newsletter

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RESEARCH
EVENTS

2 / 2022

Czech Academy of Sciences
ITAM ARCCHIP
INSTITUTE OF THEORETICAL AND APPLIED MECHANICS

EDITORIAL

Dear readers,

Despite the turbulent year 2022, we are pleased to present you the second newsletter of the Institute of Theoretical and Applied Mechanics of the CAS (ITAM). The newsletter brings information such as the successful completion of a project focused on the Roman cultural heritage; as well as about the results of a grant project in the field of aerodynamics organised by the ITAM, which was well evaluated by the Expert Committee and the Board of the Grant Agency of the Czech Republic.

Among several events recently organised by ITAM, I will mention the important international conference SHATIS'22, held in Prague at the National Technical Museum. In November 2022, as part of the Czech EU Presidency, we also organised a symposium on Heritage Science, to which representatives of the Government and the Vysočina Region were invited. The symposium was held in Telč in the premises of the former Jesuit College.

Last but not least, after a long break, we welcomed the members of the International Advisory Board in Centre Telč. The discussions about scientific and non-scientific topics led to many productive outcomes.

I wish you an interesting reading!

Stanislav Pospíšil, ITAM director

Excursion to the Climatic Wind Tunnel during the International Advisory Board Meeting. Photo: J. Novotný

SUCCESSFUL COMPLETION OF THE LIVING DANUBE LIMES PROJECT

At the end of 2022, the Living Danube Limes project (Danube Transnational Cooperation), focused on Roman cultural heritage in the Danube region, will come to an end. The project had four main pillars: it aimed to characterize the 600 year-long Roman presence in the Danube region and to collect all available information on Roman monuments in the region (including those in the territory of present-day Moravia) and to connect museums and visitor centres in the region into a cluster (Czechia will be represented by the Visitor Centre Mušov). The project did not neglect the protection of cultural heritage and sustainable tourism in the pilot sites. It culminated in the Danuvina Alacris Connecting Cruise from Germany to Romania from July to October 2022. The Danuvina Alacris is a reconstructed lusoria-type patrol boat, an original of which plied the waters of the Danube at the time when it formed the northern border of the Roman Empire. The boat was built as part of the project using traditional tools and techniques. The crew of the Connecting Voyage consisted of nearly 200 volunteers from different parts of the world (including Czechia, the USA and Australia), who took turns on the boat. The ship attracted significant public interest wherever it sailed. After the conclusion of the project, it will dock in all partner countries and, if everything goes well, it will also stay for a short time at the Nové Mlýny reservoir.

B. Přechová

WIND FLOW AND ITS EFFECTS ON CYLINDRICAL OBJECTS IN CONSTRUCTION

Last year, we successfully completed the GAČR project "Aerodynamic response of cylinder with surface irregularities in critical and transition Reynolds number regimes" — the project, with Prof. Stanislav Pospisil as the principal investigator, was awarded the "excellent" grade in the final evaluation. His main scientific contribution was determination of the flow characteristics in the cylinder surroundings and an investigation of the aerodynamic and aeroelastic response in turbulent flow in the critical and transient regime, i.e. at speeds common in structural aerodynamics. The results of the project, in addition to a theoretical understanding of the boundary layer processes and the theory of self-excited oscillations, will also find application in practical applications in structural design or in the codification of building loads. In this issue, we would like to give you a closer look. Aerodynamics, one of the pillars of research at the Institute of theoretical and Applied Mechanics, is a broad field of science in which airflow around various objects is studied. Wind and its static effects are clearly important factors in the design of structures, and the damage that wind causes each year makes for many alarming headlines. What is less well known is that a not insignificant amount of damage occurs in cases where dynamic action and response is the main cause, which may not only occur at extreme wind speeds but instead in relatively normal and even unexpected circumstances. This is also due to the fact that wind speed can be described as a composite of a mean value and a fluctuating component. The latter can be considered as a random stationary and ergodic process with a characteristic frequency spectrum for normal speeds and for most cases. In general, wind effects are divided into static and dynamic effects, which are then distinguished according to the type of response and the predominant frequencies. This complicates the situation considerably, since combinations of these effects occur and new, unexplored phenomena arise, while fluctuations often have a strong influence on the behaviour of the structure.

