340600 - DIAP-R1O12 - Applied Dynamics

Coordinating unit: 340 - EPSEVG - Vilanova i la Geltrú School of Engineering
Teaching unit: 712 - EM - Department of Mechanical Engineering
Academic year: 2019
Degree: MASTER'S DEGREE IN AUTOMATIC SYSTEMS AND INDUSTRIAL ELECTRONICS (Syllabus 2012). (Teaching unit Compulsory)
ECTS credits: 5
Teaching languages: Catalan, Spanish

Teaching staff
Coordinator: Ingrid Magnusson
Others: Ingrid Magnusson

Degree competences to which the subject contributes

Specific:
2. CC09 - Identify the symbols of mechanical systems and obtain the knowledge to determine the number of drives that will allow the desired movement of the system.

Transversal:
1. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

Teaching methodology
Theoretical explanations and practical examples solved with Matlab.

Learning objectives of the subject
The general objective of the subject is to acquire the necessary skills to be able to model and perform the dynamic analysis of a mechanical system. This study should allow the decision making both on the mechanical design process of the system as well as on the design of the control system.

Study load

<table>
<thead>
<tr>
<th>Total learning time: 125h</th>
<th>Hours large group:</th>
<th>30h</th>
<th>24.00%</th>
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<tbody>
<tr>
<td></td>
<td>Hours medium group:</td>
<td>0h</td>
<td>0.00%</td>
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<tr>
<td></td>
<td>Hours small group:</td>
<td>15h</td>
<td>12.00%</td>
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<td></td>
<td>Guided activities:</td>
<td>0h</td>
<td>0.00%</td>
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<tr>
<td></td>
<td>Self study:</td>
<td>80h</td>
<td>64.00%</td>
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### Content

<table>
<thead>
<tr>
<th>Mechanism mobility</th>
<th><strong>Learning time:</strong> 20h</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Theory classes: 4h</td>
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<tr>
<td></td>
<td>Laboratory classes: 2h</td>
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<tr>
<td></td>
<td>Self study : 14h</td>
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<table>
<thead>
<tr>
<th>Description:</th>
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<tbody>
<tr>
<td>Generalized coordinates and speeds</td>
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<tr>
<td>Independent coordinates and degrees of freedom. Holonomy</td>
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<tr>
<td>Geometric Link Equations</td>
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<tr>
<td>Redundancy</td>
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<tr>
<td>Space of configuration and subspace of accessible configurations</td>
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<tr>
<td>Unique configurations: deadlocks and bifurcation</td>
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<tr>
<td>Resolution linkage equations: geometry and numerical methods (Newton - Raphson)</td>
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<table>
<thead>
<tr>
<th>Specific objectives:</th>
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<tbody>
<tr>
<td>- Identify the different types of generalized coordinates</td>
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<tr>
<td>- Identify a non-holonomic system (one that has more independent coordinates than degrees of freedom)</td>
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<tr>
<td>- Determine the degrees of freedom of the mechanism (number of independent generalized speeds). This number coincides with the minimum number of generalized coordinates that must be known to describe the configuration of the mechanism (independent coordinates) when the system is holonomic (general situation).</td>
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<tr>
<td>- Determine how many degrees of freedom a mechanism needs to be in terms of the application of this mechanism</td>
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<tr>
<td>- Propose the geometric linking equations necessary to be able to determine the configuration of the mechanism</td>
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<td>- Propose the kinematic linkage equations from the derivation of the geometric link equations (will be practiced in future dedication guides as well)</td>
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<td>- Recognize redundant links or elements and type of redundancy</td>
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<tr>
<td>- Determine the configuration space and the subspace of accessible configurations of a mechanism</td>
</tr>
<tr>
<td>- Understand what happens to the mechanism in the singular configurations (dead center and bifurcation)</td>
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<tr>
<td>- Solve the system of geometric link equations (nonlinear system) by applying geometry of triangles (sine rule and cosine)</td>
</tr>
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</table>

Matlab:

