AGH UNIVERSITY OF SCIENCE AND TECHNOLOGY

Module name: Kinematic and dynamic simulation of mechanical systems

Academic year: 2019/2020 Code: RIMM-1-711-s ECTS credits: 3

Faculty of: Mechanical Engineering and Robotics

Field of study: Mechanical and Materials Engineering Specialty: —

Study level: First-cycle studies Form and type of study: Full-time studies

Lecture language: English Profile of education: Academic (A) Semester: 7

Course homepage: —

Responsible teacher: dr inż. Stopka Grzegorz (stopka@agh.edu.pl)

Module summary

During the course students are introduced to the theoretical background and practical aspects of kinematics and dynamics simulation in mechanical systems. As a result of the course students know how to use the simulation systems to verifying the specific mechanical design in scope of kiematic nad dynamic analysis and structural strength, as well as how to implement simulation to optimize the construction.

Description of learning outcomes for module

MLO code	Student after module completion has the knowledge/ knows how to/is able to	Connections with FLO	Method of learning outcomes verification (form of completion)
Skills: he can			
M_U001	Is able to elaborate the report from conducted simuation and present the results in form of oral presentation.		Presentation
M_U002	Is able to choose the right criterion and utilize the simulation results for optimisation or poli optimisation of designed mechanism.		Engineering project
M_U003	Is able to use the simulation results to verify the usefulness and functional parameters of designed mechanism.		Engineering project
M_U004	Is able to use the results of dynamic simulation to analyse the structural strength of chosen mechanism.		Engineering project
M_U005	Is able to interpret the simulation results, modify the analysis variables and frames of reference as well as create new output values on the basis of existing ones.		Activity during classes

M_U006	Is able to define kinematic and dynamic excitations and obtain basic kinematic and dynamic parameters from simulation.		Activity during classes
M_U007	Is able to build virtual model of simple mechanism by translating the 3D joints into kinematic ones.		Activity during classes
Knowledge: he knows and understands			
M_W001	Knows how to use the simulation results for verifying the specific construction design in scope of functionality and structural strength, as well as how to implement simulation to optimize the construction.	IMM1A_W10, IMM1A_W01	Presentation
M_W002	Knows how to include passive elements, redundant joints and degrees of freedom in modelling and simulation and how to interpret the results of such simulations.	IMM1A_W02, IMM1A_W01	Presentation
M_W003	Knows the basics of numerical solvers for mathematical models of mechanical systems used in CAD software.		Engineering project
M_W004	Knows how to model external forces, both active and dissipative, as well as kinematic excitation with given excitation. Knows how to implement drive characteristics for simulation purposes.		Activity during classes
M_W005	Knows the procedure of simulation preparation in CAD software, based on Autodesk Inventor Dynamic Simulation example. Knows how to model joints and contacts between elements and with kind of joints models are used in CAD programs and how to convert 3D mechanism joints into mechanical ones.		Activity during classes
M_W006	Knows the virtual prototyping term and its usefulness in analysis and synthesis of mechanisms and machine design and which CAD & CAE aplications can be used.		
M_W007	Knows the purpose of simulation research and what kind of simulations could be specified by the criterion of research goal. Knows what possibilities are given by using a computer to conduct mechanical simulations and what is the general scheme of creating a simulation model.		Activity during classes
M_W008	Knows the role of modelling in science and industry, especially in machine design. Knows the term of process and system modelling and understands the difference between model and real machine. Knows the relations between physical models and mathematical ones, describing kinematics and dynamics of mechanical system.		Examination

Number of hours for each form of classes

	Form of classes										
Suma	Lectures	Auditorium classes	Laboratory classes	Project classes	Conversation seminar	Seminar classes	Practical classes	Fieldwork classes	Workshops	Prace kontrolne i przejściowe	Lektorat
30	20	0	0	0	0	10	0	0	0	0	0

