Chapter 8
Future of Mechanical Engineering

Abstract Mechanical engineering is one of the oldest but evergreen branches of engineering. It is continuously evolving and adapting to new developments in science and technology. In the near future there will be more emphasis on developing sustainable technologies. Micro and nano technologies, biotechnology, mechatronics, and 3-D printing are some of the technologies that will grow tremendously in the twenty-first century. The world has become a global village now. The development of mechanical engineering will continue tackling global challenges.

Keywords Bioengineering · Mechatronics · Robotics · Nanotechnology · MEMS

8.1 Introduction

Mechanical engineering is one of the oldest branches of engineering. Evolution of mechanical engineering has been taking place through the centuries, and it is a continuous process. A number of epoch-making inventions in mechanical engineering have revolutionized the modern civilization. The invention of wheel was a landmark event in the mechanical engineering. Another landmark was the invention of steam engine, which played a major role in the industrial revolution. In the twentieth century, electronics played a major role in mechanical engineering. Nowadays, computers have become integral parts of mechanical engineering.

With the passage of time, the role and scope of the mechanical engineering is gradually transforming owing to the advancement of science and technology, new innovations, change in the need and expectations of human beings as well as their lifestyles, and globalization. These factors will serve as catalysts for significant changes within mechanical engineering in the near future. American Society of Mechanical Engineers (ASME) conducted a survey in 2011 among more than 1200 engineers (with at least two years experience in mechanical engineering related positions) to learn about the current status and the changes foreseen in mechanical engineering over the next two decades. The findings of the survey are presented in

U.S. Dixit et al., *A Brief History of Mechanical Engineering*,
Materials Forming, Machining and Tribology,
DOI 10.1007/978-3-319-42916-8_8

the report ‘The State of Mechanical Engineering: Today and Beyond’ which are important for the future of mechanical engineering in the coming days (https://www.asme.org/getmedia/752441b6-d335-4d93-9722-de8dc47321de/State-of-Mechanical-Engineering-Today-and-Beyond.aspx). Some of the key findings of the survey may be of interest to the readers. The survey mainly focussed on the emerging fields in engineering, the ability of the engineers to meet global challenges, state-of-the-art tools and techniques and their use, and professional and personal skill development. According to the survey, globalization is predicted to have a significant impact on the mechanical engineering field. Alternative energy, water, bioengineering, biomedical, environmental engineering, nanotechnology, robotics, mechatronics, latest computer technology, and electronics are expected to gain prominence in the near future. Energy, in particular, green/clean and renewable energy (solar/wind/hydraulic) will attain the maximum importance to deal with the issues of energy crisis and environmental protection. Some of the cutting-edge fields for the next twenty years are identified as virtual prototyping, motion simulation, animation, smart material, smart grid, Micro-Electro-Mechanical Systems (MEMS), green building technology, nano medicine, synthetic biology, greenhouse gas mitigation, etc. Importance of interdisciplinary skills, global team management, effective communication, computer/software skills, business skills, multilingual capability and sharing of data will remain. Social responsibility, diplomacy, leadership quality, and cost consciousness will also be important.

The history of mechanical engineering will continue to be written. As described in this book, the history of mechanical engineering started on the day when human being started using tools. The mechanical engineering got its separate identity in nineteenth century; Institution of Mechanical Engineers was formed in UK in 1847. In the near future, this distinct identity of mechanical engineering may be in danger in a positive sense. There will be more emphasis on interdisciplinary research and practice. The course structure of mechanical engineering will be dynamic depending on the changes in technology. The mechanical engineering students will have to be trained in a manner so that they are flexible, agile and have ability to grasp the knowledge of other disciplines quickly. Many may prefer to take minor degrees in other disciplines with mechanical engineering as a major.

