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BEFEKTETÉS A JÖVŐBE

2^{nd} Workshop on Innovative Materials Processing, Applications in Energy Engineering and System Control
Chairpersons: Dr. Jurij SIDOR and Dr. László KOLLÁR
Organizing Committee: Dr. László KOLLÁR, Dr. Jurij SIDOR and Dr. Ferenc SAFRANYIK
Date: May 30, 2019

Venue: Eötvös Loránd University, Faculty of Informatics, Savaria Institute of Technology, Károlyi Gáspár tér 4, 9700 Szombathely, Hungary
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Program

8.55-9.00 Jurij Sidor: ***Introduction***

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Modelling of Transmission Line Insulators and Towers Exposed to Dynamic Effects
Eötvös Loránd University, Faculty of Informatics, Savaria Institute of Technology, Szombathely, Hungary

9.20-9.40 Felipe Ortega Silva Santos
Influence of blade shape on icing of wind turbine blades
Eötvös Loránd University, Faculty of Informatics, Savaria Institute of Technology, Szombathely, Hungary

9.40-10.00 Gustavo Henrique Moers
Analysis of relationship between mechanical properties and technological parameters of sheet metals
Eötvös Loránd University, Faculty of Informatics, Savaria Institute of Technology, Szombathely, Hungary

10.00-10.20 Hugo Emanoel de Andrade Costa
Motion of Wind Turbine Blades Exposed to Non-Uniform Wind Velocity Distribution
Eötvös Loránd University, Faculty of Informatics, Savaria Institute of Technology, Szombathely, Hungary

10.20-10.35 Luis Rubio Rodriguez, László E. Kollár
Fluid Structure Interaction Analysis for 3D Model of Wind Turbine
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10.50-11.05 Tej Singh
Development of innovative materials/products by utilizing waste and natural recourses
Eötvös Loránd University, Faculty of Informatics, Savaria Institute of Technology, Szombathely, Hungary

11.05 Closing Remarks

Abstracts

Modelling of Transmission Line Insulators and Towers Exposed to Dynamic Effects

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Abstract.
Wind and ice accretion on power networks may cause heavy dynamic load resulting in serious damages to the transmission line. The present study aims to examine the effects of wind and ice shedding on the insulators and on the tower of a transmission line considering the loads acting from the vibrating conductors. The geometry is based on a tower of a 275-kV-line with two different insulator diameters (80 mm and 120 mm), and with two different insulator-tower connection (fixed, and via joint allowing free rotation). Three types of models have been constructed: line body static models, 3D static models and 3D transient dynamic models. Three load cases were simulated: (i) no ice on any cable, (ii) ice on the cables on either side of the tower, and (iii) ice on all cables. The loads on the insulators were calculated so as to consider the forces from 30-mm-diameter cables attached to the insulators, which were made of structural steel or porcelain. When simulating ice accretion, 50-mm-thick ice on the cable was assumed. For both of the static and transient dynamic models, the structural steel insulator has a smaller deformation than the porcelain insulator due to its higher Young's modulus, and greater stress develops in the structural steel insulator. The joints between the insulator and the tower reduced the deformation and stresses substantially, even for the 80-mm-diameter insulators. Further simulations of ice shedding from the conductor would allow to determine frequencies and amplitudes of the forces acting on the insulator from the vibrating conductor.

Keywords: Ansys, Ice shedding, Power network, Tower, Transient analysis

Influence of blade shape on icing of wind turbine blades

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Abstract.

The demand for energy has been increasing exponentially over the years, which is partly due to population growth and economic development. In order to fulfil this demand, new energy sources such as wind power are in development and widely used worldwide. The wind power represents a great solution for energy demand but the icing of wind turbine blades is an issue that can affect energy production. Therefore, the present study aims to establish the relationship between the blade shape of wind turbines and the icing of that shape, which is essential from the point of view of design of the blades and efficiency of the wind turbine. In order to describe the relationship between the choice of the blade shape and the ice accumulation, several computational tests (CFD) were performed to analyze the aerodynamic properties of the blade before and after the icing event. The computed aerodynamic parameters of the blade with different shapes were compared to available data. After the validation of the numerical model, the relationships between blade shape, ice accumulation, and influence on blade efficiency could be obtained. Two essentially different icing conditions were considered in the present study: (i) freezing drizzle, and (ii) in-cloud icing. More ice accumulated under freezing drizzle conditions, causing an abrupt decrease in the lift-to-drag ratio even after one hour of exposure to icing conditions. However, for in-cloud icing, it was possible to observe a significantly slower decrease in the lift-to-drag ratio. The results show that the accumulation of ice in this last condition was smaller, but it led to more "pointed" shapes than under freezing drizzle conditions. Hence, the application of the results of the present study contributes to improving the design of the blade geometry, which has great importance for increasing the efficiency in the production of energy under the type of climatic conditions considered.

Keywords: CFD, ice accretion, Fensap-ice, Wind turbine

Analysis of relationship between mechanical properties and technological parameters of sheet metals

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Abstract.

Knowledge of dependency between technological and mechanical properties of sheet metals is essential from the viewpoint of tool design and effective manufacturing. In order to describe mathematical relationship between springback coefficient and elastic-plastic properties of sheet metals, series of FEM (finite elements method) simulations and laboratory edge bending tests were accomplished. To create an ideal elastic-plastic material model of different metals tensile tests were carried out. Thereby, theoretical and numerical methods of springback prediction were analyzed and compared to edge bending tests. With the validated numerical model, springback coefficient can be calculated in a wide range of mechanical properties.

Keywords: Experimental Validation, Numerical Method, Sheet Metal Bending, Springback, Theoretical Method

Motion of Wind Turbine Blades Exposed to Non-Uniform Wind Velocity Distribution

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Abstract.
Nowadays, engineers and researchers are required to work in the wind energy field. It is due to the fact that problems and challenges related to this field have been increasing to be solved by companies and industries. The main purpose of this research is to develop models that are applicable to study the motion of wind turbine blades exposed to non-uniform wind and to determine the stress in the blade under such conditions and how the loads influence the motion of this blade. Simulations have been carried out applying Fluid Flow (Fluent) analysis, Static Structural Analysis and Transient Structural Analysis in Ansys Workbench 19.2. In order to construct numerical models of wind turbine blades exposed to non-uniform wind, a parabolic wind profile was assumed and its time dependence locally on the blade surface was considered as the blade moved in this velocity field. The drag and lift coefficients of a blade section were calculated in the fluid flow analysis, whereas the total deformation and the maximum equivalent stress in a 3D model of a blade with constant cross section were determined in the static and in the transient dynamic analysis. The Maximum Equivalent Stress was below the limit of tensile yield strength and tensile ultimate strength of the material considered. The Total Deformation in the Transient Structural Analysis was significantly smaller than in the Static Structural analysis since the rotation of the blade was allowed. Moreover, the Equivalent Stress is also reduced in the Transient Structural analysis as compared to the Static Structural analysis. Thus, it is concluded that there was no risk of blade damage under the conditions considered.

Keywords: Ansys Workbench, Static structural analysis, Transient structural analysis, Wind turbine blade

Fluid Structure Interaction Analysis for 3D Model of Wind Turbine

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Abstract.
Numerical methods approach to study complex systems to save time and money in nowadays industries. In this presentation, a comprehensive methodology for studying a 3D model of wind turbine is presented in order to investigate the behaviour of the system. ANSYS software, FLUID and FEA packages, is used for this purpose. Computational fluid dynamics (CFD) solves the equations of the air flow; mass and momentum conservation of the air flow in a pre-defined volume-domain. In this case, it is taken into account the k-omega turbulence SST model in order to define a constant 12 m⁄s velocity of the wind. CFD outputs the pressure distribution on the wind turbine blade surface. It is imported as a load, in FEA package, in order to calculate the mechanical behaviour of the blades.
Blades are composed by orthotropic composite material, which is lately used in eolic industry for this purpose. Moreover, the angular velocity of the blade is considered as centripetal load. FEA analysis results in the study of the deflection/deformation of the blade, equivalent stress (Von-Misses), and force and moment reaction. Finally, theoretical results given by ANSYS are presented and analysed. Furthermore, approximated hand calculations are provided based on data provided by industry and data obtained in the simulations. They are compared in order to give us an idea about the accuracy of our theoretical simulated results.

