harpsichord the method of Impact Nearfield Acoustical Holography was used (Le Conte et al., 2007b; Le Moyne et al., 2008). Measurements using this method are also performed at regular intervals for monitoring purposes. Changes of the acoustical field, measured in the test suggest changes of the structure (e.g. caused by aging or moisture-fluctuations).
Although the main focus is on the statical behaviour of the historical pianofortes, with regard to the intended restoration of *Tangentenflügel* MS-30, it is important not to lose track of the acoustical properties. At Musée de la Musique tests to investigate the consequences of different restoration-methods on the acoustics of a structure were carried out. Therefore, a modal analysis of faultless, cracked and differently restored test-specimens was made. The best compliance with the

acoustical behaviour of the faultless specimen was obtained by restoring the crack using small wooden reinforcements with fibre direction equal to crack direction.

The last important field of activity within this STSM is the investigation of further historical pianofortes made by the piano-makers considered in the project. Unfortunately, such instruments are not existing at Musée de la Musique. Yet, by means of plans available in the museum's mediathek, the location of appropriate instruments could be detected. Those plans and the partly existing information about the used wood-species will be a great help for our project partners from Händelhaus Halle in digitalising geometries and developing lists of materials.

At Paris Musée de la Musique professionals of different fields are united. Curators, restorers, piano-makers and scientists of distinct fields bring in expertise into the complex subject of the simulation and restoration of historical keyboard instruments. Summarising the different perceptions and approaches one gets a comprehensive overall picture and a good survey of the topic. Concerning modelling and simulation, it will be interesting to compare the qualitative results of the projects in Paris and Dresden in the future. Herefrom conclusions can be drawn concerning the necessary numerical effort and advantages and disadvantages of the chosen approach. The effort of modelling and computation can be optimised.
Since there are few institutions dealing with the structural analysis of historical keyboard instruments it is desirable to create a network between them to be able to exchange results quickly. The combination of highly different fields in one project besides makes the choice of an appropriate scope for the publication of research work and results quite difficult. Collaborating with colleagues that follow the same purpose would remarkably simplify advising other professionals, for example in terms of articles in trade journals or workshops, of this interesting and important field of research.

References

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