8.2 Future Directions in Mechanical Engineering

The importance of engineering research and innovations, their applications, and applied hands-on engineering practice will play a major role for future developments of mechanical engineering. Cooperation and collaboration are required among nations, countries, educational institutions, and industries to meet the global challenges. Currently, mechanical engineering is perceived as a discipline that applies the principles of physics, design, manufacturing, and maintenance of mechanical systems (Davim 2014). For a mechanical engineer, the knowledge of the modern subjects is essential in addition to the fundamental subjects of classical mechanical engineering. Latest topics and technologies such as nanotechnology, nanomechanics, microelectronics, computational mechanics, mechatronics and robotics, alternative energy, and sustainability are gradually becoming widespread and relevant for the decades to come. Some topics that will attain prominence in the future are briefly presented here.

Sustainable energy: The growing demand for energy in the last two decades involving all spheres of human civilization is an alarming issue leading to energy crisis. The need arises to explore the means of sustainable energy for sustainable development. Moreover, to reduce harmful environmental effects, there are new industrial regulations of the government to go green. Research in sustainable energy is the call of the day to address the environmental issues. Without sustainable energy, overall global development will remain a dream. Efforts are on to extract energy from renewable sources such as wind, water, the Sun, and biomass which are inexhaustible and clean. Developing latest technologies to harness renewable energy is a promising research area. Additionally, importance should be given to energy efficiency, i.e., getting more from our existing resources. UN Secretary-General Ban Ki-moon has asked investors to at least double clean energy investments by 2020 to reduce climate risks, end energy poverty, and create a safer, more prosperous future for this and future generations (http://www.se4all.org/content/un-secretary-general-urges-doubling-clean-energy-investment-2020). The underlying philosophy of sustainable development is that for raising our present standard of living, the interests of future generations should not be sacrificed. Sustainability includes environmental, economical, and social aspects.

Nanotechnology: Emergence of nanotechnology has tremendous benefits on various fields of engineering and medical science. Nanomaterials have enhanced properties and are lighter and stronger compared to other materials. Some feel that nanotechnology will be the next industrial revolution (Bhushan 2010). Manufacturing with nanotechnology will reduce material requirements, time, and cost and also solve the problems of shortage of water and power. Effects of nanotechnology on life and health of people and on the environment are studied and green nano design principles are reported to have developed for positive environmental effects (http://www.nanowerk.com/spotlight/spotid=42342_1.php). Recently, nanotechnology is used to manufacture multipurpose fish shaped microrobots called microfish that can swim in liquids. Functional nanoparticles are added into the microfish body, and they can be used for detoxification, sensing, and drug delivery (http://phys.org/news/2015-08-3d-printing-microscopic-fish-team-method.html). A nanoparticle is an aggregate of atoms bonded together with a radius between 1 and 100 nm (1 nm = one billionth of a meter), typically consisting of 10–10^5 atoms. The diameter of a typical human hair is 75,000 nm. Nano electromechanical systems (NEMS) are typically less than 100 nm in size. A number of examples of advanced research in nanotechnology can be cited. Nano particles can be dispersed in the liquid for getting enhanced thermal conductivity. In a study, Eastman et al. (2001) has shown that when nanosized copper particles were dispersed in ethylene glycol, its thermal conductivity got enhanced by 40 %, when the concentration of nanoparticles was 0.3 vol.%, and the mean diameter was less than 10 nm. Nanotechnology has tremendous potential to be explored in the near future.

If only one length of a three-dimensional nanostructure is of nanodimension, the structure is called a quantum well. A quantum wire has two sides of nanometer length, and a quantum dot has all three dimensions in the nanorange (Bhushan 2010). The prefix quantum signifies the importance of quantum mechanics in understanding the nanotechnology. Although nanotechnology is a technology of twenty-first century, it was envisioned by Richard P. Feynman, a Nobel Laureate in physics, in a lecture in December 1959 (Feynman 1960).