Keywords: Ansys, CFD, Finite element analysis, Simulation, Wind turbine

Lagrangian method to predict mechanical behavior of granular assemblies

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Abstract.
Discrete Element Method (DEM) is a numerical technique developed by Cundall and Strack in 1979 for modeling mechanical properties of particulate materials based on solving the equation of motion of all individual particles. Normal and tangential forces and moments during particle-particle and particle-wall interactions are calculated by a simulation cycle in discrete time steps with repeated use of Newton's second law of motion and the angular momentum theorem. This method is commonly used to define behavior and motion of granular materials in several fields of research included granular phenomena. By using this method, the mechanical properties of granules can be described and beneficial information could be obtained to understand complex behavior of these materials. However determination of micromechanical parameters (calibration of the discrete model) and computational demand of simulations are two main shortcomings of DEM. Using this numerical technique, macro behavior of granular assemblies is modeled with multiple, so-called micromechanical parameters of individual elements, nevertheless nowadays there is no suitable method for calibrating these parameters, thus macro behavior of particulate systems are highly dependent on micro behaviors. Other main disadvantage of discrete element based calculations is their great computational demand. Approximate interaction detection and solving dynamic equations on all single elements in every discrete time steps is a challenge even for the best computers, because not only the number of particles, but also total number of calculation steps increases simulation time. One of the most difficult problems during discrete modeling is the simulation of industrial scale processes, namely even simplest procedure involves several billion of interactions and particles, and for this reason it is impossible to model these both from practical and computing viewpoint.

Keywords: Calibration, Discrete element method, Mechanics of granular materials

Development of innovative materials/products by utilizing waste and natural recourses

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Abstract.
One can envision that the evolution within the field of science and technology to a great extent relied upon the advancement of materials. The prosperity and the progress of our society are governed and mainly judged by the availability or ample production of quality products, which originate from materials. Industrialization plays a central role in today's society by producing quality goods and products by using different materials that stimulate economic growth and raise the standard of living. At one side industrialization has a beneficial influence on the economy of any country and on the other side any industrial activity generates various kinds of waste, which can impose a negative impact on our health and environment. The demand of good living standard along with ever increasing population results in waste generation growth. Landfilling, incineration, recycling or reuse of waste and prevention of synthetic materials are generally adopted for reducing waste and for developing a sustainable environment. One cannot totally prevent the use of synthetic materials but the materials can be synthesized using sustainable "green energy" approach instead of chemical approach. In this presentation, the potential outcome of using industrial waste such as cement bypass dust in the development of an innovative product such as car`s disc brake pads and metal nanoparticles synthesis, using natural recourses such as Cannabis sativa is presented. The study demonstrates that the utilization of waste and natural recourses not only helps in reducing the production cost but also helps in lowering the environmental burden.

Keywords: Brake pad, Cannabis sativa, Cement bypass dust, Nanoparticle, Waste material

Short communications

Modelling of Transmission Line Insulators and Towers Exposed to Dynamic Effects

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Abstract
Wind and ice accretion on power networks may cause heavy dynamic load resulting in serious damage to the transmission line. The present study aims to examine the effects of wind and ice shedding on the insulators and on the tower of a transmission line considering the loads acting from the vibrating conductors.

Keywords: Ansys, Ice shedding, Power network, Tower, Transient analysis

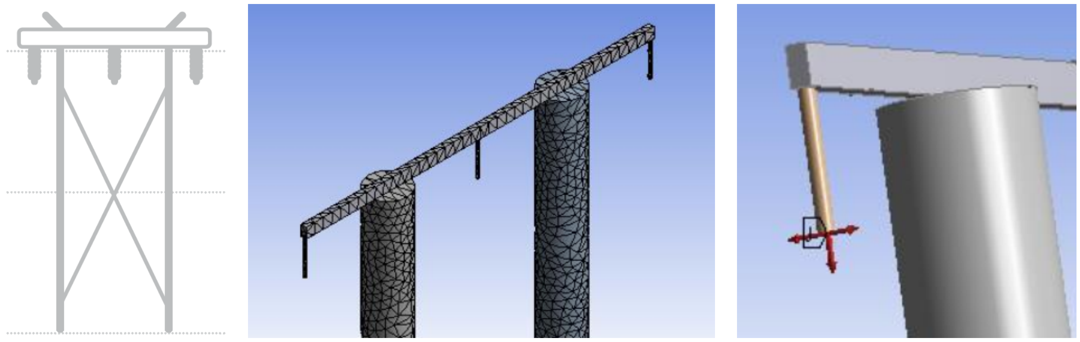
Introduction

The structures where transmission line cables are hanged are exposed to static and dynamic loads. These loads are due to the cable weight and to such phenomena as wind and icing events. The elements of transmission lines should endure additional loads caused by these phenomena when the line is located in such regions where ice may accumulate on the cables and on the structure. Consequently, the additional loads have to be taken into account in the design and construction of these structures where these phenomena are expected. The tower and suspension support the cables, therefore the loads on the cables generate loads on the tower and suspensions. Wind-induced vibration can be categorized in three types: aeolian vibration, galloping and wake-induced oscillation of conductor bundles [1, 2]. Ice shedding is a phenomenon that might induce high dynamic loads on the conductors and consequently on the insulators and tower itself [2]. The main goal of this project is to construct a numerical model of transmission line towers and suspensions, which is applicable to determine the dynamic load on the suspension and on the tower during conductor vibration due to such natural effects as wind and ice shedding from the conductor.

Methodology

The numerical model of a tower with insulators in a 275 kV transmission line [3] have been constructed using the commercial finite element software Ansys [4]. The draft of the tower and its meshed geometry in the numerical model are shown in Figs. 1(a) and 1(b).
Insulators were modelled with circular cross section of two different diameters, i.e. 80 mm and 120 mm, and with two different materials, i.e. structural steel and porcelain. The connections of the insulators and the tower were considered either fixed or via joints allowing free rotation around the transverse direction. The conductors itself were not modelled, but the loads from the conductors were considered by forces at the free end of the insulators (see Fig. 1(c)). These forces represented the weight of the cable and ice, and the lift and drag forces due to wind. They were calculated considering the statics and dynamics of suspended cables [5]. The lift force varied in time, other forces were assumed to be constant.

[1] Corresponding author



(a) (b) (c)

Fig. 1: (a) Draft of tower; (b) Numerical model of tower with mesh; (c) Insulator with forces from conductor

Three load cases were studied in the static analysis: (i) no ice on any cable; (ii) ice on cables in one side of the insulators; (iii) ice on all the cables. In the transient structural analysis different scenarios were simulated considering the effects of aeolian vibration of the conductor and ice shedding from one side of the insulators.

Results

Deformation and stress in the insulators and in the towers were determined in the static equilibrium and during the conductor vibration. The greatest stress developed in the case when there was ice on the conductors on one side of the insulators, and no ice on the other side. The greatest value of stress obtained for the case of smaller insulator diameter made of porcelain and connected to the tower via fixed joint. This value may be reduced significantly by increasing the insulator diameter and connecting the insulators to the tower via joints. Table 1 lists the maximum values of deformation and stress obtained during the transient structural analysis of aeolian vibration and ice shedding, respectively. Figs. 2(a) and 2(b) show the deformation during aeolian vibration and vibration following ice shedding, respectively, for porcelain insulator with diameter of 80 mm, with fixed connection to the tower.