Fig. 1. Examples of icing and rope damage from aeroelastic oscillation.

Structural aerodynamics is not only a matter of larger structural units, but also of structural details and load-bearing elements such as bridge cables and hangers of various shapes. The cross-sectional profiles of these structural elements significantly influence the wrap-around modes. The project investigators have focused their efforts on the aerodynamics and aeroelasticity of a cylinder with a circular cross-section and various surface roughnesses, which arises under different climatic or technological conditions and which strongly influences the wrapping regime. An example is icing on the rope or a permanent defect in the rope caused during manufacture or use. As the air flows over the surface of the body, disturbances in the stability of the flow occur, forming so-called shear layers that continue into the drift. This leads to vortex shedding and vortex formation and to rapid pressure changes, which then cause oscillations in a frequency band characterised by a dimensionless Strouhal number. A response thus produced can last for a very long time under certain circumstances. The amplitude of the oscillations depends on the attenuation, expressed by the value of the Scruton number.

An interesting oscillation takes place when resonance occurs at a certain wind speed. If the deflection exceeds a certain threshold, the interaction between the flow and the body leads to a change in the frequency of the vortex shedding, and this starts to match the natural frequency of the oscillator. This phenomenon is known as locking and is a manifestation of nonlinear oscillations in the so-called limit cycle. There occur large deflections in the oscillations which leading to damage, as seen in Figure 1(d).

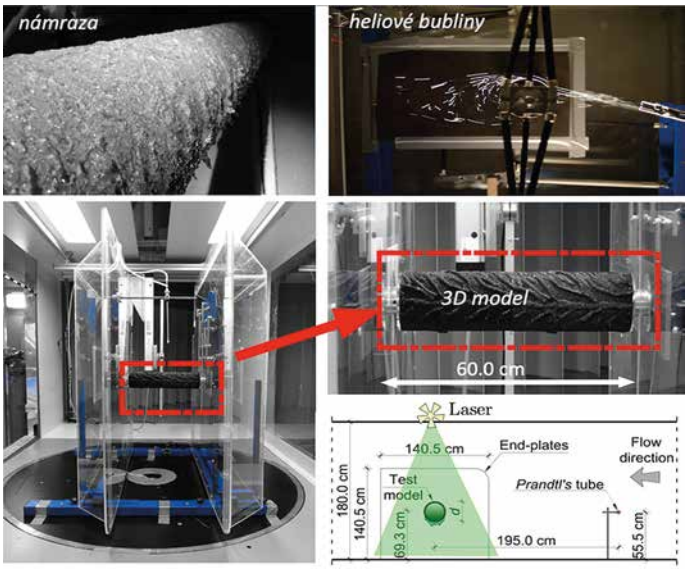


Fig. 2. Arrangement of the wind tunnel experiment.

Air can flow at low and high velocities, i.e. in different regimes in which its properties are different. As a result of the change in the flow regime, various sized vortices are created, their frequency changes, and hence the frequency of the aerodynamic forces applied changes. The velocity field is quantified by measuring the velocities of the flow at its various points. Constant thermal anemometry (hot wire) or integral methods based on laser illumination and camera sensing of the particle velocity field are used. A schematic of the set-up illustrating this method is shown in Figure 2. The three flow regimes are then depicted in the contour maps in Figure 3, from which the dimensions of the vortices, their distances and also, for example, the drag forces that the current generates on the body can be determined. It can be seen that they can indeed vary significantly depending on the surface. For example, the resistance of a smooth body halves when the current is more turbulent. Intuitively, if there is frost on the cylinder, its drag will also increase, but on the other hand, the presence of frost leads to an increase in the transverse force and sometimes to a change in the moment of force, which can cause unstable oscillations in the wind.