FLO matrix in relation to forms of classes

MLO code	Student after module completion has the knowledge/ knows how to/is able to	Form of classes										
		Lectures	Auditorium classes	Laboratory classes	Project classes	Conversation seminar	Seminar classes	Practical classes	Fieldwork classes	Workshops	Prace kontrolne i przejściowe	Lektorat
Skills: he can												
M_U001	Is able to elaborate the report from conducted simuation and present the results in form of oral presentation.	-	-	-	-	-	+	-	-	-	-	-
M_U002	Is able to choose the right criterion and utilize the simulation results for optimisation or poli optimisation of designed mechanism.	-	-	-	-	-	+	-	-	-	-	-
M_U003	Is able to use the simulation results to verify the usefulness and functional parameters of designed mechanism.	-	-	-	-	-	+	-	-	-	-	-
M_U004	Is able to use the results of dynamic simulation to analyse the structural strength of chosen mechanism.	-	-	-	-	-	+	-	-	-	-	-
M_U005	Is able to interpret the simulation results, modify the analysis variables and frames of reference as well as create new output values on the basis of existing ones.	-	-	-	-	-	+	-	-	-	-	-
M_U006	Is able to define kinematic and dynamic excitations and obtain basic kinematic and dynamic parameters from simulation.	-	-	-	-	-	+	-	-	-	-	-
M_U007	Is able to build virtual model of simple mechanism by translating the 3D joints into kinematic ones.	-	-	-	-	-	+	-	-	-	-	-
Knowledge: he knows and understands												

M_W001	Knows how to use the simulation results for verifying the specific construction design in scope of functionality and structural strength, as well as how to implement simulation to optimize the construction.	+	-	-	-	-	-	-	-	-	-	-
M_W002	Knows how to include passive elements, redundant joints and degrees of freedom in modelling and simulation and how to interpret the results of such simulations.	+	-	-	-	-	-	-	-	-	-	-
M_W003	Knows the basics of numerical solvers for mathematical models of mechanical systems used in CAD software.	+	-	-	-	-	-	-	-	-	-	-
M_W004	Knows how to model external forces, both active and dissipative, as well as kinematic excitation with given excitation. Knows how to implement drive characteristics for simulation purposes.	+	-	-	-	-	-	-	-	-	-	-
M_W005	Knows the procedure of simulation preparation in CAD software, based on Autodesk Inventor Dynamic Simulation example. Knows how to model joints and contacts between elements and with kind of joints models are used in CAD programs and how to convert 3D mechanism joints into mechanical ones.	+	-	-	-	-	-	-	-	-	-	-
M_W006	Knows the virtual prototyping term and its usefulness in analysis and synthesis of mechanisms and machine design and which CAD & CAE aplications can be used.	+	-	-	-	-	-	-	-	-	-	-
M_W007	Knows the purpose of simulation research and what kind of simulations could be specified by the criterion of research goal. Knows what possibilities are given by using a computer to conduct mechanical simulations and what is the general scheme of creating a simulation model.	+	-	-	-	-	-	-	-	-	-	-
M_W008	Knows the role of modelling in science and industry, especially in machine design. Knows the term of process and system modelling and understands the difference between model and real machine. Knows the relations between physical models and mathematical ones, describing kinematics and dynamics of mechanical system.	+	-	-	-	-	-	-	-	-	-	-

Student workload (ECTS credits balance)

Student activity form	Student workload
Udział w zajęciach dydaktycznych/praktyka	30 h
Preparation for classes	10 h
przygotowanie projektu, prezentacji, pracy pisemnej, sprawozdania	50 h
Summary student workload	90 h
Module ECTS credits	3 ECTS

Additional information

Module content

Lectures

Selected aspects of modeling and simulation in machine design

Definitions of model and simulation. Types of physical and mathematical models. The use of computer aid in creating and solving mathematical models as a tool for simulation studies. The concept and methods of virtual prototyping. Objectives, tasks, possibilities and limitations of the use of computer simulation in the analysis of kinematics and dynamics of physical systems. Selected issues of kinematics and dynamics multibody simulation of mechanisms.

Selected issues of Theory of Mechanisms and Machines

Classification and characteristics of members of the mechanism and kinematic pairs. The concept of group and systematics of kinetic groups. Multibody mathematical models and methods for solving. The problems arising from the presence of pasive and redundant elements and unnecessary degrees of freedom.

