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ISBN 978-3-319-05920-4 ISBN 978-3-319-05921-1 (eBook)
DOI 10.1007/978-3-319-05921-1
Springer Cham Heidelberg New York Dordrecht London

Library of Congress Control Number: 2014944530

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

Computer-aided design (CAD), 3D modeling, and engineering analysis can be efficiently applied in many research and industrial fields including aerospace, defense, automobile, consumer product, and many other product development. These efficient research and engineering tools apply computer-assisted technology to perform 3D modeling on different products, support geometrical design, make structural analysis, assist optimal product design, create graphic and engineering drawings, and generate production documents. This technology helps scientists and technical professionals efficiently import basic geometrical inputs and design information to accelerate the engineering design process, with well-controlled design documents, to support production and manufacturing processes. Currently these research and engineering tools have been playing more and more important roles in different businesses and enterprises due to their financial and technical importance in business, industrial, engineering, and manufacturing applications. The computer-aided modeling and analysis allow more sophisticated, flexible, reliable, and cost-effective manufacturing control. Automation and automated production system are to use control system to reduce human labor intervention during manufacturing processes and put strong impact on industries. Automation and automated system design not only raise the production rate but also control the product quality. It can effectively keep consistent product quality, reduce production lead time, ease material handling, maintain optimal work flow, and meet the product requirement by controlling the flexible and convertible manufacturing/production processes. Computer-aided modeling and engineering design can quickly simulate and model the automated production systems and reduce product development life cycles. Computer-aided engineering solution can improve and optimize the industrial integral processes in design, development, engineering analysis, and product manufacturing. Also the present and future economic globalization requires cost-effective manufacturing via highly industrial automation, efficient design tooling, and better production control. This book describes the technology, types, and general applications of these research and engineering tools through conceptual analysis and real case study in computer-aided design, 3D modeling, and engineering analysis. Some new product systems, developed by author, are introduced to help readers understand how to design and develop new product systems by using computer-aided design, engineering analysis, and prototype experiment. The case studies include design and development of green/sustainable energy systems (solar still, solar panel, and wind power energy), biomedical and surgical instruments, energy-saving cooling system, automated and high-speed assembly system (highly viscous liquid filling and chemical gas charging), robotic system for industrial/automated manufacturing, magnetic sealing system, and high-speed packaging machinery system. Multiple engineering case studies in this book aim at the introduction, study, and analysis by using computer-aided modeling and engineering analysis for industrial and engineering applications. All these newly developed product systems have also been verified by prototyping and testing to validate the functionality of these new systems. Both computer-aided analysis and experimental methodologies introduced in this book show close results that positively show the feasibility and credibility of analytic and experimental methodologies introduced in this book.

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Contents

1 Introduction

3D modeling can perform mathematic and geometric analysis on 3D object surfaces via CAD software (Gupta et al. 2010). 3D models can be expressed as 2D images via process of 3D rendering and used in computer-aided simulation to study physical phenomena (Kim and Kim 2011). 3D models can also be geometrically created by 3D printing process. 3D modeling technology allows efficient modeling processes including curve-controlled modeling that can simulate the motion of 3D objects instead of only static geometry (Senthil et al. 2013). 3D computer graphics software can assist 3D modeling processes to create 3D geometrical models. 3D models can represent 3D objects by collecting points connected by different geometric entities including lines, triangles, squares, rectangles, curved surfaces, and irregular geometries in three-dimensional space (Lee et al. 2010). 3D modeling is widely utilized in many different areas, such as 3D graphics design, product development, and computer games (Sun et al. 2005). 3D modeling processes include solid modeling that defines object by volume and shell/boundary modeling that determines object by defining surfaces and boundary (Sipiran and Bustos 2010). 3D modeling can transform all object points, such as internal points and points on circumference surfaces, into polygon elements representing the sphere and volume for model rendering (Ouertani et al. 2011). Triangular modeling meshing is widely used since the meshes can be easily rendered. Polygon meshing element is another modeling method but it is not very popular since the tessellation processing is not provided in the transition to achieve rendering surfaces (Li et al. 2012). 3D polygonal modeling is one of the most popular modeling methods due to its accurate, flexible, and quick meshing process. In 3D polygonal modeling, 3D points are linked via many tiny line elements to generate polygonal meshes (Harik et al. 2008). 3D curved modeling is another common method, in which all the object surfaces are specified by curves that are manipulated by the weight-controlled points in 3D space. The curves will move close to the points when weight of these 3D points is increased for more accurate modeling process (Reich and Paz 2008). Compared to 2D modeling methodology, 3D modeling can change and animate parts with (1) quick object rendering, (2) easier object

J. Zheng Li, *CAD, 3D Modeling, Engineering Analysis, and Prototype Experimentation*, DOI 10.1007/978-3-319-05921-1_1

rendering, and (3) more accurate rendering (Tian et al. 2009). 3D modeling has been applied in different businesses and industries including movie filming, consumer product design, industrial design, cartoon animation, video gaming, architecture design, and engineering research (Walthall et al. 2011). CAD software can be used to assist 3D modeling for product design and development.