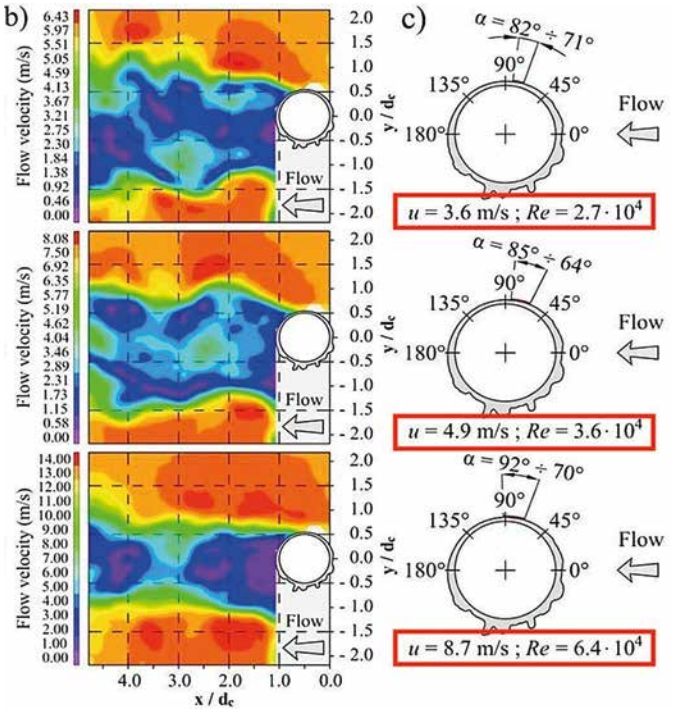
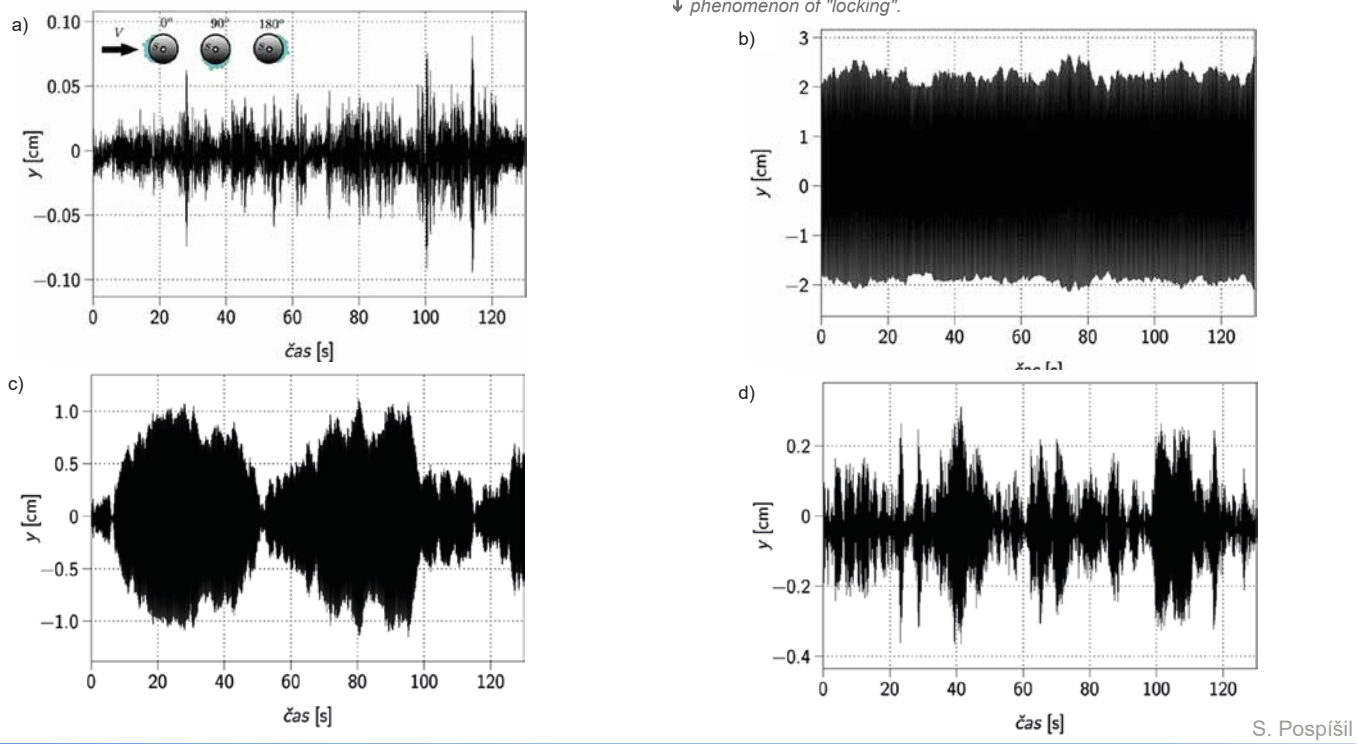