- Create a list of instructions to determine the configuration of the mechanism from an estimated initial solution, using the N-R method.
- Create a routine to apply the N-R method sequentially to determine all configurations accessible from an initial configuration.
- Present the results graphically.
- Calculate the value of a trigonometric function at different points and represent the values of the function graphically, as a function of the independent variable.
- Graphically represent the subspace of accessible configurations.
- Make an animation with the movement of the mechanism (in order to show the different configurations of the mechanism, without paying attention to the time).
- Raise the geometric linking equations necessary to be able to determine the configuration of the mechanism and solve them using the numerical method N-R.
### Kinematics of mechanisms

**Description:**
Kinematic linkage equations from time derivation of the geometric linkage equations. Resolution by matrix method from the development in partial derivatives. Kinematic linkage equations from the kinematic study of the links and the fundamental equations of kinematics.

**Specific objectives:**
- Derive "manually" the geometric linkage equations with respect to time to find the kinematic linkage equations (first and second derivative)
- Derive, with the help of Matlab, the geometric linkage equations with respect to time by its formulation in partial derivatives (use of the Jacobian matrix), to find generalized velocities and their derivatives.
- Formulate, where appropriate, the equations of government associated with each degree of freedom
- Solve with matrix methods implemented in Matlab the system of linear equations obtained with either of the two previously described methods, to find generalized velocities and their derivatives.
- Identify the geometric constraints imposed by the different kinematic links
- Apply the fundamental equations of kinematics for the calculation of velocities and accelerations in a member of the mechanism
- Express the set of previous equations in matrix form and solve the system for the generalized dependent velocities and their derivatives, "by hand" and with the help of Matlab.

**Matlab:**
- Create a routine for sequentially calculating the configuration (based on ICs), generalized speeds (based on generalized coordinates and independent generalized speeds) and those derived from generalized speeds (as a function of generalized coordinates, Generalized velocities and those derived from independent generalized velocities) in a mechanism.
- Obtain the kinematic study described in the previous point as a function of time if a governing equation is available for each independent coordinate.
- Graph the previous results.

**NX:**
- Starting from a 2D modeling assembly, define a simulation scenario (kinematic members and pairs, driving the motion and defining results) to perform the kinematic study of a mechanism with three-dimensional movement.

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**Learning time:** 38h
- Theory classes: 10h
- Laboratory classes: 2h
- Self study: 26h
## Dynamical analysis of mechanisms

### Description:
- Joint forces. Free Body Diagrams.
- Determination of all the unknowns of the system proposing matrix resolution. Particular case: mechanism in equilibrium.
- Direct dynamic analysis.
- Equation characteristic of the movement by the method of virtual powers
- Equation characteristic of the movement by the method of reduction to an axis.

### Specific objectives:

<table>
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<th>Learning time: 59h</th>
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<tbody>
<tr>
<td>Theory classes: 15h</td>
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<td>Laboratory classes: 8h</td>
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<tr>
<td>Self study: 36h</td>
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- Identify the reactions potentially existing in the different links (in plane mechanisms it will also contemplate the reactions in other plans that are not the one of movement).
- Represent the DCLL of all members of the mechanism.
- Arrange the necessary vector equations in each member of the mechanism, express them in matrix form and solve the system with the help of Matlab.
- Interpret the results obtained from the static analysis of the mechanism.
- Represent the DCLI of each member within the mechanism, including for each member its D'Alembert torque.
- Arrange the necessary vector equations in each member of the mechanism, express them in matrix form and solve the system with the help of Matlab.
- Interpret the results obtained from the dynamic analysis of the mechanism.
- Propose one or more appropriate virtual movements so that the application of the method for each virtual movement allows to obtain the equations necessary to determine the unknowns of interest.
- For each virtual movement apply the method, which implies:
  Or identify which forces have a non-zero associated virtual power
  Or determine the virtual velocity distribution necessary to determine all non-zero virtual powers (all speeds must be a function of a single generalized velocity)
  Or replace the virtual speeds and eliminate the generalized velocity thus obtaining the dynamic equation
  - Express these dynamic equations in matrix form
  - Solve, with the help of Matlab, the dynamic equations together with the kinematic equations of the accelerations, in one or consecutive configurations of the mechanism.
  - Determining the expression of the equivalent mass of a reduced system to a linear coordinate
  - Determine the expression of the equivalent moment of inertia of a reduced system at an angular coordinate
  - Determining the expression of the reduced force to a linear coordinate, for any force or torque applied on a system
  - Determine the expression of the reduced torque at an angular coordinate, for any force or torque applied on a system
  - From the reduced parameters of a system, express the equation of its motion. This may allow the student to:
    O In case of cyclical machines, from the study of motion calculate the degree of irregularity of the speed.
    O Calculate the time (and space) used by a machine in the acceleration transient until it reaches the speed regime.
    O Calculate the time (and space) used by a machine to move from the speed of the speed to the point of stop.
  - Determine the flywheel necessary to achieve a certain degree of irregularity.
  - Determine the inertia required of a machine in case of having to limit the maximum acceleration of the machine (elevators, forklifts, amusement park ...)
  - Determine the linking forces in the mechanism with or without steering wheel in the different parts of a machine and, therefore, to assess the quality of the kinematic chain in case of having to comply with limited linking forces.