Bioengineering and Biomechanics: Biomechanics is the application of the principles of mechanics to living biological beings. For example, it studies human body as a combination of links and connecting joints and analyze the functions of human body and the amount of stress, load and impact it can withstand. Bioengineering is mainly used for designing artificial replacements for various body parts of human beings based on the biomechanics analysis. With the advances in medical science and technology, now it is possible to replace vital body parts, thus giving relief to millions of patients across the globe. Bioengineering can produce customized products such as ear plugs for hearing aids, prosthetics of body parts, cosmetic dentistry, and artificial bone replacements in knee, jaw, and scalp in biomedical applications. Research is going on to produce artificial chests and necks. With the latest cutting edge technology, researchers are able to invent devices for brain activity monitoring, body function monitoring, drug delivery inside human body, and for many more functions. Bioengineers have developed a portable and wearable brain activity monitoring system that is equipped with sensors for collecting brain activity data and use for neuro-imaging, feedback, and clinical diagnostics (http://phys.org/news/2016-01-brain-lab.html). Another breakthrough in Bioengineering is the development of a tiny MEMS flow sensor that can be used for intravenous (IV) therapy for drug infusion in human being (http://phys.org/news/2016-01-iv-infusion-cave-fish-inspired-sensor.html). Bioengineering and biomechanics is one area where the mechanical engineering has a wonderful role to play to bring smiles to millions suffering from ailment. The area of synthetic biology is also picking up. Synthetic Biology comprises the design and construction of new biological parts, devices, and systems as well as the re-design of existing, natural biological systems for useful purposes (http://syntheticbiology.org/).

3-D Printing: 3-D printing has emerged as a frontier technology in the recent times in manufacturing sector for its obvious benefits. 3-D printing is an additive manufacturing process where parts are fabricated layer by layer from 3-D CAD model. This technique has immense potential for the future. The need for tooling is eliminated, and complex geometry can be directly manufactured from the digital model, thus enabling faster ways of manufacturing a part. It tremendously reduces the manufacturing lead time and very useful for customized products. Materials used for 3-D printing may be metal, plastic, ceramics, glass, and paper. Efforts are going on to achieve multi-material 3-D printing for fabrication. Recently, researchers at MIT's Computer Science and Artificial Intelligence Laboratory are reported to build a 3-D printer that can print ten different materials simultaneously by using 3-D scanning techniques (http://phys.org/news/2015-08-multifab3d-prints-materials-required-video.html). 3-D printing is also used to build microbots with complex shapes and functions. Experts are of the view that additive manufacturing is going to usher in the fourth industrial revolution, viz. 'Industry 4.0' that will revolutionize the production methods with the concept of 'Digital Transformation of Industries' (http://phys.org/news/2016-01-industry-additive.html). The 3-D printing technology has to be more advanced to meet the challenges of the fourth industrial revolution. Manufacturing will become leaner, faster, and customized catering to the customers' needs. Fast advances in research in 3-D printing technology are going to bring in a new era of e-manufacturing in the near future.

Robotics and Mechatronics: Mechatronics is essential for several key areas in mechanical engineering, for example robotics, intelligent motion control, automation, flexible manufacturing systems (FMS), CAD/CAM, automated guided vehicles (AGV), data communication systems, actuators, and sensors. There has been a tremendous progress in the field of mechatronics and advance research is going on. Some latest mechatronic products are biometrics, automatic climate control, automatic unmanned vehicles, microbots, etc. Robotics is the application of mechanical and electrical engineering and mechatronics to create robot which is a reprogrammable manipulator that can interact with the environment for performing specific functions. Incorporating artificial intelligence to robots has taken robotics to a new height. Intelligent robots are now used in almost all fields of human life, viz. manufacturing industry, household activities, medical surgery, space and undersea explorations, cleaning, and repairing. Recently, researchers have created a robotic finger with artificial skin that can detect pressure when a human finger touches the robotic finger and transmit the same to a nerve cell (http://phys.org/news/2015-10-artificial-skin-pressure-sensation-brain.html). It aims to give some sensory capabilities of human skin to prosthetic replacements. Robots such as ASIMO (Advanced Step in Innovative Mobility) can walk, jog, climb, and perform a variety of other tasks otherwise done by human beings (http://asimo.honda.com/downloads/pdf/honda-asimo-robot-fact-sheet.pdf). There is a tremendous advancement in robotics, and Japan is the pioneer in making robots that almost lookalike to human beings called humanoid. Hiroshi Ishiguro, the famous Japanese professor has developed several humanoids. For example, Geminoid F, the world's first humanoid film actor; Geminoid HI-1, a lookalike of professor Ishiguro; and the latest addition is Erica, the most beautiful and intelligent humanoid in the world according to the professor which has the ability to understand and respond to questions with humanlike changes in her facial expression (http://www.theguardian.com/technology/2015/dec/31/erica-the-most-beautiful-and-intelligent-android-ever-leads-japans-robot-revolution). The Japanese have started using robots in everyday life as receptionists, helper at home, companion for children and elderly, and hotel staff. The robot Nadine, named after her creator Professor Nadia Thalmann, works as a receptionist at Singapore's Nanyang University that exhibits personality, moods and emotions (http://www.wired.co.uk/news/archive/2016-01/04/robot-receptionist). Robotics and mechatronics have extreme potential for the future as their application area encompasses all spheres of human life. Intelligent humanoids possessing human emotions and capability may do away with the need of human beings in the near future.