Table 1: Deformation and stress during aeolian vibration and vibration following ice shedding

	Model	**Deformation (mm)**		**Max. stress (MPa)**	
		aeolian	ice shedding	aeolian	ice shedding
No Joint	Structural Steel 80 mm	11,71	9,36	246,96	187,81
	Structural Steel 120 mm	5,05	5,36	82,57	59,13
	Porcelain 80 mm	19,01	13,15	259,65	167,35
	Porcelain 120 mm	6,02	5,65	74,93	48,81
Joint	Structural Steel 80 mm	1,05	3,46	10,16	6,24
	Structural Steel 120 mm	1,12	3,47	12,25	6,4
	Porcelain 80 mm	1,03	3,46	9,21	6,12
	Porcelain 120 mm	1,04	3,47	10,29	6,25

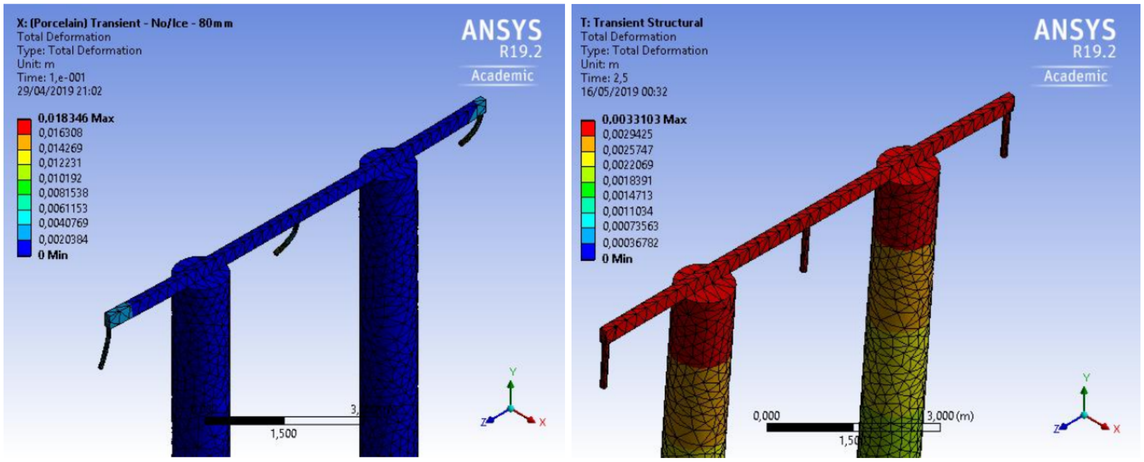


Fig. 2: Deformation in insulators and towers (a) aeolian vibration; (b) vibration following ice shedding

Conclusions

Numerical simulations were carried out to find deformation and stress in a tower with insulators of a 275 kV transmission line during aeolian vibration of the conductors and vibration following ice shedding. The diameter and material of the insulator, and its connection to the tower were varied. The greatest stress developed for asymmetric load when one of conductors connected to the insulator was loaded by ice, whereas there was no ice on the other one. The maximum stress was close to the yield stress of the material, but it is reduced significantly by increasing the insulator diameter and by connecting the insulators to the tower via joints.

Acknowledgment

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Influence of blade shape on icing of wind turbine blades

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Abstract
Ice accretion on wind turbine blades changes the blade shape that determines the aerodynamic properties of the blade. This phenomenon affects seriously the energy production of the wind turbine. Aerodynamic performance degradation depends to a great degree on the geometry of the blade and on the ambient conditions. The ice shape and the resulting modification in the aerodynamic coefficients are examined in this study, considering different blade shapes and different icing conditions.

Keywords: CFD, Fensap-Ice, Ice accretion, Wind turbine

Introduction

The world's energy demand has been increasing in recent years. One of the ways to meet this demand has been the development of renewable energy technologies. An example is wind energy that comes from the reaction of the wind on a wind turbine. Since wind speed increases with altitude close to sea level, and available wind power is higher at lower temperature due to increased air density, cold regions provide an excellent environment for exploiting wind energy. On the other hand, the extreme conditions that these places present may involve freezing. The ice that accumulates on the blades diminishes the energy production and reduces the lifetime and safety of wind turbines [1, 2]. Numerical models have been constructed in this project in order to simulate ice accretion on wind turbine blades and to calculate the aerodynamic coefficients of the iced blades. Results contribute to understanding the influence of icing on wind turbine performance.

Methodology

Blade shapes of the wind turbine were assumed in the form of four different airfoils chosen form the NACA 4-digit series. These are the NACA2412, NACA4412, NACA6412 and NACA8412 airfoils. Ice accretion on 3D geometries was simulated using Ansys Fensap-Ice [3]. Then, the airflow around the iced blades was modelled applying Ansys Fluent [4] in order to obtain the aerodynamic coefficients of these shapes. The 3D geometry meant a short part of the blade with constant cross section, whereas the 2D geometry was obtained by taking the mid-section of these shapes. Two essentially different icing conditions were considered: freezing

Table 1: Thermodynamic parameters describing in-cloud icing and freezing drizzle conditions [5]

Icing condition	Wind Speed	Air Temperature	Liquid Water Content	Median Volume Diameter	Air Relative Humidity
	(m/s)	(°C)	(g/m³)	(µm)	(%)
In-Cloud Icing	20	-10	0.3	27	95
Freezing Drizzle	10	-5	1.5	62	80

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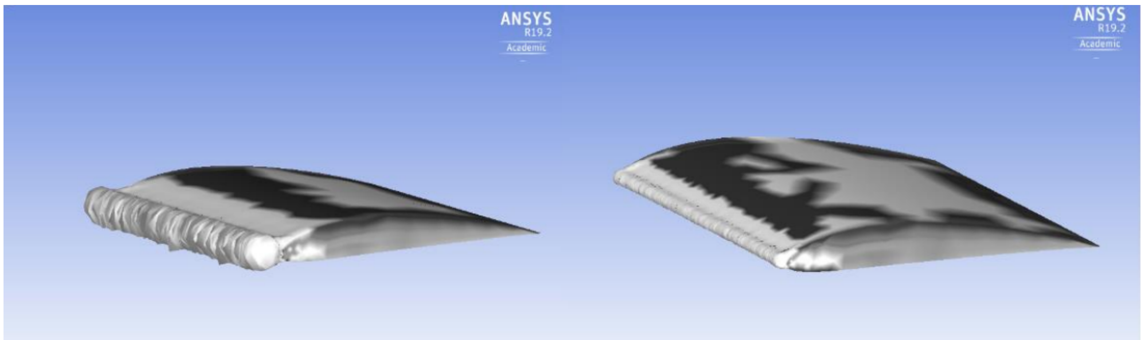
drizzle and in-cloud icing conditions. The thermodynamic parameters describing a typical case of each of these conditions are summarized in Table 1.

Results

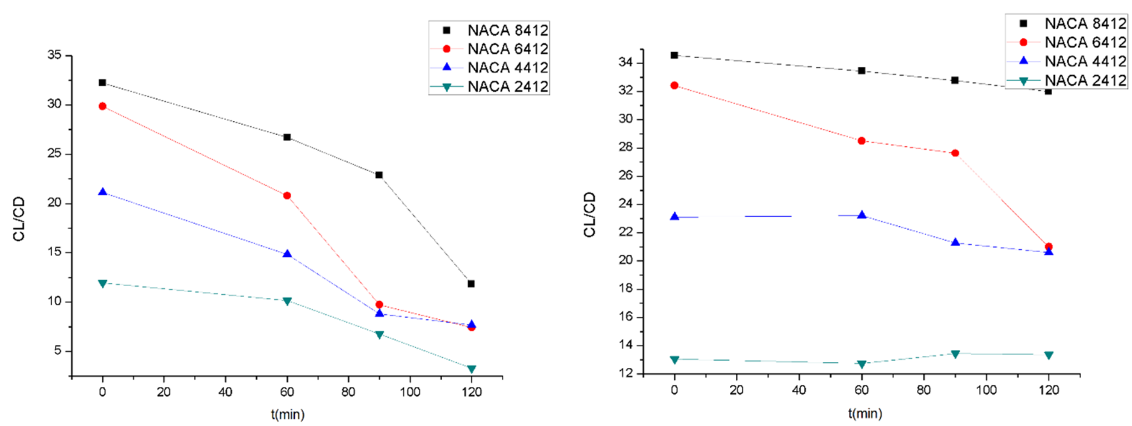
Ice accretion was simulated during different time intervals for the four blade shapes and for the two icing conditions listed in Section "Methodology". The longest simulations were carried out on the NACA4412 airfoil, which considered four hours of icing. Fig. 1 clearly shows the great amount of ice and the changed profile obtained under freezing drizzle conditions, and the smaller amount of ice obtained under in-cloud icing conditions.