Computer-aided design (CAD) is to apply computer systems to assist the engineering process for creating, modifying, analyzing, and optimizing the product design (Stefano et al. 2013). CAD software is used to accelerate design process, improve design quality, ease technical communication via engineering documentation, and build database for production (Veltkamp et al. 2011). CAD results can be output in electronic files for printing, manufacturing process, production operation, etc. The CAD systems can be applied in different product designs including electronic, civil, mechanical, and automated systems (Pessoa et al. 2012). CAD is an efficient engineering design tool that has been widely used in different applications including designs of car, ship, aircraft, industrial products, and architecture. (Starly et al. 2005). CAD can also be extensively applied to generate computer-aided animation for filming, commercial advertising, and product manuals (Kosmadoudia et al. 2013). Current CAD software packages provide 2D drafting and 3D solid modeling. CAD can allow three-dimensional object rotation, view designed object from different angles, and check full geometrical features from inside and outside of desired objects (Piatt et al. 2006). CAD can be applied for building conceptual design and product layout, defining production methods via structural analysis of product assembly, and detailing engineering 3D models/2D manufacturing drawings (Sung et al. 2011). CAD systems were originally developed with computer languages including Algol and Fortran but CAD technology has been significantly changed due to development of object-oriented programming (Vincent et al. 2013). Modern CAD systems have been developed using interaction of graphical user interface with object geometry and boundary envelop to control relationships among different object geometries in complex sketches, part models, and product assemblies (López-Sastre et al. 2013). Currently CAD systems can work with most platforms such as Windows, UNIX, Mac OS X, and Linux. Today there are many different CAD systems applied in business, research, engineering, and industry including Pro/Engineer, SolidWorks, CATIA, Solid Edge, Inventor, Unigraphics, CADDS, and AutoCAD (Rocca 2012). Computer-aided design and engineering analysis have been applied to create 3D product features, specify the material information in mechanical and thermal properties, define geometrical shape, determine part dimension, perform manufacturing tolerance control, and analyze the system functionality and structure of product systems (Adán et al. 2012; Chae et al. 2011). CAD technology significantly reduces drafting time and efficiently helps professionals in product design and development (Chaouch and Verroust-Blondet 2009). Current CAD software packages provide efficient ways to control product design in 3D space, make engineering drawings quickly, and allow users easily review product design in different views to accelerate the design process (Claes et al. 2011). Compared to the manual drafting design, CAD technology can significantly shorten the design time, improve design quality, and optimize complex geometric design (Adams and Yang 2004). CAD technology can be applied to assist geometric dimensioning and tolerancing (GD&T) control, create conceptual design, make assembly layout, and perform kinematic and dynamic analysis (Goel et al. 2012). 3D geometrical parameters and boundary conditions can be used to specify the product dimensions, shape, and solid elements (Bertoni and Chirumalla 2011). The computer-aided engineering analysis (CAE) can be used with CAD to determine the structural strength of products including tensile, yield, principal, and shear strength (Ding, et al. 2009). CAD system can also be used to perform graphic simulations for preparing different enterprise documents, such as project of environmental protection in which the CAD-assisted constructions can be superimposed into existing environmental graphic piles to determine what effects will be caused to the environment if targeted constructions are being built (Catalano et al. 2011). Computer-aided design of automated system brings cost-effective processes to control complex manufacturing systems and production in industry (Fuge et al. 2012).

In this book, the CAD software of Pro/Engineer is utilized for 3D solid modeling/product design and Autodesk simulation software is used for engineering simulation/structural analysis.