Analysis of kinematics and dynamics kinematics using computer applications CAD and CAE

Features of the dynamics simulation in Autodesk Inventor as a CAD-CAE system example in scope of kinematics and dynamics simulation. Scope and limitations. The possibility of applying for models with a high degree of abstraction as well as for 3D solid models created using CAD modeler. The procedure of model simulation by setting the simulation parameters, define connections, analysis of the kinematic chain and kinematic groups, simulation run, obtaining results and their interpretation.

Modeling and simulation studies of drive systems

Discrete and simplified models of drive systems. Formulation of equations of movements. The model description of particular component characteristics, such as motors, couplings, reducers. Multiples and reduced models. Description of interactions between internal and external forces, both active and passive. Ability to identify the characteristics of the external resistance resulting from the implementation of transport processes or technologies.

Characteristics of computer programs for simulation studies kinematics and dynamics of mechanical systems.

Characteristics of computer applications to simulate the kinematics and dynamics models based on rigid bodies. Features of the application of MES (Mechanical Event

Simulation) in Autodesk Simulation Multiphysics in scope of rigid bodies dynamics and deformable solids FEM models model integration.

Seminar classes

Analysis of mechanisms kinematics and dynamics models with a high degree of abstraction
Implementation of the kinematic chain model with a high degree of abstraction in 3D CAD modeler. Simulation settings and definitions of parts and their connections. Simulation and development of its results.

Analysis of kinematics and dynamics of mechanisms to 3D solid models
Creation and assembly of mechanism based on existing 3D solid models kinematic chain with a high degree of abstraction. Definitions of joints. Simulation and discussion of its results.

Simulation of models with adnvanced joints and contact connections
Simulation of mechanism with spring-damper elements and contact connections. Discussion about performance of each simulation. Examination of the sensitivity of the model to change the characteristics of the selected calls and parameters of elements.

excavator boom simulation studies
Simulation studies of industrial excavator boom structure. Examination of the sensitivity of the model to change the characteristics of the selected calls and parameters of elements. Results analysis and their export to FEM software.

Simulation tests of drive system
The selection of models the drive source and other components of the powertrain. Defining characteristics of these elements in dynamic simulation environment. Defining characteristics and parameters of resistance forces. Conducting simulation. Discussion of results.

Teaching methods and techniques:

Lectures: Treści prezentowane na wykładzie są przekazywane w formie prezentacji multimedialnej w połączeniu z klasycznym wykładem tablicowym wzbogaconymi o pokazy odnoszące się do prezentowanych zagadnień.
Seminar classes: Na zajęciach seminaryjnych podstawą jest prezentacja multimedialna oraz ustna prowadzona przez studentów. Kolejnym ważnym elementem kształcenia są odpowiedzi na powstałe pytania, a także dyskusja studentów nad prezentowanymi treściami.

Warunki i sposób zaliczenia poszczególnych form zajęć, w tym zasady zaliczeń poprawkowych, a także warunki dopuszczenia do egzaminu:

During seminars students are required to pass an oral presentation. Topics of tasks (presentations) will be asked at the beginning of the seminar.

Zasady udziału w poszczególnych zajęciach, ze wskazaniem, czy obecność studenta na zajęciach jest obowiązkowa:

Lectures:
– Attendance is mandatory: No
– Participation rules in classes: Studenci uczestniczą w zajęciach poznając kolejne treści nauczania zgodnie z syllabusem przedmiotu. Studenci winni na bieżąco zadawać pytania i wyjaśniać wątpliwości. Rejestracja audiowizualna wykładu wymaga zgody prowadzącego.
Seminar classes:
– Attendance is mandatory: Yes

– Participation rules in classes: Studenci prezentują na forum grupy temat wskazany przez prowadzącego oraz uczestniczą w dyskusji nad tym tematem. Ocenie podlega zarówno wartość merytoryczna prezentacji, jak i tzw. kompetencje miękkie.