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<th>Actuators</th>
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**Description:**
Mechanical characteristic of the motors
Sturdy characteristic curve
Equilibrium of a mechanical system. stability
Regulation of a machine

**Learning time:** 13h
Theory classes: 4h
Self study: 9h
## Planning of activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Hours</th>
<th>Description</th>
<th>Support materials</th>
</tr>
</thead>
</table>
| **(A1) CLASS THEORY AND PROBLEMES** | 67h 30m | Theory classes: 30h  
Self study: 37h 30m | Work in the classroom  
Digital Campus Notes |

**Description:**
Work in the classroom

**Support materials:**
Digital Campus Notes

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</table>
| **(A2) Laboratory Practices** | 45h   | Laboratory classes: 18h  
Self study: 27h | Resolution by the student of different dynamic studies of mechanical systems, sometimes individually and other times in groups. The resolution is carried out applying different methodologies: proposing the equations of the theoretical model and solving them by programming in MATLAB; or, by simulating the systems through the CAD / CAE program of SIEMENS NX.  
Reports with the statement (specification of the mechanical system to be studied) and the results to be obtained from the study, available to the students on the platform of the DIGITAL CAMPUS. Both the MATLAB and the SIEMENS NX are installed in the informatic classrooms of the school. The school also has licenses to install the SIEMENS NX on each student's personal computer, so they can work more autonomously.  
Most of the activities will be evaluated individually, vis a vis with the teaching staff, without the need to write any report. Some of the activities will require the presentation of a report with the description of the work carried out and the results and conclusions obtained. Both the reports (if required) and the files that justify the different studies carried out, will be delivered through the platform of the DIGITAL CAMPUS. | **Specific objectives:** To apply the knowledge introduced in the theory sessions in the study of different practical cases. |

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| **(A3) Assessment of Learning** | 12h 30m | Guided activities: 3h  
Self study: 9h 30m | Two individual and written tests, carried out with the help of a computer that has MATLAB and SIEMENS NX. In addition, a continuous assessment is carried out in individual tutorials, distributed throughout the course, in which the correct acquisition of the concepts worked is verified and their adequate application in the study of practical cases (proposed and worked in the laboratory sessions). | **Specific objectives:** Certify the degree of achievement of aprenetatge |
Qualification system

The final grade (QF) takes into account all the work done over the course. It is obtained from the expression:

\[ QF = 0.5 \times \text{Continuous Avaluation of practical exercises} + \max((0.25 \times \text{Partial Exam} + 0.25 \times \text{Final Exam}); 0.5 \times \text{Final Exam}) \]

There is a reevaluation exam where the 50% of the subject corresponding to exams can be reevaluated (not the 50% corresponding to the Continuous Avaluation of practical exercises).

Regulations for carrying out activities

All exams are to be done individually and consulting all documents and sources considered necessary.

Bibliography

Basic:


Complementary: