Módulo No. 4 – v2014

Análisis Cinemático y Dinámico Computacional de Mecanismos Planos.

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1. INTRODUCCION.

En este módulo se desarrolla y se aplica un método de análisis cinemático y dinámico de mecanismos totalmente basado en la utilización del ordenador y con muy pocas limitaciones en cuanto al tipo de problema que puede resolverse, abarcando tanto las máquinas o mecanismos que poseen movimiento plano como las que poseen movimiento en el espacio. Se suponen conocidos los fundamentos de la Teoría de Mecanismos y Máquinas que se han presentado en módulos previos. Tras la realización de las actividades prácticas que se proponen, el alumno debería saber utilizar este método sistemático de planteamiento de las ecuaciones en las que se basa el análisis cinemático y dinámico de mecanismos a cualquier sistema mecánico que tuviera que estudiar por razones profesionales.

1.1. Campo de Aplicación.

En esta sección, que como todas las que figuran en este módulo han sido seleccionadas de los libros del Prof. Haug, de la Universidad de Iowa, se define el concepto de *sistema mecánico,* se recuerda el tipo de ecuaciones que se obtienen al estudiar el movimiento y las fuerzas que lo producen en los sistemas mecánicos. Se insiste sobre las no linealidades que aparecen, comentándose a continuación los tres *tipos de análisis* básicos que es posible realizar con este tipo de sistemas. Se recuerda el concepto de *análisis cinemático,* como aquel que se basa en el estudio del movimiento independientemente de las fuerzas que lo producen, indicando que para resolver el problema de posición es necesario solucionar un sistema de ecuaciones algebraico no lineal, siendo lineales los sistemas que se plantean para los problemas de velocidad y aceleración. A continuación se recuerda el concepto de *análisis dinámico (directo),* como el que estudia tanto el movimiento y las fuerzas que lo producen, y se recuerda que para llevarlo a cabo es necesario resolver o un sistema de ecuaciones diferenciales si se plantea utilizando coordenadas independientes; o un sistema mixto de ecuaciones diferenciales y algebraicas, si se utiliza, por ejemplo, coordenadas cartesianas dependientes, tal y como se hará en esta asignatura. Se recuerda que el denominado problema de *configuración equilibrio* es un caso especial de análisis dinámico. Por último se recuerda en que consiste en *análisis dinámico inverso*.

A continuación se comentan los *tipos de fuerzas* de fuerzas que se deberían considerar en esta asignatura, que en entre otras van a ser la fuerza de la gravedad, y las fuerzas que provocan elementos mecánicos tales como los muelles y los amortiguadores. Fuerzas todas ellas con las que tomó contacto en asignaturas previas.

Por último, se hace una revisión de algunas *aplicaciones típicas* que se considerarán durante la asignatura. Se recuerda que el *mecanismo deslizadera manivela*, ya conocido, lo podemos encontrar en un motor de explosión de 8 cilindros en V, en una punzonadora, en un mecanismo regulador de bolas, realizando una descripción pormenorizada de todos estos sistemas mecánicos. Seguidamente se habla del mecanismo *cuadrilátero articulado*, también conocido, y se indica que lo podemos encontrar en la suspensión trasera de un vehículo industrial, en los limpiaparabrisas de los automóviles, y en determinados sistemas de manutención y almacenaje. De nuevo se describen con detalle todos estos sistemas. A continuación se habla de otros dispositivos mecánicos, ya conocido, comúnmente encontrado en los sistemas mecánicos, como son los *engranajes*. Seguidamente se habla de mecanismos más complicados como son los *mecanismos de retorno rápido,* también conocidos. Se presenta el *robot industrial* y se comentan algunas características generales del mismo. Por último se comentan aspectos interesantes relacionados con los *sistemas se suspensión de los automóviles*. Se indica que durante la asignatura se tendrá ocasión de tratar con todos estos sistemas resolviendo numéricamente algunos problemas relacionados con ellos.