(a) (b)

Fig. 1: Iced shapes of NACA4412 airfoil (a) freezing drizzle; (b) in-cloud icing

Further iced shapes were obtained after modelling 60 min, 90 min and 120 min of icing event. Then, the aerodynamic coefficients, i.e. the lift coefficient and the drag coefficient, were calculated in the mid-section taken from each of the iced shapes. Fig. 2 shows the change of lift-to-drag ratios with the duration of icing event. The lift-to-drag ratio after 60, 90 and 120 min of icing reduces to about 70-80%, 40-70% and 25-35%, respectively, of its value obtained for the bare blade. Thus, freezing drizzle has a severe effect on the aerodynamics of the blade after a relatively short time. The reduction of the lift-to-drag ratio is significantly smaller under in-cloud icing condition. The values after 120 min of icing are still close to 90% of the values obtained for the bare blade.



(a) (b)

Fig. 2: Lift-to-drag ratio for different blade shapes obtained after different intervals of icing event (a) freezing drizzle; (b) in-cloud icing

Conclusions

The present study considered four different sections of wind turbine blades, and simulated icing on those blades and calculated the aerodynamic coefficients of the iced blades under two different icing conditions. Results reveal the variation of the aerodynamic coefficients on the iced shapes with the duration of icing event. The lift-to-drag ratio reduces significantly under freezing drizzle conditions, its value after about 1h30min of icing becomes less than the half of the value obtained for the bare blade. This reduction is less severe under in-cloud icing conditions; thus, the wind turbine can operate for a relatively longer time under such conditions without a significant power loss.

Acknowledgment

This paper was supported by the ÚNKP-18-4 New National Excellence Program of the Ministry of Human Capacities. The research was carried out in the frame of the project "EFOP-3.6.1-16-2016-00018 – Improving the role of research + development + innovation in the higher education through institutional developments assisting intelligent specialization in Sopron and Szombathely".

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Analysis of relationship between mechanical properties and technological parameters of sheet metals

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Abstract

Springback is a common problem on sheet metal bending, on this occurrence the sheet metal tries to return to its original shape after the bending, which leads to poor dimension precision. Therefore, theoretical and numerical methods of springback prediction were analysed and compared to edge bending tests. With the validated numerical model, springback coefficient can be calculated in a wide range of mechanical properties.

Keywords: Springback. Sheet Metal Bending. Numerical Method. Theoretical Method. Experimental Validation.

Introduction

Sheet metal bending is a process in which a planer sheet is plastically deformed between tools (dies) to obtain the desired final configuration [1]. Although the process is quite simple, the bending operation presents some technical problems, such as the poor dimension precision, because the considerable elastic recovery during unloading which leads to springback [2]. In this study, the elastic-plastic properties of sheet metals and the springback coefficient will be investigated, and mathematical relationships between mechanical properties and springback will be described. Thereby, to create an ideal elastic-plastic material model of different metals, tensile tests will be carried out, planning to design an ideal numerical model on software ANSYS, to simulate the edge bending of sheet metal with different computational parameters and calculate the springback coefficient. In order to validate these simulations, edge bending experiments will be carried out and the springback coefficient will be properly measured. With the comparison the numerical and experimental results, a validated FEM model will be established and with this springback coefficient can be calculated in a wide range of mechanical properties.

Methodology

In order to create an ideal elastic-plastic material model, first of all, tensile tests were carried out in an universal testing machine for two different common materials, Aluminum Alloy and Mild Steel. The stress-strain curve was obtained from the tensile tests, and from these curves, trending lines for the Elastic and the Plastic zones were created aiming obtaining the material properties necessary for the chosen material model. The FEM material model chosen was the Bilinear Isotropic hardening. This model requires the Elasticity Modulus, the Yield Stress, the Tangent Modulus and the Poisson's Ratio. Afterwards, a bending procedure was depicted on Ansys Static Structural, on a 2D Plane Stress model. The boundary conditions were defined and

[3] Corresponding author

several simulations of the bending procedure for both material models and different bending angles were carried out. A two steps analysis was conducted, where on the first step the sheet was bent and on the second step the sheet was unloaded, in order to analyze the elastic recovery of the material. From these simulations the springback coefficient was calculated by the numerical method. In order to validate these results bending experiments were carried out on a bending machine with geometry similar as the numerical geometry, thus several sheets from Aluminium and Steel were bent and the springback was measured.

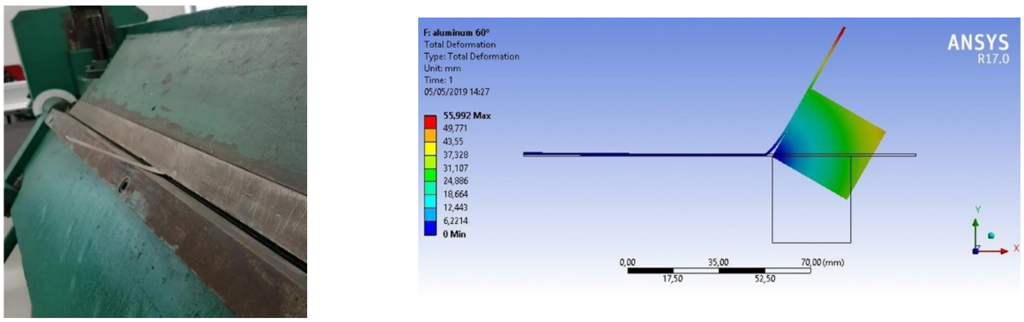

Figure 1: Sheet metal bending by the numerical method and the experimental method.

In addition, a theoretical method to predict the springback, using Gardiner's equation were analyzed in order to compare the results.

Results

The springback coefficient results were analyzed for the three cases: theoretical, numerical and experimental, as can be seen in Figure 2. It was observed that the theoretical method is not so similar to the experimental one, especially for the aluminium sheet, and the average error between these two methods is 33.3%, thus it was concluded that this method it isn't the best method in case of soft materials, but can be used as an estimation in case of harder materials. On the other hand, the numerical method was observed as quite similar to the experimental one, the average error between these two methods is 5.8%, consequently the numerical simulation is useful and validated as a method to predict the springabck for different materials and in a wide range of bending angles.

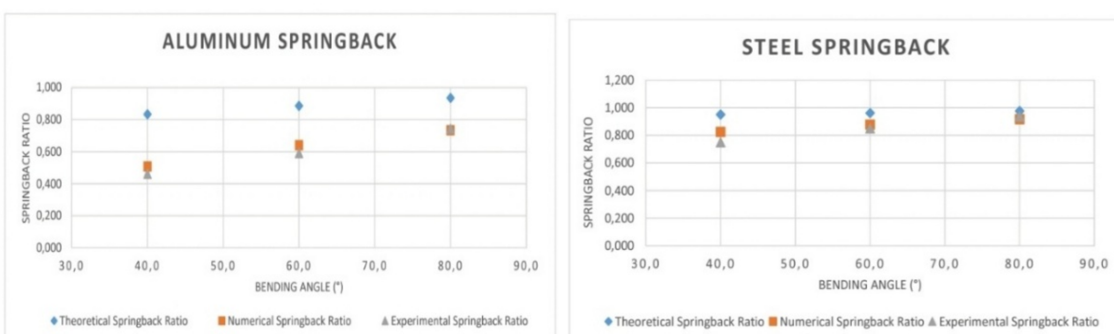

Figure 2: Springback coefficient results for the Aluminum and the Steel sheets.

Once the numerical method was validated a parameter sensitivity test was carried out aiming to analyze the influence of material properties and geometrical parameters on springback coefficient. The parameter sensitivity test consists to define the initial parameters, and subsequently, vary in a wide range one of the parameters, keeping the other ones fixed. It was observed that the springback coefficient increases with higher Young's Modulus, thicker sheets and greater bending angles, it decreases with higher yield stress, and the influence of the Tangent Modulus and the Poisson's Ratio was also analyzed, but it was noticed that these parameters does not affect the springback coefficient.