1.1 Solar Energy System for Water Distillation

People can have daily clean and pure drinking water easily since getting clean water is simply opening the faucet. However, in many underdeveloped countries or in some extreme disaster-related situations, it is difficult to get clean and pure water (Anjaneyulu et al. 2012). Solar distilling process is a way of changing impure water into clean water. Based on report from the World Health Organization, about 1.1 billion people over the world are not able to find safe drinking water. Among them, about 2.1 million people die each year due to drinking of contaminated water (Badran et al. 2005). The solar distilling process is a method of distilling water by using the heat from the sun to generate moisture evaporation from humid environment and applying air to cool the condenser to produce filtrated water. Distillation process is one of the methods to control water purification (Jabbar et al. 2009). Sunlight is one of multiple heat energies that can be applied to perform water distillation process. In solar water distillation process, there is no fuel cost but requires associated costly distilling equipment (Manikandan et al. 2013). Although the solar distilling drinking water costs several times that of water supplied from city utilities, it is still less expensive than the bottle water in outside store due to its energy-wise distilling process (Lattemann and Höpner 2008). In case the local residents are worried about purification quality or concerned about the purified addictives added to the local city water, solar distilling of tap water will be a safe and energy-saving process (Chakraborty et al. 2004). Since the energy cost is continuously increased and the pressure of more human population is constantly exerted on current available freshwater, the solar desalination of seawater has its energy-efficient and cost-economic advantages (Jabbar et al. 2009; Li 2011c). In solar still unit, the impure water is gathered around the outside surface of collector and evaporated by sunlight that is absorbed through clear plastic panel. When pure water vapor passes the condenser, it will get cooled and condensed on the cold surface. The filtrated water droplet will drip down by its gravity to the pure water collector at lower chamber in solar still unit. This distilling process takes away the impurities including heavy metals and microbiological organisms from environmental water (Tiwari and Tiwari 2007). The solar still system can also be applied in the places where rainwater, well water, or city water is not available. In case of power outage during severe weather conditions, such as hurricane season, the solar distillation system can supply an alternative clean water resource. The basic basin-type solar still unit mainly consists of some stones, transparent plastic or glass panel, condenser, and collector to store condensed pre-water (Yang et al. 2011). As the sun heats and evaporates the moisture, water vapor moves to condenser where the vapor gets cold and condensed to form water droplet which will drop down to pure water collector at the bottom of solar still unit. Other solar distill systems, such as wick solar still, can distil the salt water. In wick solar still system, salted water input in from the top gets evaporated after heated by the sunlight through transparent plastic or glass panel (Alloway 2000). The vapor starts condensation at the underside of plastic panel and drips to the bottom collector. The purity of distilled water stored in the bottom collector relies on how much salt can be separated from the salt water in solar distillation unit. If more wicks are constructed in the solar still, more heat can be transmitted to the salt water which makes more distilled water product. A plastic fine grid thin plate can be installed in order to capture more brine from salt water before it goes down to the container. This will provide longer time to heat up impure water and separate the brine from salt water. The wick-type solar still should be equipped with good seal in order to prevent vapor from escaping to the outside environment. Some wicks should be darkened in order to absorb more heat to increase distilled water productivity (Jabbar et al. 2009). There are several other different types of solar sill designs including the single-basin distillation unit that consists of a basin equipped with a tilted thin glass or plastic plate to hold impure water. The dark basins can function better to capture the sunlight energy. The solar distillation units equipped with glass usually show durable function and longer life but the units equipped with plastic sheet are of lower cost and have easy installations. The tilted thin glass or plastic plate permits the water to easily drain out of the solar distillation units into the collector through a tube (Anjaneyulu et al. 2012).

1.2 Wind Power Turbine System

The wind power is a process in which the wind turbine converts wind energy into mechanical (kinetic) energy (Ogbonnaya 2011; Passon et al. 2007). The mechanical energy can be applied to generate the electricity in wind power plant system, or employed to operate machinery or pumping water in windmill or wind pump system (Agarwal and Manuel 2007; Simhauser 2010; Saravanamuttoo et al. 2009).

Wind power density which is related to the wind velocity and air density can be used to calculate the mean annual power generated in each square meter of turbine sweeping sectional area and the density changes with different heights (Bir and Jonkman 2007; Kim et al. 2011; Li 2013; Vallee et al. 2009). In the real wind power turbine, it is not possible to capture total wind power since some acquired air will exit the turbine system. The ratio of inlet and outlet wind velocity should be considered in the wind turbine system design and the maximum efficiency of gained wind power by current turbine is around 60 % (Carey 2010; Li 2012f; Singh and Nestmann 2011). The power delivered by wind turbine system will be reduced due to the losses in gear train, converter, rotor blade, and generator (Fulton et al. 2006). The turbines are normally placed at upwind location of structural tower and turbine rotor blades are constructed in strong stiffness to keep the blades from being bended into structural tower due to strong gusty wind (Christodoulou et al. 2011; Li 2012f; Ogbonnaya et al. 2010). Wind turbine systems have been designed to capture the wind energy in a specific place and aerodynamic analysis can be employed to verify the proper height of structural tower, to decide the feasible control systems, and to determine the rotor blade geometry and numbers (Komandur and Sunder 2008; MacLeod and Jastremski 2010; Silva et al. 2011).