Fig. 3. Contour maps for different cylinder wrap-around icing regimes.

Following the determination of the static forces and frequencies, Prof. Pospíšil's team continued the study of the oscillations on an oscillator (section model of a bridge suspension) with different technological roughness and with icing. The basis of this work was the analysis of "resonance" curves and oscillation amplitudes. Attention should be drawn to the fact that as the wind speed increases, oscillations occur in essentially four experimental regimes, which the research team was able to identify in agreement with theoretical analyses of a nonlinear oscillator of the Van der Pol type.

In the pre-critical state shown in Figure 4(a), the response is determined by randomly separating vortices over a relatively wide frequency band. As the velocity increases, a short stretch of resonance occurs in the Strouhal number region. Then the frequency of the separating vortices is very close to the natural frequency of the oscillator (Figure 4b). From this state, it transitions to the so-called quasiperiodic regime, arising from the locking effect. In this case, there is an interference and synchronization between the frequencies of the deflection and the vortices, which are close to each other (Figure 4c). When the wind speed increases further, the system eventually enters the post-critical regime, in which normal oscillations occur.

Fig. 4. Response of the cylinder during flow-body interaction, which results from onlinear oscillations in the so-called limit cycle and leads to the physical phenomenon of "locking".



S. Pospíšil

DATA ANALYSIS FROM METEOROLOGICAL STATION KOPISTY

The Department of Dynamics and Aerodynamics, in cooperation with the Institute of Atmospheric Physics and the Czech Hydrometeorological Institute, is preparing a data analysis from the Kopisty meteorological observatory near Most. The weather observatory is located in the heavily industrialised landscape of northern Bohemia affected by opencast lignite mining, and there is also a large petrochemical plant in the vicinity; both of these factors strongly influence the air quality in this location. The Kopisty meteorological observatory was built in the 1960s to monitor the conditions of exhalation spread.

The station is equipped with meteorological instruments for measuring rainfall, sunshine, cloud cover, etc. as well as sonic anemometers on a mast at heights of 20, 40, 60 and 80 m used to measure wind speed and direction. This is one of only two sites in the country where atmospheric properties are measured in relation to elevation. The sharing of meteorological data between IAF and ITAM will contribute to an understanding of wind flow at this site, and, from an "engineering" point of view, to an understanding of wind flow in the boundary layer of the atmosphere in a landscape heavily affected by human activity. Based on the analysis, a special boundary layer could be modelled in a wind tunnel, and the results can also be used in numerical modelling (as boundary conditions).