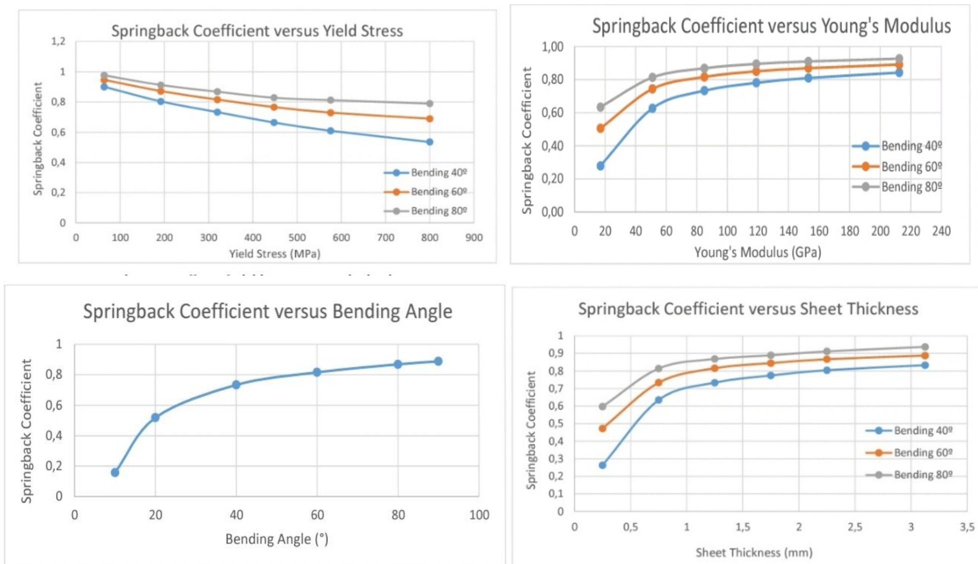

Figure 3: Parameter Sensitivity Test Results.

Conclusions

It can be concluded from this study that the theoretical method using Gardiner's Equation has an average error of 33.3% and that it can be used as an estimation in case of hard materials, but it is not the best approximation for soft materials. And, on the other hand, the numerical method using Ansys Static Structural and the Bilinear Isotropic Hardening Material Model has an average error of 5.8% so it has a good accuracy and it can be used on the springback prediction in a wide range of bending angles and for different materials. Furthermore, as a result from the parameter sensitivity tests it is noticeable that the springback coefficient increases with stiffer materials, thicker sheets and greater bending angles, it decreases with higher yield stress, and that the Tangent Modulus and the Poisson's Ratio does not affect the springback.

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Motion of Wind Turbine Blades Exposed to Non-Uniform Wind Velocity Distribution

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Abstract

Non-uniform wind velocity distribution may result in uneven load along the wind turbine blades and on other structures of the wind turbine. Numerical models have been developed in this project, which are applicable to study the motion of wind turbine blades exposed to non-uniform wind, and to determine the stress in the blade under such conditions. Simulation results also reveal how such loads influence the motion of the blade.

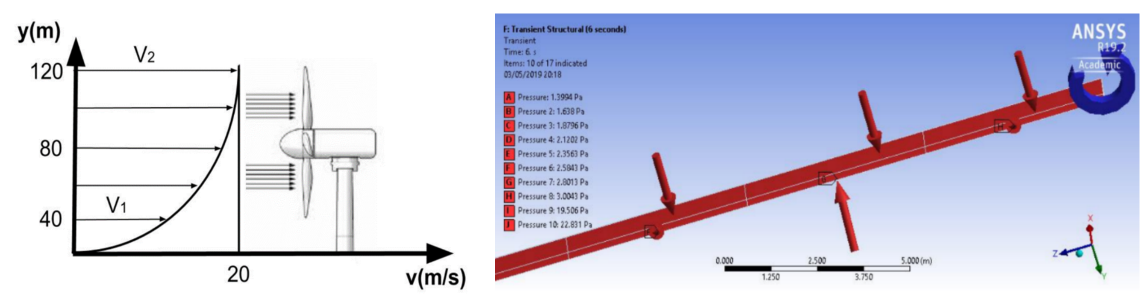
Keywords: Ansys Workbench, Static structural analysis, Transient structural analysis, Wind turbine blade

Introduction

The wind energy branch has been increasing fast in the world. Many companies search for expertise to minimize the problems related to the wind turbines. The wind turbine blade is designed to operate under constant wind or non-constant velocity distribution, which should be treated as even or uneven load. These loads generate stresses and deformations, and may also result in vibration problems [1]. The motion of wind turbine blades exposed to non-uniform wind is studied in this project. Numerical models are constructed to determine the deformation of the blade and the stress that develops in the blade during such motion.

Methodology

The commercial finite element software Ansys [2] was applied to construct the numerical models of a wind turbine blade. The models considered simplified blade geometries with cross section defined by the NACA2412 airfoil. The air flow around a 2D section of the blade was simulated using Ansys Fluent, and the aerodynamic properties were studied. Then, a 3D model of a 40-m long blade with constant cross section was constructed, and the effects of non-uniform wind were examined on a fixed blade and on a rotating blade applying static structural analysis and transient structural analysis, respectively.



(a) (b)

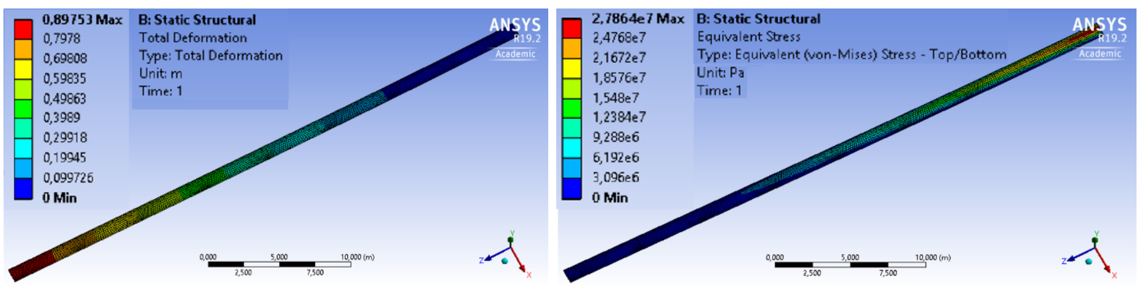
Fig. 1: (a) Wind velocity distribution; (b) Loads on the blade surface due to wind

[4] Corresponding author

The velocity distribution of wind in the atmospheric boundary layer was modelled by a parabolic velocity profile (see Fig. 1(a)). The lift and drag forces were calculated at different altitudes, and the pressure on given surfaces of the blade was determined correspondingly [3]. One end of the blade was fixed in the static analysis, whereas the blade was rotating around this end in the dynamic analysis. The model with the loads is drawn in Fig. 1(b). Since the blade was moving in the dynamic analysis, the force from the wind was time dependent.

Results

The deformation of the blade and the stress developing in the blade was calculated in the static structural analysis. This model simulated the case when the wind turbine is shut down, but the wind applies a load on the fixed blade. The maximum deformation at the blade tip was obtained 89.75 cm, and the maximum stress developed at the axis, i.e. at the fixed end of the blade, and its value was obtained 27.86 MPa under the conditions considered.



(a) (b)

Fig. 2: (a) Deformation and (b) stress in blade in static structural analysis

In the dynamic analysis, the time of one rotation was assumed to be 6 s. Since free rotation was assumed at the axis, the deformation and the stress reduced as compared to the case of fixed blade. The maximum value of stress was obtained to be 18.2 MPa at the axis of rotation.

Conclusions

Numerical models of a wind turbine blade exposed to non-uniform wind velocity distribution have been constructed. The deformation of the blade and the stress developed in the blade were determined when the blade is fixed, and when the blade rotates with a constant angular velocity. The deformation is greatest at the blade tip, and the stress is greatest at the axis, when the blade is fixed. However, the stresses obtained under the conditions considered are significantly smaller than those that could lead to damage in the blade material.

Acknowledgment

This paper was supported by the ÚNKP-18-4 New National Excellence Program of the Ministry of Human Capacities. The research was carried out in the frame of the project "EFOP-3.6.1-16-2016-00018 – Improving the role of research + development + innovation in the higher education through institutional developments assisting intelligent specialization in Sopron and Szombathely".

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Analysis of fluid structure interaction for 3D model of wind turbine

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Abstract
This work uses ANSYS fluent and FEA in order to study the interaction between air fluid and wind turbine structure. It is used a three dimensional system with three blades wind turbine but periodicity the flow around one blade is simulating and extrapolate to the three blades.