1.3 Solar Panel Tracking System

The global warming demands and requests the alternate energy resources from green and renewable energy sources including solar power energy. The solar panel tracking systems are the device that orients solar panel following movement of the sun (Bhandari and Stadler 2009; Munilla 2013). Solar panel can be photovoltaic and reflective panels or some optical related devices. In photovoltaic flat panel system, tracking mechanism is applied to reduce the incidental angle between input sunlight and solar panel to increase the incoming energy received from the sun. In concentrated solar photovoltaic system, the tracking mechanism is employed to orient optical device towards the sun to receive maximum direct sunlight energy (Brinkworth and Sandberg 2006; Li 2013b). The effective sunlight-receiving area in solar panel system changes with the cosine of angular deviation between panel direction and the sun (Hoke and Komor 2012). Since sunlight has two components in which around 90 % of solar energy is contained in direct sunlight and rest energy is contained in diffusive sunlight, the sun requires to be visible as much as possible; otherwise more direct sunlight energy will be proportionately reduced in cloudy sky (Darling et al. 2011). The tracking system with accuracies of $\pm 4.5°$ can catch more than 98.8 % of the energy from direct sunlight and also 100 % of the diffusive sunlight (Laird 2011; Mendonça and Jacobs 2009). Although the sun moves 360° from east to west each day, the approximate visible portion of the sun is around 180° (average half day time). If a solar panel in horizontal location does not rotate from east (dawn) to west (sunset), only sunlight that travels about 80° could be caught and rest of the sunlight energy in the early morning and late afternoon will be lost (Timilsina et al. 2012). The solar panel orientation from east to west can help to maximize the capture of daily sunlight energy. Single-axial tracking system that has one degree of freedom with angular rotation around one axis can be applied to this solar system (Wang et al. 2011). There are several types of single-axial tracking systems including horizontal, vertical, inclined, and polar aimed single-axial tracking systems. In horizontal single-axial tracking system, the orientating axis is installed horizontally related to the ground and setup of multiple solar panel groups is simple since all rotating axes of all groups can be maintained parallel to each other. In vertical single-axial tracking system, the orientating axis is mounted vertically related to the ground. This tracking system rotates solar panel from east to west during the day and it works more efficiently than horizontal axial solar tracking system at higher elevation (Myers et al. 2010). The setup of multiple groups in vertical axial tracking systems should consider reducing the shade to minimize unexpected sunlight energy losses. In tilted single-axial tracking system, it has two rotating axes with which the solar panel can rotate around horizontal axis and vertical axis individually. The tilted angle system can be adjusted to decrease the wind load pressure (Simhauser 2010). The multiple group setups are needed to reduce the shade to minimize the sunlight energy losses. Although the panels in group setups can be adjusted without shade when perpendicular to the rotating axis, the setups that parallel to their rotating axes are complicated and will be limited by the panel tilted angles and its elevations. The polar aimed single-axial tracking system equips a telescope-guided unit and tilted single axis is adjusted to aim at the polar star. In this tracking system, the solar system's tilted axial angle equals to its site latitude that keeps good alignment between rotating axis of tracking system and orientating axis of the earth. The sun travels 48° between the north and south as well in a full year and only sunlight that travels about 24° could be caught (Branker et al. 2011). The tracking system with orientation from the east to the west (daily movement) and from the north to the south (seasonal movement) called double-axial solar tracking system should be used to minimize the lost sunlight energy. The double-axial tracking system that has two degrees of freedom with angular rotation around two axes can also be employed to the solar system. In this system, two axes are normally perpendicular to each other (Ramadhan and Naseeb 2011). The primary axis is the rotating axis related to the ground and secondary axis is normal to the primary axis. Several major types of double-axial tracking systems include tip-tilted double-axial tracker and azimuth-altitudinal double-axial tracker (Falconett and Nagasaka 2010). The rotation of solar panel related to the tracking system is important to the solar function and double-axial tracker permits better receiving of solar energy due to its capability of tracking the sun in vertical and horizontal directions. Some factors should be considered while selecting the types of tracking systems, such as environment condition, local latitude, on-site weather, electrical price, and installation dimensions. The tracking systems using motor drivers and gearing unit to orientate the solar panels are directed by controller to track the sun traveling directions (Ferrey 2006; Ramadhan and Naseeb 2011).