For the purposes of this course, a mechanical system is defined as a collection of interconnected rigid bodies that can move relative to one another, consistent with joints that limit relative motion of pairs of bodies. The motion of a mechanical system may be prescribed (establecer) by defining the time history of the position or relative position of some of its bodies. The motion of the system is then determined by algebraic kinematic relations or from differential equations of motion and externally applied forces, in which case the motion of the system is determined by laws of physics. Kinematics and dynamics of mechanical systems are characterized by large amplitude motion, which leads to geometric nonlinearity that is reflected in the algebraic equations of constraint and differential equations of motion.

1.2. Tipos de Análisis.

Five basically different kinds of analysis are employed in the design of mechanical systems:

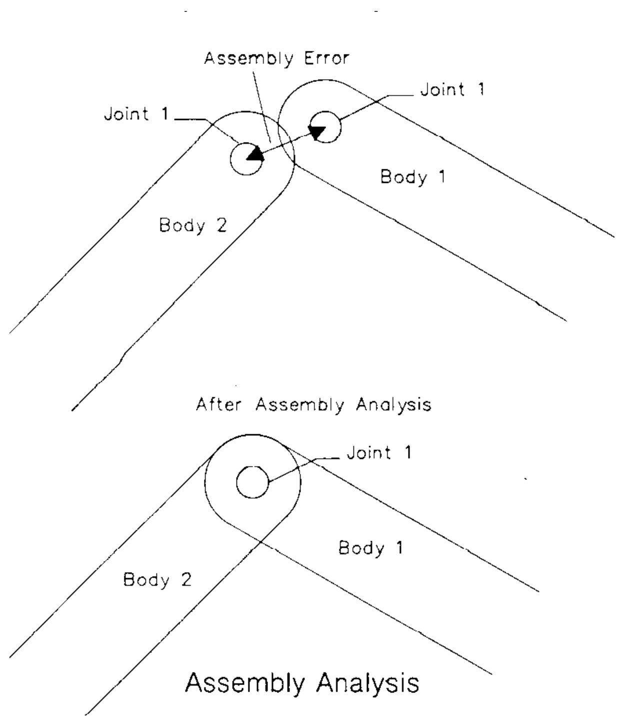

Imagen 4.1. Análisis de ensamblado.

(1) *Assembly Analysis* is used to assemble all bodies within your model into a configuration that satisfies all joint and constraint connections. Since the model creation process allows for coordinates of body and joint locations to be inexact, the assembly algorithm minimizes the error in all the specified joints to determine body positions which best satisfy the constraints.

The results of assembly analysis are the positions of all bodies within your model. Assembly analysis is automatically performed prior to all other types of analysis or it can be performed by itself.

(2) *Kinematic Analysis* of a mechanical system concerns the motion of the system independent of forces that produce the motion. Kinematic analysis is used to calculate the motions of the various bodies in the mechanism, disregarding both their mass properties and any forces in the system.

Mechanisms analyzed kinematically must have all degrees of freedom eliminated. This is accomplished by specifying "drivers". For each degree of freedom, a driver must be added to the data which defines the motion of a coordinate or a relationship between coordinates as a function of time. Typically, the time history of position or relative position of one or more bodies in the system is prescribed.

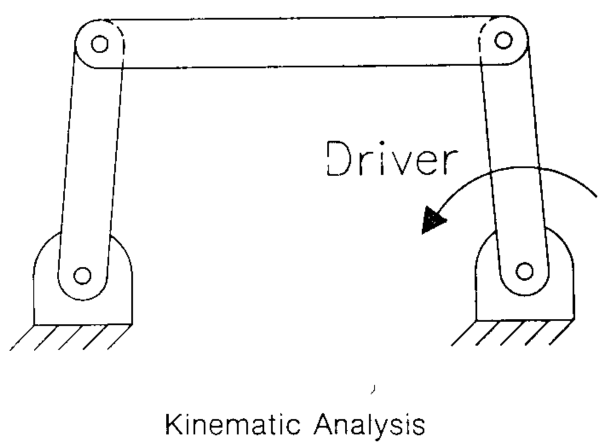

Imagen 4.2. Análisis cinemático.

Time histories of position, velocity, and acceleration of the remaining bodies are then determined by solving systems of nonlinear algebraic equations for position and linear algebraic equations for velocity and acceleration. The results of kinematic analysis are the positions, velocities, and accelerations of all the bodies in the model for each time step in the analysis.