Method of calculating the final grade

The final grade is issued on the basis of an oral presentation. (80%) and activity during the discussion (20%)

Sposób i tryb wyrównywania zaległości powstałych wskutek nieobecności studenta na zajęciach:

Additional task will be given. In this case student are required to prepare a short presentation and present it in individual mode.

Prerequisites and additional requirements

Compulsory subjects before starting the course: Mechanics and Computer aided design.
During seminars exemplary exercises and simulations will be presented; students are welcome and encouraged to bring their own mobile computers with Autodesk Inventor and try to do these examples simultaneously.

Recommended literature and teaching resources

1 Cannon jr. R.H. – Dynamika układów fizycznych, WNT Warszawa 1973 r.
2 Frączek J., Wojtyra M. : Kinematyka układów wieloczłonowych-metody obliczeniowe, WNT Warszawa 2008 r.
3 Osiński Zb. – Mechanika ogólna , Wydawnictwo Naukowe PWN,Warszawa 1994 r.
4 Wojtyra M., Frączek J.: Metoda układów wieloczłonowych w dynamice mechanizmów. Ćwiczenia z zastosowaniem programu ADAMS. OWPW, 2007.
Oprogramowanie firmy Autodesk – licencje w wersjach akademickich jak Inventor Professional, Autodesk Simulation Multiphysics dostępne do pobrania przez studentów na stronie firmy Autodesk.
Materiały pomocnicze i ćwiczenia do programu Autodesk Inventor Professional dostępne na stronie firmy Autodesk.

Scientific publications of module course instructors related to the topic of the module

1.Gospodarczyk P., Mendyka P., Stopka G. i inni: Wybrane zagadnienia modelowania procesów urabiania, ładowania i odstawy w kompleksach ścianowych. Wydawnictwa AGH, Kraków 2015.
2.Gospodarczyk P., Stopka G i inni: Wire rope net structures as safety devices in mine shaft deepening. Challenging rope applications : proceedings of the OIPEEC conference 2015 / 5th international Stuttgart ropedays, Stuttgart, Germany, 2015
3.Mendyka P., Kotwica K., Gospodarczyk P., Stopka G., Bołoz Ł., The design and analisys of driling and bolting rig for narrow vein exploitation, 16th International Multidisciplinary Scientific Conference SGEM, Albena, Bulgaria, 2016
4.Gospodarczyk P., Mendyka P., Stopka G Badania symulacyjne w projektowaniu innowacyjnego rozwiązania spągoładowarki. Nowoczesne metody eksploatacji węgla i skał zwięzłych – monografia. Kraków, 2013.
5.Stopka G., Ostapów L, Badania modelowe i stanowiskowe obciążeń dynamicznych podwozia wąskiego wozu wiercącego — Dynamic simulation and laboratory tests of chassis of drilling rig for narrow vein deposits. Mechanizacja, automatyzacja i robotyzacja w górnictwie : monografia : praca zbiorowa. T. 2, Problemy eksploatacji i zarządzania w górnictwie podziemnym i odkrywkowym / red. nauk. Krzysztof Krauze ; Centrum Badań i Dozoru Górnictwa Podziemnego Sp. z o.o. w Lędzinach, Katedra Maszyn Górniczych, Przeróbczych i Transportowych. AGH w Krakowie. — Lędziny ; Kraków : Centrum Badań i Dozoru Górnictwa Podziemnego Sp. z o.o., 2017. — Artykuły opublikowane w monografii zostały wygłoszone na IV. Międzynarodowej Konferencji „Mechanizacja, Automatyzacja i Robotyzacja w Górnictwie", która odbyła się 21-23 czerwca 2017 r. w Wiśle. — ISBN: 978-83-944406-8-8 ; e-ISBN: 978-83-944406-9-5. — S. 113–119. — Bibliogr. s. 119, Streszcz., Abstr.
6.Gospodarczyk P., Stopka G. i inni: Badania innowacyjnego rozwiązania kabiny operatora dla dołowych maszyn samojezdnych. Napędy i Sterowanie. 2/2015.

Additional information

None