1.4 Energy-Saving Cooling System

The cooling process is to move heat from one place to another place and heat transfers are driven not only by mechanical energy but also by the energies from electricity, heat, and magnetism (Bagarella et al. 2013; Christian and Hermes 2013; Lucas and Koehler 2012). There are many applications using cooling systems including cryogenics, commercial freezers, residential refrigerators, and air conditioners (Agrawal and Karimi 2012; Barbosa and Sigwalt 2012; Li 2009d). The current widely used applications of cooling systems are for industrial cooling processes in manufacturing and production, air conditioning for residential and commercial buildings, medical treatments, surgical operations, climate-controlled food conservation, and many others (Derking et al. 2012; Engelbrecht et al. 2012; Oró et al. 2012a, b). In industrial and production processes, the cooling systems can be applied for gas liquefaction, air purification, oil refinery, and metallic material temper treatment (Khan et al. 2012; Li 2012; Mumanachit et al. 2012). There are several cooling processes including cyclic cooling (i.e., vapor cycle and gas cycle), magnetic cooling, and thermoelectric cooling (Ally et al. 2012; Sanaye and Asgari 2013). In cyclic cooling process, heat is taken away from lower temperature source and released to higher temperature source that is driven by external energy work. The refrigerant absorbs and releases the heat as it circulates in a cooling system (Bhanja and Kundu 2011; Shamsoddini and Khorasani 2012). The cyclic cooling processes include vapor cooling cycle and gas cooling cycle (Egolf et al. 2012; Zhu et al. 2013). In vapor cooling cycle, vapor is compressed with no change of entropy and leaves compressor at higher temperature but pressure is still below the vapor pressure at that associated temperature. The vapor starts condensing into the liquid phase after passing the condenser and the evaporation will be generated when liquidized refrigerant flows across the expansive valve to absorb the heat through evaporator unit to cool external environment (Colombo et al. 2012; Cuevas et al. 2012). In gas cooling cycle, the gas phase does not change during compression and expansion. The cooling capacity equals the product of gaseous specific heat and temperature rise in lower temperature source (Abed et al. 2013; Thomas et al. 2012). The gas cooling cycle is widely applied as cooling system in gas turbine-driven fight jet or airplane. In thermoelectric cooling system, the heat flow between two different media contacts is driven by Peltier effect that is widely applied in mobile cooling unit for temperature control of instruments and electronic devices (Coşkun et al. 2012; Šarevski and Šarevski 2012). In magnetic cooling system, the refrigerating media is usually a paramagnetic salt and active magnetic dipoles are from the electron shells of paramagnetic atoms (Ayou et al. 2012; Faúndez et al. 2013). The multiple magnetic dipoles in cooling media are driven to be aligned under higher magnetic field and degrees of freedom in cooling media are being put into lower entropy environment (Aprea et al. 2013; Qureshi and Zubair 2013). The thermal sink then receives heat removed from cooling media due to its entropic loss. The contacts between cooling media and thermal sink is then disconnected and the unit is insulated causing switch-off in magnetic field that raises thermal capacity of cooling media and reducing its temperature below thermal sink temperature (Gheisari et al. 2012; Kagawa et al. 2013).

The coefficient of performance (COP) of a cooling system is a critical parameter in judging the systematic efficiency of a cooling system (Kitanovski et al. 2012; Piacentino and Talamo 2013). COP is designated as the ratio of cooling capacity to external energy input (Kumlutaş et al. 2012). The performance factor (PF) of a cooling system is another important parameter in examining the systematic efficiency of a cooling system. PF is determined by the ratio of energy input to cooling capacity (Ekren et al. 2011; Góral and Kluza 2012). The newly developed cooling system introduced in this book focused on energy saving and manufacturing cost reduction due to its simplified design.