P. Michálek

INTERNATIONAL CONFERENCE SHATIS'22 ABOUT TIMBER STRUCTURES

The Institute of Theoretical and Applied Mechanics CAS hosted the international conference on timber structures SHATIS´22 - International Conference on Structural Health Assessment of Timber Structures in September 2022. The University Centre for Energy Efficient Buildings CTU in Prague collaborated on the event, which was also supported by The National Heritage Institute (NPÚ) and The National Technical Museum (NTM).

The conference contributions were divided into 5 main sections:

- The Basics of timber structure design
- Timber properties
- Monitoring and survey of timber structures
- Structural interventions
- Case studies / research & practice

The main success of the conference lies in the meeting of researchers with practitioners and in the freedom that they feel during discussions on current topics related to timber structures, both modern and historical. This was confirmed in this year's session which more than 70 participants from all over the world attended (the most distant countries were the USA, Chile and Japan). The keynote lectures were presented by Jorge M. Branco from The University of Minho („Structural assessment of timber structures: Knowns, known unknowns, and unknown unknowns.") and Václav Sebera from Mendel University in Brno („Who talks about wood?"). The conference took place in the halls of NTM and the participants visited the National Memorial on Vítkov Hill and the Ledebour gardens as part of the social programme. The technical, guided tour of the roof structures of select historical buildings was a part of the programme as well, and it received an extraordinary response from the audience. The participants got the chance to visit the roofs of Vladislav Hall at Prague Castle, the Church of Our Lady before Týn and the Old Town Bridge Tower.

Excursion of the Týnský church rafters. Foto: M. Piazza

The upcoming event in 2024 will be hosted by the University in Zagreb, Croatia. More on shatis22.itam.cas.cz

H. Hasníková

SYMPOSIUM ON HERITAGE SCIENCE HELD IN TELČ

On 7-8 November 2022, ITAM CAS in cooperation with the University Centre Telč, Masaryk University organized a symposium called "Heritage Science: Interdisciplinarity, Internationality and Infrastructures". The event took place within the broader framework of the Czech Presidency of the European Union Council and under the auspices of the Vysočina Region. The event was officially opened by the 1st Deputy Governor of the Vysočina Region Hana Hajnová, the Mayor of Telč Vladimír Brtník, the representative of the European Research Infrastructure for Heritage Science E-RIHS Vania Virgili, the Director of ITAM CAS Stanislav Pospíšil and the Director of UCT MUNI Jaroslav Makovec.

In the last two decades, Heritage Science has developed into an independent scientific discipline combining the humanities, and the social, natural and technical sciences. The two-day symposium featured presentations by heritage science experts from major domestic institutions, demonstrating the potential of heritage science to address contemporary social, cultural, economic, political and environmental challenges. Over the course of two days, the participants of the symposium, which was also open to the general public, were thus introduced to heritage science in its diversity and unity, and its regional, European, and global scope. Special emphasis was put on the role of research infrastructure in the field of heritage science. The event was a follow-up to the symposium "Heritage for the Future, Science for Heritage: A European Adventure for Research and Innovation", which took place at the Louvre during the French Presidency of the Council of the European Union in March 2022. The symposium was supported by the Czech Academy of Sciences under the AV21 Strategy.

J. Novotný

VISIT FROM RWE

In September 2022, we were pleased to welcome a number of important visitors to our institute in Prague, in connection to an ongoing commercial project specifically addressing issues related to the development of hydrogen technologies in the gas sector. (Also addressed within the framework of the AV21 Strategy – Sustainable Energy Programme). Our institute was visited by Mr. Andreas Frohwein, Technical Managing Director at RWE Gasspeicher GmbH/ innogy Gas Storage NWE/ RWE Gas Storage West GmbH, accompanied by some Czech colleagues from RWE Gas Storage and co-investigators from Technopark Kralupy – VŠCHT.

Discussions mainly pertained to the issues and risks associated with the material and fracture characterization of steels used in gas-storage technology in connection with hydrogen exposure in the context of the planned hydrogen blending in the European gas system (P2G - Power to Gas). The meeting was followed by a short excursion to the institute's laboratories.

M. Šperl

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