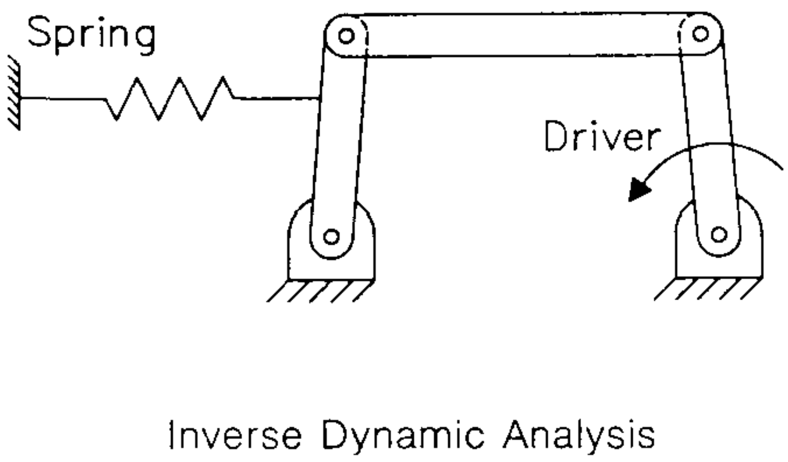

Imagen 4.3. Análisis Dinámico Inverso.

(3) *Inverse Dynamic Analysis* uses features of both kinematic and dynamic analysis. As in kinematic analysis, drivers must be added to your model in order to eliminate all degrees of freedom.

The time history of positions or relative positions of one or more bodies in the system is prescribed, leading to complete determination of position, velocity, and acceleration of the system from the equations of kinematics. However, mass properties of all the bodies are also required as in dynamic analysis.

From the motion of the bodies specified by the drivers, the forces required to produce the prescribed motion can be calculated. The equations of motion of the system are then solved, with known position, velocity, and acceleration, as algebraic equations to determine the forces that are required to generate the prescribed motion. The results are the body positions, velocities, and accelerations and the reaction forces in the various joints and constraints in the model. The reaction forces present due to the driving constraints can be interpreted as the forces necessary to generate the prescribed motion.

(4) *Static Analysis*. A special case of dynamic analysis is the determination of an equilibrium position of the system under the action of forces that are independent of time. Static analysis uses the mass properties of bodies and any forces acting upon them to calculate a model configuration which minimizes the potential energy of the system.

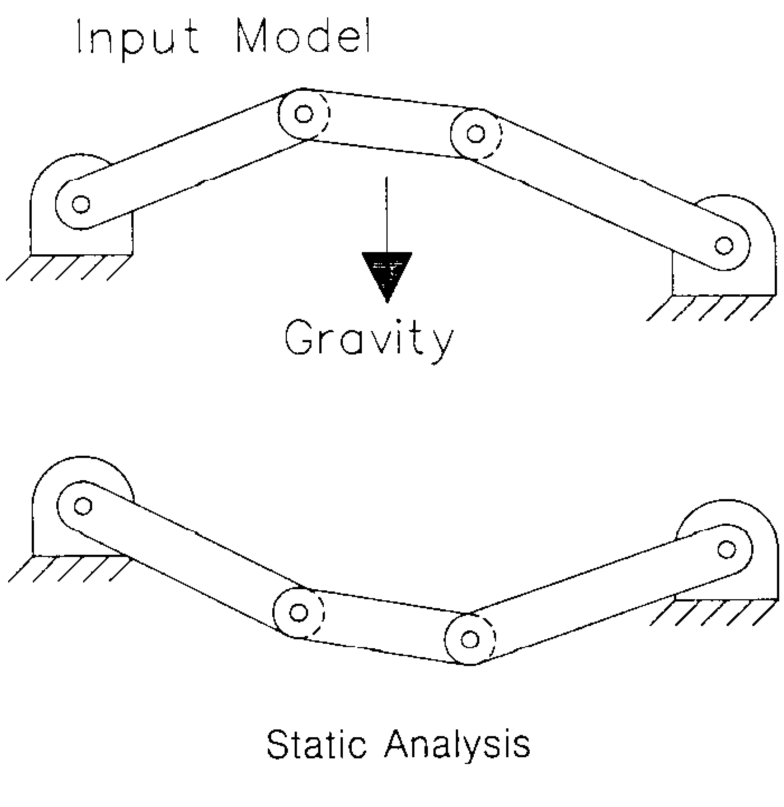

Imagen 4.4. Análisis Estático.