Keywords: Ansys, computational fluid dynamics, finite element analysis, wind turbine

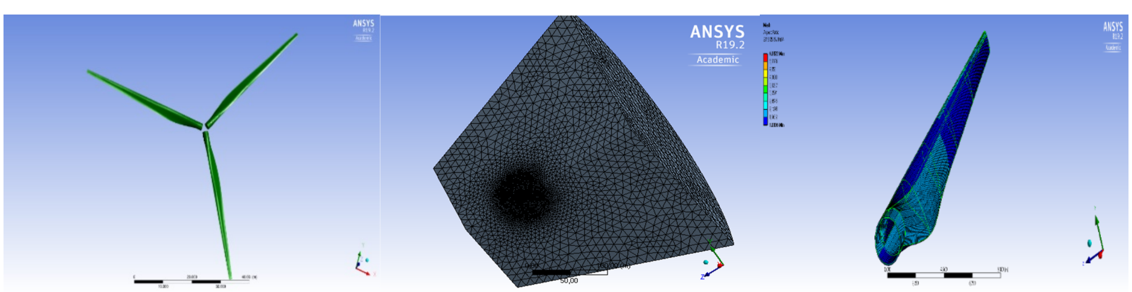
Introduction

Numerical methods approaches to study complex systems save time and money in nowadays industries. In this presentation, a comprehensive methodology for studying 3D wind turbine is presented in order to investigate the behaviour of the system. ANSYS software, FLUID and FEA packages, is used for this purpose. Computational fluid dynamics (CFD) solves the equations of the airflow; mass and momentum conservation of the airflow in a pre-defined volume -domain. In this case, it is taken into account the k-omega turbulence SST model in order to define a constant $12\,{}^{m}/_{s}$ velocity of the wind. CFD outputs the pressure distribution on the surface of the wind turbine blade. It is imported as a load, in FEA package, in order to calculate the mechanical behaviour of the blades.

Blades are composed by orthotropic composite material, which is lately used in Eolic industry for this purpose. Moreover, the angular velocity of the blade is considered as centripetal load. FEA analysis results in the study of the deflection/deformation of the blade, equivalent stress (Von-Misses) and, force and moment reaction. Finally, theoretical results given by ANSYS are presented and analysed. Furthermore, approximated hand calculations are provided based on data provided by industry and data obtained in the simulations. They are compared in order to give us an idea about the accuracy of our theoretical simulated results.

Methodology

In this study, it is intended to evaluate the mechanical behaviour of the wind turbine blades considering the pressure distribution on the blades due to the effect of the air fluid and centripetal (force) loading due to the angular velocity of the wind turbine blades.

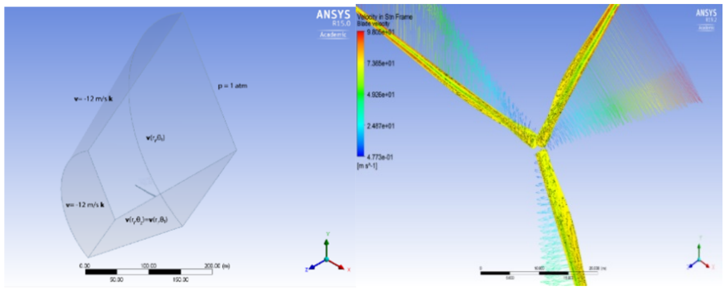


(a) (b) (c)

Fig. 1: (a) 3-blades wind turbine; (b) Meshing of the aerodynamic load on the blade; (c) Meshing of the blade

[5] Corresponding author

Step 1, Aerodynamics (CFD): The aerodynamic load on the blade is considered. It is defined a suitable domain where air flows with its corresponding meshing and boundary conditions. The governing equations are continuity (conservation of mass) and Navier-Stokes (conservation of moment) including Coriolis and centripetal force. The frame of reference rotates with the blade in order not to require a moving mess. Furthermore, it is used the Reynolds Averaged form of continuity and momentum and use the SST k-omega turbulence model to close the equation set.



(a) (b)

Fig. 2: (a) Aerodynamics boundary conditions; (b) Outputs of the aerodynamics, pressure distribution and wind velocity

Step 2, Blades (FEA): The presures on the wetted areas of the blade are passed as pressure loads to the mechanical blade and stresses and deformations of the blade are analysed. It is defined a blade, it is meshed and the pressure is loaded. For this purpose, it is used shell theory for curved surfaces in order to calcule deflections and stresses on blades. Moreover, it is simulated the effect of having our blade be connected to a hub which gives us information such as forces and bending moments. Mention that the effect of the blade being rotating acts as a centripetal loading. Finally, large defletion effect considers stress stiffening, the faster the blade is spinning, the stiffer the response is going to be.

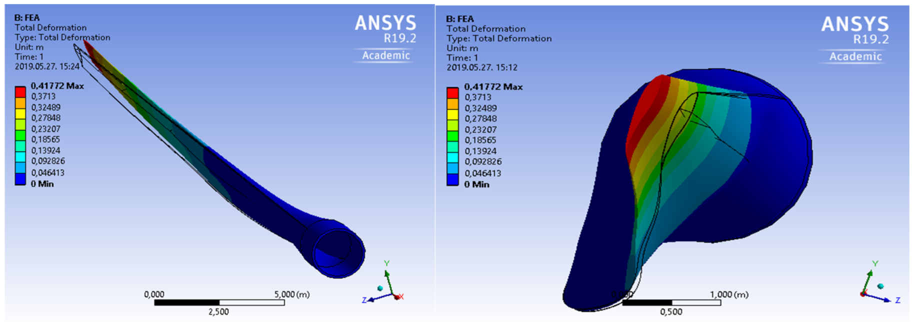
Conditions of the simulations are the following:

- Turbulent wind flows towards negative z-direction at $12 {}^{m}/_{s}$. Therefore, blade spinning clockwise at -2.22$ {}^{rad}/_{s}$. Tip speed ratio (blade velocity to incoming wind velocity) equal to 8. Blade is connected to a hub, but hub not included in the model. Blade root offset, 1m.
- Standard air conditions are considered: 15°C, density $1.225 {}^{kg}/_{m^3}$, and viscosity $1.7894 \cdot 10^{-4} {}^{kg}/_{ms}$.
- The blade is 42.3m long with cylindrical shape at the root, then transitions in the root, body and tip with diferent size airfoils. Pitch angle varies giving a twist of 4° at the tip.
- An orthotropic composite material is used to fabricate the blade with the following properties; density $1550 {}^{kg}/_{m^3}$, Young modulus in X-Y-Z directions (Pa): $1.1375 \cdot 10^{11}$-$7.583 \cdot 10^{9}$-$7.583 \cdot 10^{9}$, Poisson's ratio XY-YZ-XZ: 0.32, 0.37, 0.35, and shear modulus XY-YZ-XZ (Pa): $5.546 \cdot 10^{9}$-$2.964 \cdot 10^{9}$-$2.964 \cdot 10^{9}$.

Results

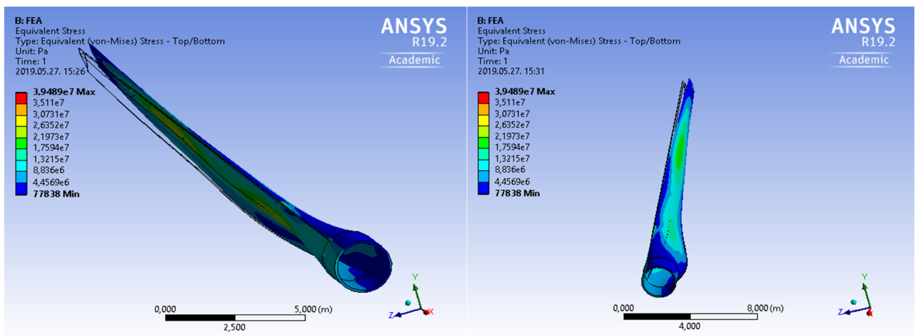
Deformations/deflections and equivalent (Von Misses) stresses of the blade are obtained in the static equilibrium. Furthermore, force and moment reactions in the connection between the blade and hub are also calculated. These outputs give us an understanding of what it is happening in the system in these conditions. As it is expected, the X-component of the force is the biggest one as the Y-component of the moment is. Figure 3 shows deformations and figure

4 stresses on the blade. Figure 5 pictures the force and moment components. Theoretical results given by ANSYS suit well with the obtained using hand calculations and experimental ones.