1.5 Automated and High-Speed Manufacturing Systems

Automated machinery system is to apply various control systems to control and operate the machinery with minimized or decreased human intervention (Bao et al. 2013; Janchiv et al. 2013). The major advantages of automated machinery system include reducing labor, saving energy, optimizing material usage, improving quality, keeping accuracy, and maintaining precision (Andrikopoulos et al. 2013; Bay et al. 2008; Jeon et al. 2013). Automated machinery systems can be supported by many different ways including computers, pneumatics, hydraulics, mechanics, and electronics (Baniardalani and Askari 2013; Kim et al. 2013). Two popular controls applied to automated machinery system are feedback control and sequential control (Koo et al. 2013; Li 2011b; Liu et al. 2013). The feedback control includes continuous measurement by applying optical or proximity sensors and computes adjustments to maintain the allowable range for measured variables (Bang et al. 2013; Beebe 2009; Liaquat and Malik 2013). For example, when using feedback control for air-heating system, the sensor detects the heated air temperature and the signal is being continuously fed back to the systematic controller to compare with targeted variable setting (Berretti et al. 2012; Che et al. 2013; Lini et al. 2013). The temperature difference is calculated in the controller and the signal will be sent to the heater after temperature adjustment has been determined (Nikolakopoulos and Alexis 2013; Pai 2013; Tombari et al. 2010a, b). The sequential control involves executing programmed logic sequence in discrete operations. The relay logic is one of the forms in sequential control and electrical relays control electric contacts that can make either connection or disconnection between the electronic devices (Berretti et al. 2012; Cho et al. 2013; Park et al. 2013). For example, when applying sequential control for elevator, relay logic has been created while engaging or disengaging the electrical contacts to start or stop electric motor to operate the elevator (Bouazza and Ouali 2013; Li 2012; Lini et al. 2013). Machine tools can be automatically operated by numerical control (NC). Automated machinery systems can be applied in manufacturing and assembly processes, such as petroleum refining, power generation, chemical production, plastic molding and injection, steel making, automobile assembly, food processing, automated welding, and many other industrial applications (Choi et al. 2013; Sami and Patton 2013; Tuan et al. 2013). The major advantages using automated machinery systems include higher productivity, better quality, more consistency, less human involvement, and reduced labor cost (Faltemier et al. 2008; Ullah et al. 2013). The automated system is preferably used, where the cyclic time has to be reduced, higher accuracy must be maintained, working environment is hazardous or dangerous to the human, and job task is far beyond the operator's capability, to keep strong economic competitiveness of enterprises in the challenging market (Lee et al. 2013; Seifabadi et al. 2013). Automated machinery system can meet the growing demand for flexibility and convertibility in production processes. The manufacturing industries are continuously demanding the capability to flexibly change from making one product to another new product with no need to completely set up a new production line (Han et al. 2013; Li 2011b; Seok et al. 2013). The numerical control (NC) has been currently applied to control automated production systems in many companies quickly expanding the automated applications and widely benefiting the human activities (Christophe et al. 2010; Hu et al. 2013; Van et al. 2013). Computer-aided control technology can be employed as the basis to create complicated industrial systems through implementing mathematical and business's functioning models, such as computer-aided design (CAD), computer-aided engineering analysis (CAE), and computer-aided manufacturing (CAM) (Ding et al. 2013; Han et al. 2013; Wang and Yang 2013). The integration of information technology (IT) with industrial machines and manufacturing processes can significantly support the control system design and development, such as programmable logic control (PLC) system (Jeon et al. 2013; Ji et al. 2013; Lamooki 2013). The PLC system can be normally used to control the operation sequence between input sensors and output actuators. The automated control systems can be widely applied in different industries including producing aerospace, food, mining, automotive, environmental waste process, medicines, agricultural products, chemicals, metal working, product inspection, and machine cutting (Huang et al. 2010; Kong and Tomizuka 2013; Lee et al. 2013). The importance to increase manufacturing rate is to integrate the automated software with machinery drives, production services, and business solutions to make company more competitive (Li et al. 2013; Yang et al. 2013).

1.6 Robotic System for Industrial Applications

Robotic technology is a technical field dealing with engineering design, manufacturing operation, automatic applications, computational control, sensing feedback, and data processing (Howard et al. 2006). The robotic system design usually integrates the technologies of computer science, mechanical engineering, electronic engineering, and manufacturing engineering (Kazerooni 2005; Li et al. 2011). The mathematical expression of a robotic system is used to control algorithms in observing how a functioning process has been handled (Harja et al. 2007).