The resulting position of each body is reported along with the potential energy of the model at the beginning and end of the analysis run.

Static analysis is valid for all conservative systems. To perform static analysis for a model which contains nonconservative forces, the user can run the model under dynamic analysis, making sure to include one or more damping elements. When velocities of all bodies approach zero, the model will be in a static equilibrium.

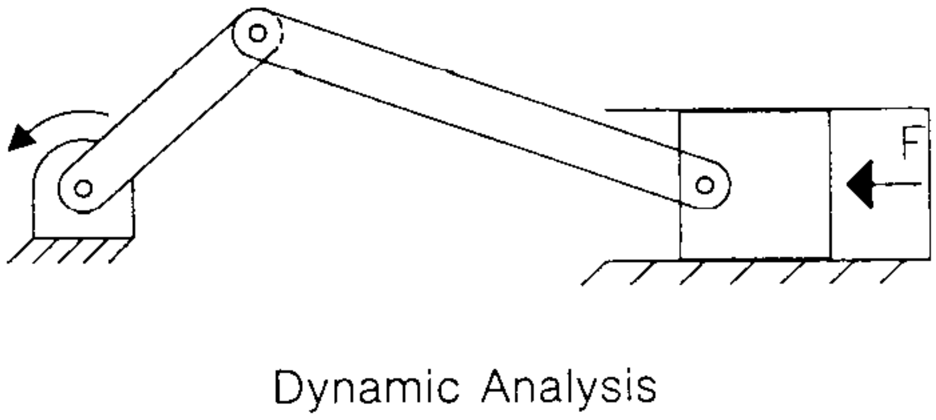

Imagen 4.5. Análisis Dinámico Directo.

(5) *Dynamic Analysis* of a mechanical system concerns the motion of the system that is due to the action of applied forces. Dynamic analysis calculates the motion ot the bodies in the system based on the mass properties and forces acting on the bodies. These forces include gravity and any external applied forces. The motion of the system, under the action of applied forces, is required to be consistent with kinematic relations that are imposed on the system by joints that connect bodies in the system. The equations of dynamics are differential equations or a combination of differential and algebraic equations. Initial conditions of the bodies, i.e., initial position and velocity, are specified at the start of an analysis. Rather than specifying initial conditions for every coordinate in the model, it is only necessary to specify conditions for the independent coordinates which are non zero.

The results of dynamic analysis are the positions, velocities, and accelerations of all the bodies in the model for each time step and all internal reaction forces in the joints and constraints.

1.3. Tipos de Fuerzas.

An important consideration that serves to classify mechanical systems concerns the source of FORCES that act on the system. This is particularly important in modern mechanical systems in which some form of control is exerted. Force effects due to electrical and hydraulic feedback control subsystems play a crucial role in the dynamics of modem mechanical systems. The scope of mechanical system dynamics is, therefore, heavily dependent on the classes of force systems that act on the system. The most elementary form of force that acts on a mechanical system is *gravitational force*, which is normally taken as constant and acting perpendicular to the surface of the earth. Other relatively simple forces that act on bodies in a system, due to interaction with their environment, include *aerodynamic forces* and *friction* and *damping forces* that act due to the relative motion of the components of the system. An important class of forces that act in a mechanical system is associated with *compliant elements*, such as coil springs, leaf springs, tires, shock absorbers, and a multitude of other deformable components that have reaction forces and moments associated with them. Forces due to compliant elements act between bodies in the system and are functions of their relative position and velocity.

A mechanical system is defined as a collection of bodies (or links) in which some or all of the bodies can move relative to one another. Mechanical systems may range from the very simple to the very complex.