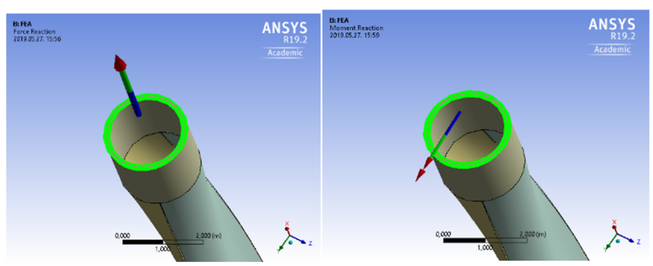
(a) (b)

Fig. 3: Deformation in blades (a) back perspective; (b) front perspective



(a) (b)

Fig. 4: Equivalent stress distribution on blade (a) faced to flow; (b) back faced to flow



(a) (b)

Fig. 5: (a) Resultant force; (b) resultant moment

Acknowledgment

The research was carried out in the frame of the project "EFOP-3.6.1-16-2016-00018 – Improving the role of research + development + innovation in the higher education through institutional developments assisting intelligent specialization in Sopron and Szombathely".

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Lagrangian method to predict mechanical behaviour of granular assemblies

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Abstract
Discrete Element Method (DEM) is a numerical technique developed by Cundall and Strack in 1979 for modeling mechanical properties of particulate materials based on solving the equation of motion of all individual particles. By using this method, the mechanical properties of granules can be described and beneficial information could be obtained to understand complex behaviour of these materials. However determination of micromechanical parameters (calibration of the discrete model) and computational demand of simulations are two main shortcomings of DEM

Keywords: Granular Materials, Discrete Element Method, Calibration

Introduction

Calibration means the determination of parameters governing the mechanical interaction of the individual particles and walls making up our discrete element model (DEM). Since the elaboration of DEM [1], calibration is the most difficult part of the DEM modeling process. Direct measurement of the parameters governing the particle-particle, particle-wall interactions would be the best solution, but in most of the cases it is impossible. It can also happen that even the measured parameters would not be suitable for modeling purposes, as the applied constitutive equations in the numerical calculations are only approximations. In most of the cases the proper measured values of these parameters are not needed, but a combination of parameters ensuring the modeled macro behaviour to be the same as the measured one.

Standard shear testing technique

The standard shear technique [2] is one of the most commonly used calibration method [3], [4]. The standard shear testing technique for particulate solids is based on the so called Jenike shear cell (see Fig. 1). Material sample is placed into the shear apparatus and before shear a vertical force F_N is applied to the upper plate and hence to the particulate solid within the cell to pre-compress the material sample.

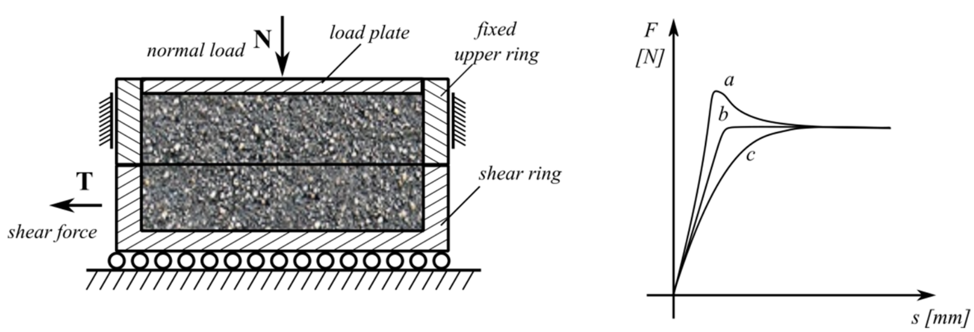

Fig. 1: Jenike's shear cell and a typical shear diagrams

A horizontal force is applied to the bracket by a mechanically driven measuring stem which is driven forwards at a steady rate of 1-3 mm/min . This stem is attached to the drive system through a force transducer which measures the shear force F_T. During the operation the shear ring moves from the original offset position to the opposite. During shear a shear zone develops inside the sample, and in this way we can create a shear stress shear strain plot. By knowing the shear stress values corresponding to a given compressive normal stress, the parameters of the failure line can be determined in the form of $T = \varphi N + c$, where T is the shear stress, N is the normal stress, φ is called the internal friction angle of the assembly and c is the cohesion (see Fig. 2). Naturally, the failure curve of the material is not always linear, but the linear approximation of the failure curve is a common method in the practice [5].

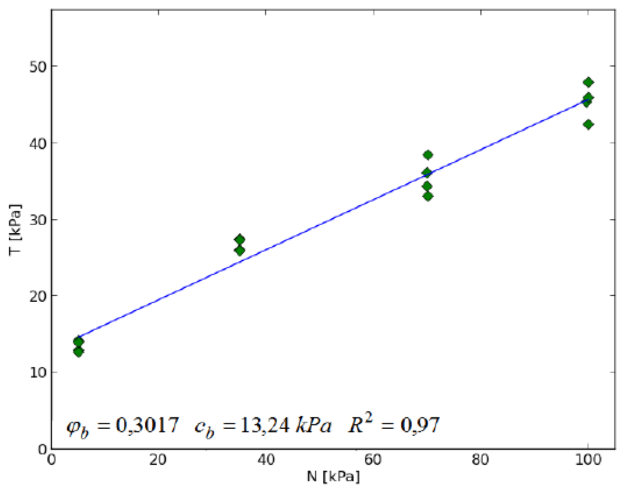

Fig. 2: A typical, linearized failure curve

Discrete element modeling

DEM models the mechanical behaviour of bulk materials by applying and solving the equation of motion on each singular particle of the bulk material assembly. The out of balance forces arising during particle-particle and particle-wall interactions are calculated during the simulation circle, which is a cycle with repeated application of the Newtonian laws of motion to obtain the acceleration, velocity and displacement. The displacement is then used to evaluate the contact forces and moments acting due to the interactions between the particles in their new position. In this article, YADE discrete element method software was used for numerical modeling [6]. In YADE the approximate collision detection filters out the impossible collisions, and after this step, a more computationally expensive collision detection algorithm evaluates the possible interactions between these individual particles. After having exact collision detection, it is possible to model the interaction between the particles in contact. DEM interaction model uses two stiffnesses: K_N normal stiffness and $_{KT}$ shear stiffness. K_N is related to the Young's modulus of the particles material, and K_T is defined as a given fraction of K_N. YADE evaluates the K_N stiffness by modeling the two particles in contact as a serial connection of two springs having length equal to the radius of particles in contact:

$$K_N = 2\frac{E_1 r_1 E_2 r_2}{E_1 r_1 + E_2 r_2} \quad (1)$$

The kinematic variables (displacements) of the contact are called as strains in YADE terminology. To evaluate the normal strain, there is a reference distance d_0 (or equilibrium distance) used to convert the evaluated displacements to dimensionless strain: $d_0 = |\mathbf{C}_2 - \mathbf{C}_1|$, where $\mathbf{C}_1$ and $\mathbf{C}_2$ are the initial position vectors of the two contacting spheres centres. For the constitutive laws YADE uses an equivalent cross-section $A_{eq} = \pi \min(r_1; r_2)^2$ to convert stresses into forces. By knowing the normal and shear displacements u_N, u_T, normal and shear forces are computed in the following way:

$$F_N = K_N u_N, \tag{2}$$

$$F_T = \begin{cases} F_N \tan\varphi \text{, if } |K_T u_T| > F_N \tan\varphi \\ K_T u_T, \text{ otherwise.} \end{cases} \tag{3}$$

If we have cohesive model, cohesive interactions bonds between particles are used to represent the materials cohesive properties. The normal force is $F_N = \min(K_N u_N; a_N)$, where a_N is the normal adhesion. The tangential shear force is $F_T = K_T u_T$, the plasticity condition defines the maximum value of the shear force, by default $F_T^{max} = F_N \tan\varphi + a_S$, where a_S is the shear adhesion. If the maximum tensile or maximum shear force is reached, the cohesive link is broken. The forces and torques evaluated above are used to integrate the equations of motion (linear- and angular momentum theorem) of the particles in contact. From the equations of motion by integration the new particle positions can be determined, and based on the new particle positions, the simulation circle can start again from collision detection.