In history, the robotic systems were sometime being used to simulate human behavior and perform certain tasks. Today, the robotic systems are rapidly developing with continuous advances of automation technology, scientific research, and engineering design (Lerman et al. 2006). The robotic systems can perform different special jobs that are heavy duty, too dirty, very dull, and environmentally hazardous to the humans. Robotic systems are more accurate and reliable than humans so they have been widely applied in production processes including product packaging, manufacturing assembly, material transport, space exploration, surgical procedure, and many others (Pounds et al. 2004; Ratti and Vachtsevanos 2010). The actuators in robotic systems, such as motors and drivers, transfer the stored energy to the different kinds of motions including linear and angular movement (Mian et al. 2010). The mechanism of robotic systems is controlled to perform different functions. The sensors allow robotic systems to obtain data information from measurement and decide the related response to perform different tasks (Kennedy and Desai 2003; Salti et al. 2013). In the robotic operation, sensors receive and provide information of external conditions (i.e., location, temperature, pressure) and situations of robotic system itself (i.e., location of its arm, gripper, joint pin points) (Klopcar et al. 2007; Tapus et al. 2008). All these received data information can be collected, calculated, and executed in systematic controller to instruct the movement of robotic system. The robotic systems can be used for manipulating the products including picking and placing parts in the manufacturing processes (Leibe et al. 2008). The robotic arms, equipped with mechanical or vacuum grippers, can move around in a range of 3D motion by more advanced ways using balanced dynamic algorithm (Mellinger et al. 2010). The robotic motion study focuses on two areas: kinematic motion and dynamic motion. Direct kinematic motion study performs the calculation of gripper location, rotation, speed, and accelerated rate while the associated connecting joint values are given (Rachidi et al. 2013; Shakernia et al. 2002). Inverse kinematics motion study considers the situation in which the connecting joint values are computed while the gripper position values are given (Mian et al. 2008). The kinematics can deal with the collision prevention, singularity elimination, and system redundancy. After getting associated locations, speeds, and accelerations by applying kinematics, the effect of forces on its motion can be determined by employing the dynamics (Shen et al. 2008; Tsagarakis and Caldwell 2003). The direct dynamics focuses on the computation of acceleration in robotic systems if exerted forces are given and inverse dynamics studies the robotic driving forces required to generate the robotic system acceleration (Tapus et al. 2007). All the above information can be applied to adjust and control the algorithms of the robotic systems (Torbjorn et al. 2009).

1.7 Magnetic Sealing System

There are several types of magnetic sealing systems. The magnetic liquid seals are applied in rotating machinery to allow rotation while keeping a tight seal by using ferrofluid, that is contained in place by applying the permanent magnet, as the physical barrier to prevent leaking (González-Jorge et al. 2005; Mitamura et al. 2008). Magnetic liquid rotating seals have almost no requirement of maintenance and very low leakage in the different applications (Shlyk et al. 2004). This type of seal is normally installed in mechanical assemblies with a centralized shaft, support bearings, external housing, and other components. The support bearings offer two critical functions: keeping shaft centralized with even seal gap and holding outside loads. Since the magnetic liquid rotating seal is actually an oil-distributive fluid contained magnetically between rotary shaft and stationary wall inside of housing, the life cycle for this type of seal is increased and frictional torque load is reduced (Cong et al. 2005; González-Jorge et al. 2007). There is no requirement for electrical power since magnet has been permanently charged. Magnetic rotary liquid seal system is designed for many applications for gaseous and vapor sealing but not for pressured fluid sealing due to weakness caused by sharp varied temperature, alternative pressure, high speed, differential loads, and severe environmental changes (Hirsch 2003; Li 2010). Another magnetic seal, also called vacuum seal, relies on the technology of using electromagnetic field to hold metal components together. This magnetic sealing unit is usually applied to seal the nonenvironment-friendly products and keep hazardous materials from leakage (Topal et al. 2003; Zydlo et al. 2005). It has been designed to block any impurities or tiny particles that intended to permeate the seal mechanism and build up an airtight seal between rotary shaft and stationary wall inside the housing (Ochonski 2005; Tušek et al. 2011).

A new type of magnetic sealing system introduced in this book focuses on more reliable functioning sealing system with less manufacturing cost and enlarged life cycles. Currently many rotary machineries use the conventional seals in lip or labyrinth geometrical shapes (Li et al. 2005). However, these conventional seals show significant wear and leakages of gas and liquid through these types of seals were detected (Takashi 2002). The life cycle of these traditional seals is much shorter than that of magnetic seals (Morton and Fruh 2002). The magnetic sealing mechanism can be applied to improve sealing function in different engineering applications (Zhao et al. 2006).