In addition to the above, there are a number of fields where the application of mechanical engineering has significant scope for developments in future. Some of these are virtual prototyping, automation, motion simulation, animation, micro-electronics, smart material, smart grid, Micro-Electro-Mechanical Systems (MEMS), biotechnology, intelligent machines, molecular manufacturing, lean and agile manufacturing, water resource management, environmental engineering, design for environment, green building technology, greenhouse gas mitigation, nanomedicine, synthetic biology, information technology, remote inspection, self driven automobiles, offshore technology, safety design engineering, and space science.

8.3 Challenges Ahead

Mechanical engineering has to invent the latest cutting edge technology in the near future by focusing on the following aspects:

- New innovations and continuous improvement of the product and service
- Global collaboration among countries, educational institutions, and industries
- The scarcity of water and energy
- Energy efficiency
- Alternative sources of clean/green energy
- Power generation and storage
- Environmental degradation
- Technologies to mitigate greenhouse gases and climate change.
- Environmentally friendly technology for sustainable development
- Emphasis on the issues of automation, networking, integration, knowledge sharing, and skill development

According to the ASME report, '2028 Vision for Mechanical Engineering', mechanical engineering is entrusted with the responsibility of developing technologies that ensures a cleaner, healthier, safer, and sustainable global environment over the next two decades (http://newswise.com/articles/future-trends-in-mechanical-engineering). According to the report, nanotechnology and biotechnology will dominate the future in the next 20 years and will provide the building blocks to meet the challenges in the fields of medicine, energy, water management, aeronautics, agriculture, environmental management, farming and food production, housing, transportation, safety, security, healthcare, and water resources. Thus, mechanical engineering will be at the forefront of developing cutting-edge technology in the near future.

Although technology brings comfort to human beings, it comes with own side effects. Sometimes it brings disaster which may be attributed to man or nature. Future mechanical engineers should gear up for tackling various challenges including those created by existing technologies. Recently, sustainable engineering has become very popular. In simple words, sustainable engineering means providing engineering solutions without sacrificing the interest of future generations. It is necessary to use minimum resources of the nature and also produce minimum waste. Thus, the importance of optimization has increased drastically. Westkamper et al. (2000) has listed the following factors being confronted by the world:

1. A rising consumption of natural resources
2. The dramatic increase in world population
3. Environmental impacts, i.e., limited natural resources (energy and materials)
4. Global communication networks based on standards
5. An unstoppable worldwide globalization

They have advocated using life cycle management in an efficient manner.

Technology has profound influence on the culture and civilization. The influence is positive as well as negative. The first industrial civilization created a lot of economic disparity among people, although it made it possible to produce the goods at cheaper rates. In the age of information technology, there is a digital divide. Higher income group people have greater access to technology causing huge knowledge gap. There is a danger to our environment, ecology, and flora and fauna. Hence, there is an increasing emphasis on green or environmentally friendly manufacturing (Dixit et al. 2012). In the area of metal cutting, the minimum quantity lubrication (MQL) and dry machining have become popular.