Discrete element model of shear test

A slightly modified version of Jenike's shear cell was used for the discrete element modeling purposes, as in this case the lid is rectangular (see Fig. 3). We evaluated the normal-force shear force diagrams in case of four different pre-compressing forces four times (16 simulations for one failure line) to get one failure line similar to the example showed in Fig. 2. It can be seen, there, that the compression of the material sample starts only after the granular material poured into the shear box is in a state of rest. The constant compressive force value is maintained by up- and downwards motion of the compressing plate.

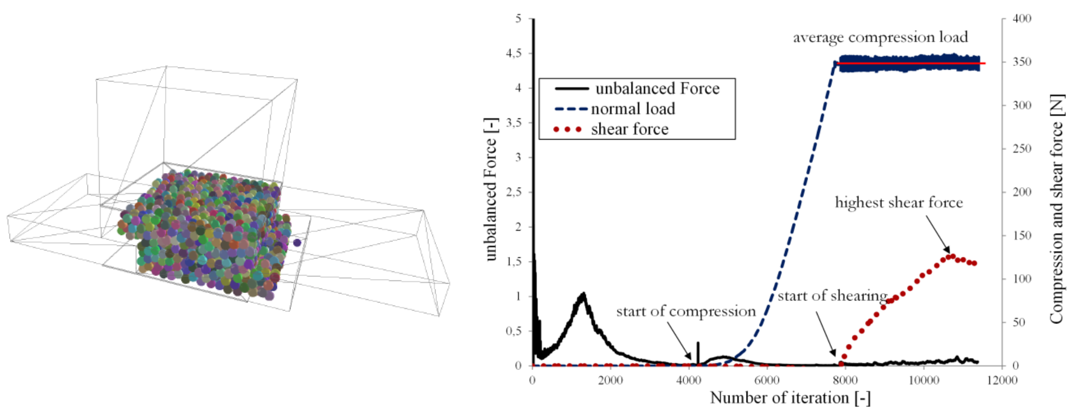

Fig. 3: DEM model of standard shear test and typical registered values in simulations

Conclusions

Calibration of discrete element based models is still a challenging question of the engineering practice. It would be preferable to have a standard calibration method available for use. My opinion is that the standard shear testing technique is a well-grounded method applicable to ensure properly calibrated discrete element models. The calibration itself is a time consuming, monotonic process which is (in many cases) based on trial and error methods. It is supposed that this process can be automatized. For the automatization, the process must be rigorously controlled; the trial and error process must be superseded by sensitivity test based gradient methods. In this article, it was demonstrated, that this is possible. The discrete element calibration can be automatized. A first part of a highly autonomous algorithm can be constructed, which is capable to find desired macromechanical behaviour by systematic modification of micromechanical parameters. The change of micromechanical parameters must be based on initial sensitivity analysis to realize relatively short calibration time.

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Development of innovative materials/products by utilizing waste and natural recourses

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Abstract
In recent years, the utilization of industrial wastes and natural recourses emerged as a novel technology in the development of innovative products and materials. Therefore, in this paper the applicability of cement dust, which is a waste of cement industry, in automotive brake pads and a novel green method for the synthesis of hydroxyapatite nanoparticles from *Cannabis sativa* leaf extract have been explored.
Keywords: Waste; Cement dust; Brake pad; *Cannabis sativa*; Hydroxyapatite nanoparticle

Introduction

A significant percent of progress within the field of science and technology mainly depends on the advancement of materials. It is common to note, that the prosperity and the progress of any country are in one hand judged by the production of quality products ranging from real estate, transportation, food, medicines, communication etc. and on the other hand the ability to reduce the production of waste materials. Any industrial activity generates various kinds of wastes, which can cause adverse impact on our health and environment if not treated properly [1]. Over the years, industrial waste has been successfully utilized in the development of innovative products [2, 3]. Moreover, prevention/reduction in the use synthetic materials may also helps in developing a sustainable environment. One cannot totally prevent the use of synthetic materials but the materials can be synthesized using sustainable "green energy" approach instead of chemical approach. *Cannabis sativa* is one of the oldest psychotropic medicines known to humanity. The *Cannabis* plant presents a remarkable therapeutic potential as antiemetics, analgesics, cancer and in the treatment of spinal cord injuries, glaucoma and epilepsy [4]. Therefore, in this study, the possibilities of industrial wastes such as cement dust in the development of an innovative product such as car`s disc brake pads and synthesis of nanoparticles such as hydroxyapatite to be used in the development of dental composites using natural recourses such as *Cannabis sativa* is presented.

Materials and Methodology

Cement dust (25 mesh size), a waste of cement industry, four types of phenolic resin as binder, graphite, Kevlar and lapinus fibers were used for the development of car`s disc brake pad. While *Cannabis sativa* leaf extract, calcium chloride, sodium hydroxide, disodium phosphate, distilled water were used for synthesizing hydroxyapatite nanoparticles. Brake pads were developed by mechanical mixing of ingredients and temperature moulding, while the tribological tests were performed in accordance with the Economic Commission for Europe (ECE R-90) regulation using Krauss machine. For the synthesis of hydroxyapatite nanoparticles, about 20% of *Cannabis sativa* leaf extract was added to 40% of aqueous solution of calcium chloride and sonicated for one hour. Thereafter 40% solution of disodium phosphate added to this solution

[6] Corresponding author

and further sonicated for one hour. The appearance of brownish yellow colour indicated the synthesis of hydroxyapatite nanoparticles.

Results

The developed brake pads are presented in Figure 1. The braking performance in terms of coefficient of friction and friction stability was evaluated by running ECE R-90 testing procedure on a Krauss machine. The experimental results indicated that, highest coefficient of friction (0.243) with excellent friction stability of 0.924 was achieved for phenolic resin based cement dust filled brake pad.

Fig. 1: Developed brake pads.

The TEM (transmission electron microscope) micrographs of the synthesized hydroxyapatite nanoparticles are presented in Figure 2. The micrograph reveals mixed shape (spherical, hexagonal, nano rods) for the synthesized hydroxyapatite nanoparticles in the size range of 200 nm.

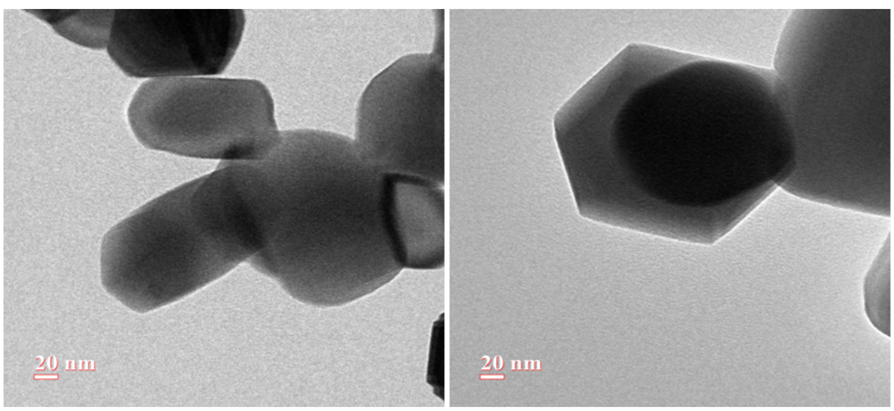

Fig. 2: TEM micrographs of the synthesized hydroxyapatite nanoparticles.

Conclusions

The presented research consist two parts, in first part, cement dust, a waste from cement industry is proposed to be used in car`s brake pads and in second part hydroxyapatite nanoparticles synthesized using green energy approach are proposed to be used in dental materials.

Excellent braking results achieved for straight phenolic resin as binder reinforced with cement waste particles.

Hydroxyapatite nanoparticles successfully synthesized using *Cannabis sativa* plant leaf extract and can be used in dental materials.
Finally, the study concludes that the utilization of waste and natural recourses not only helps in reducing the production cost but also helps in lowering the environmental burden.

Acknowledgment
The research was supported by the "EFOP-3.5.1-16-2017-12. project.

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