1.8 Automated and High-Speed Packaging Machinery System

The packaging engineering and technology is a technical field ranging from packing system design to final product placement. All the sequential layouts in the production line should be taken into account while designing the package system for any developed end products (Fuge et al. 2012; Han and Lee 2013; Jeon et al. 2013). Packaging production systems are used to reliably package the products to prevent products from damage during delivery and in the storage (Cho et al. 2013; Fusco and Russo 2013). Many innovations in the packaging systems were initially developed for military practices since certain military packaged products must be transported in the most severe environment, harsh distribution, terrible storage, and dangerous conditions (Chu and Chang 2005; Jeong et al. 2013;

Lee et al. 2010). When designing the package engineering systems, it should focus on the industrial and technical aspects in production, marketing, industrial logistics, materials being handled, and final product-related design (Devanathan and Ramani 2010; Harja et al. 2007; Hu et al. 2013). The package being processed must prevent the products from breakdown while keeping the cost-effective and efficient packaging production cycles. The objectives of packaging technique target that the products wrapped in the package should be kept from ruin caused by external compression, physical shock, harsh drop-off, varied temperature, mechanical vibration, and electrostatic discharge (Gerkey and Matarić 2004; Goel et al. 2012; Jiang et al. 2013). The transport packaging needs to follow the standard logistics system in order to meet the protective strength and holding capability of transporting packages. The package design and testing might be performed within the company or from outside packaging engineering firms (Andrikopoulos et al. 2013; Baniardalani and Askari 2013). To pack products by machinery system, the packaging machine selections should consider its packaging capabilities, technical requirements, systematic maintainability, labor involvement, packing reliability, operation safety, machine serviceability, flexibility to be integrated into the production line, layout space, front and running cost, energy efficiency, and ergonomic design for future transport handling (Agarwal and Manuel 2007; Gao et al. 2013; Seifabadi et al. 2013). Automated packaging systems can improve packing quality and increase productivity. There are many types of packaging machineries including systems for cartooning, bottling, accumulation, collection, slitting, sealing, converting, filling, and wrapping (Kim et al. 2013; Salti et al. 2013; Song and Li 2013). Packages are designed from many different types of hard or flexible materials that have folding lines to permit further folding into the package shapes. Some major processes that packaging manufacturing is mainly involved in are extrusion-assisted forming, thermo-assisted forming, molding-assisted forming, and other technology-assisted forming processes (Koo et al. 2013; Regli et al. 2011; Seifabadi et al. 2013). Packaging productions can be designed for high-speed processes including filling, packing, and shipping (Fang et al. 2013; Rezgui et al. 2011). The structural and thermal analysis of packing tools and materials requires to be performed to evaluate the packaging quality and its further improvement (Ratti and Vachtsevanos 2010; Wang et al. 2013). Good packaging system design makes products more tangible to the users, sets a tight customer connection, and efficiently influences marketing decision to engage (Passalis et al. 2011; Yoon 2013). It is very important to understand how to combine global marketing information with customer needs and cultural preference to effectively join current and future compelling global discipline (Stefano et al. 2013; Zhu 2013).

1.9 Biomedical and Surgical Systems

New biomedical and surgical instruments have been designed and developed to perform complex surgery and biomedical treatment by applying the minimally body-invasive approaches and reliable medical instruments (Brown et al. 2007; Cheng et al. 2004; Kavitha and Ramakrishnan 2011). Many different medical treatments and surgical procedures can be facilitated efficiently for gynecology, urology, prostatectomy, general medical treatment, cardiac valve restore, plastic surgery, orthopedics, and neurology by applying good medical instruments (Ballihi et al. 2012; Chambers et al. 2013; Kosta et al. 2012). Doctors and surgeons are required to know the knowledge and learn the skills to correctly use different surgical instruments in sterile and aseptic surgical environment (Fadzil et al. 2011; Kayalvizhi et al. 2013). The goal of newly developed biomedical and surgical instruments is for doctors and surgeons to be able to perform the medical treatments more smoothly and efficiently to ensure that the medical operative procedures are safe and instrument functions are reliable (Gill and Munroe 2012; Goy et al. 2012; Kumar et al. 2012). To carry through a surgical procedure, doctors and surgeons must well control and accurately manipulate the medical instruments to keep full safety and functioning features that are designed for minimum human errors (Hemalatha and Manivannan 2011; Janghel et al. 2012; Li 2012). New biomedical and surgical instruments are designed and developed to improve upon conventional surgical procedures to ease and benefit doctors and surgeons in medical treatments and surgical operations by providing clear visualization, precise control, ergonomic satisfaction, consistent function, safe interaction, and flexible adjustment (Haddad-Mashadrizeh et al. 2013; Kalantzaki et al. 2013; Li 2011). The newly designed and developed biomedical and surgical instruments introduced in this book also aim at eliminating surgiclip drop-off incident, less operational force, more stable driving mechanism, and more robust structural design while manipulating the thick body tissues in medical treatments and surgical operations.

Part I

Energy Systems

sample content of CAD, 3D Modeling, Engineering Analysis, and Prototype Experimentation: Industrial and Research Applications

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