Modern day mechanical engineers will have to look into all the aspects in totality. There is a realization about including a lot of subjects from humanities and social science including the subject on professional ethics in the engineering curricula. There is no looking back. Problems created by technology will be solved by technology only. Health, safety, and environment will be the part of all engineering curricula. In future, the focus will be on producing smart and intelligent machines and structures. The computational techniques like neural network, evolutionary optimization, and fuzzy logic will be important. However, the hardware sector will also be strengthened. Smart materials and structures will be able to identify their own faults and take corrective actions. Machines may be able to replicate themselves. Already there is a significant progress in self-assembly.

8.4 Conclusions

In this chapter, a brief description of the topics relevant to mechanical engineering in the near future is presented. The challenges and goals to be achieved by mechanical engineering in the coming decades are discussed in a nutshell. There are lots to do in mechanical engineering in the future for the welfare of mankind and our planet earth. The machines will always be there, but their avatars will be different. Wheels and levers are amongst the oldest components, which still find applications. However, at many places they have been replaced by electronic components. For example, unlike mechanical watches, electronic watches do not contain wheel and lever. Steam engines, which caused the first industrial revolution, are extinct now. Their place has been taken by turbines and electric motors. Mechanical engineering has to adapt to these changes, but its history will always continue as machines are integral part of human civilization.

References

Bhushan, B. (2010). Introduction to nanotechnology. In B. Bhushan (Ed.), *Springer handbook of nanotechnolgy* (pp. 1–13). London: Springer.

Davim, J. P. (Ed.). (2014). *Modern mechanical engineering—research, development and education*. London: Springer.

Dixit, U. S., Sarma, D. K., & Davim, J. P. (2012). *Environmentally friendly machining*. New York: Springer.

Eastman, J. A., Choi, S. U. S., Li, S., Yu, W., & Thompson, L. J. (2001). Anomalously increased effective thermal conductivities of ethylene glycol-based nanofluids containing copper nanoparticles. *Applied Physics Letters, 78*(6), 718–720.

Feynman, R. P. (1960). There's plenty of room at the bottom. *Engineering & Science, 23*(5), 22–36.

Westkamper, E., Alting, L., & Arndt, G. (2000). Life cycle management and assessment: approaches and visions towards sustainable manufacturing (key note paper). *CIRP Annals—Manufacturing Technology, 49*(2), 501–526.

Retrieved January 23, 2016 from http://asimo.honda.com/downloads/pdf/honda-asimo-robot-fact-sheet.pdf.

Retrieved January 29, 2016 from http://newswise.com/articles/future-trends-in-mechanical-engineering.

Retrieved January 25, 2016 from http://phys.org/news/2015-08-3d-printing-microscopic-fish-team-method.html.

Retrieved January 25, 2016 from http://phys.org/news/2015-08-multifab-3d-prints-materials-required-video.html.

Retrieved January 19, 2016 from http://phys.org/news/2015-10-artificial-skin-pressure-sensation-brain.html.

Retrieved January 23, 2016 from http://phys.org/news/2016-01-brain-lab.html.

Retrieved January 25, 2016 from http://phys.org/news/2016-01-industry-additive.html.

Retrieved January 23, 2016 from http://phys.org/news/2016-01-iv-infusion-cave-fish-inspired-sensor.html.

Retrieved May 14, 2016 from https://www.asme.org/getmedia/752441b6-d335-4d93-9722-de8dc47321de/State-of-Mechanical-Engineering-Today-and-Beyond.aspx.

Retrieved January 19, 2016 from https://www.asme.org/getmedia/752441b6-d335-4d93-9722-de8dc47321de/State-of-Mechanical-Engineering-Today-and-Beyond.aspx.

Retrieved January 23, 2016 from http://www.nanowerk.com/spotlight/spotid=42342_1.php.

Retrieved January 27, 2016 from http://www.se4all.org/content/un-secretary-general-urges-doubling-clean-energy-investment-2020.

Retrieved February 18, 2016 from http://syntheticbiology.org/.

Retrieved January 27, 2016 from http://www.theguardian.com/technology/2015/dec/31/erica-the-most-beautiful-and-intelligent-android-ever-leads-japans-robot-revolution.
Retrieved January 27, 2016 from http://www.wired.co.uk/news/archive/2016-01/04/robot-receptionist.