Machine Elements and Design Fundamental

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Abstract

The Mechanical Engineering essence is the understanding of all the available resources, their effective utilization, and making use of the law of nature to help, gain and benefit the entire humanity. Mechanical Engineering is the applied science using scientific knowledge and procedures as the means to accomplish a specific practical and useful results. It is related to the sense that involves a proper understanding of all the scientific principles and effectively applying them to attain the designated goal. The machine design in mechanical engineering is the most crucial section of engineering, and it deals with the design, conception, refinement, development of machines and component application together with the mechanical apparatus of every kind.

In the professional engineering, the main concern is to obtain the requisite solutions to all the practical problems in the machinery production. The solutions should reflect the knowledge, understanding and application of the underlying technology and science. However, normally the mere understanding is not sufficient. The related empirical knowledge together with engineering judgment become the most prerequisite. For instance, no scientist can entirely understand electricity. However, it does not prevent any electrical engineer from creating highly useful and functional electrical devices. Likewise, no scientist can fully understand metal fatigues and combustion procedures, yet, the mechanical engineers utilize the knowledge and insight available to generate highly useful and functional combustion engines. When more scientific solutions are accessible, engineers can devise better explanations and clarifications to practical problems. This study tries to analyze and evaluate the perception and usefulness of AM- additive
manufacturing systems and technologies to understand machine elements, product design and its development.

**Keywords:** AM-Additive Manufacturing, Machine Elements, Machine Design, Mechanical Engineering Fundamentals.

1) **Introduction**

Machine element mentions the machine elementary components. These elements are composed of three fundamental types:

1. The structural components like bearings, splines, frame members, seals, axles, lubricants and fasteners;

2. The mechanisms involved in the machine that control and manage machinery movement in different ways like a belt, gear or chain, linkages, drives, cam that follow and function the machine movement and system, involving clutches and brakes; and

3. Controlling components like switches, indicators, buttons, actuators, sensors, computer controllers, and so on (Chako, 2000).

Machine Design, is highly iterative and an innovative process, which can be defined as the application of technical information, scientific principles together with innovative ideas and imagination to describe a mechanical system or a machine to perform precise functions with maximum efficiency and economy (George Nivish, 2015).

1.1 **Mechanical behavior of the machine**

Whereas, the Machine design stipulates and charts the fundamental principles involved in the following three sections:

**Mechanical behavior** of the machine including static mechanism concerned with the machine at rest together with the forces in equilibrium, as compared with the dynamics, concerned with the
machine in motion under the act of forces, vibrations, fatigue. Reliability, strength of materials, and so on (Yang & Zhao, 2015).

The Machine elements include the major mechanical parts of the entire machine, and includes bearings, gears, springs, fasteners, couplings, seals, and so on;

The Process of Manufacturing includes computerized machine control areas, ergonomics, quality control, engineering statistics, and life cycle conditions and analysis (Matthews, 2005).

Machine elements are basic features of mechanical parts utilized as the building block of many machines. They are standardized, designed for common sizes, and customized for specialized specific applications (Klebanov, et al., 2008).

Machine elements may be attributed as a part, like screw threads, integral bearings, or they can be discrete parts like pulleys, axles, wheels, gears or rolling-element bearing. It can also be a simple machine emphasized as machine elements, because several machine elements include concepts of several simple machines. For instance, a lead screw includes a screw thread, while it is a tilted plane covering a cylinder (Wang, 2014).

Many mechanical engineering tasks, invention, design involves a familiarity and knowledge of several machine elements, a creative and intelligent combining of elements to form an assembly of component that fills the need and serves an application. Generally, the machine element color, shape and texture covers a vital function of a machine to provide an operational and styling the interface of a machine mechanical components and its users (Norton, 2010).

1.2 Constructional Objectives

Machine or Object Designing is basically a decision-making procedure. When there is a problem or complication, we have to design an effective solution. In different words, designing is to formulate and structure a plan to justify and satisfy specific needs and create the object with a physical reality (Abed, 2015). For instance, while designing an element like chair, several factors have to be considered: (a) Main purpose to design a chair, whether an office chair, an easy chair or to accompany the dining table; (b) To design chair for a child or for a grown up person; (c) Chair Material, its strength, cost must be determined; (d) Lastly, to design the aesthetics of the
chair. In fact, every person actively participates in design, in some manner, in our daily activities because of the problems posed and to need to solve them (Wiberg & Andersson, 2019).

1.3 Mechanical Engineering Machine Design in Wide Perspective

The engineering procedure of solving problems always considers practically appropriate areas for an intensive scientific explanation and research. The engineers use the basic scientific knowledge, ingenuity, and imagination supplemented and complemented by the professional judgment and empirical information to solve several pressing problems. This research paper is concerned with the fundamental application of specific machine components and elements with their design to explain the Mechanical Engineering Machine Design in Wide Perspective, Basic Concept of machine elements and design philosophy, Fundamentals, Purpose, Principles and classifications of machine design (Abed, Fadhil, & Al-Yaseen, 2020). The Simplicity and Complexity of machine design are important in various types of Machine Design modern techniques to cultivate an awareness of its importance.

1.4 Basic Concept of machine elements and design philosophy

Machine Elements

Every machine is made of various elements, components, units or parts. Every element of a machine part is designed separately to make a final machine assembly. Every element collectedly assembled to make a complete machine after small components joined together by welding, riveting, and so on to make a final machine as designed for various applications (Sharma & Aggarwal, 2014).

Machine Element Classification

They are classified into two major types:

1. The General purpose elements; and

2. The Special purpose elements. They are described as mentioned below:
1. **General purpose elements** are common to several different machines serving diverse applications and hence, they are known as general purpose elements. For instance, bearings, couplings, axles, nuts, keys, bolts, shafts, and so on.

2. **Special purpose elements** are used for specific purposes of machine, and hence, known as special purpose and application elements. For example, connecting rods and piston are used in compressors and engines, while blades are utilized in blowers and turbines. Also, push roads, crankshaft, cylinder, cam shafts, are other examples (Norton, 2010).

**The major functions of machine elements**

Several mechanical designs and inventions in the engineering tasks include the knowledge of different machine elements. By creative and intelligent combination of these elements the component assembly is formed to fill the needs and serve an application (Das, Lashkari & Sengupta, 2006).

**Mechanical elements**

Mechanical elements like Clutch; Belt, Cable drives, Chain, Brake, Cam, Gear train; and follower systems like Linkage; Simple machine are helpful in the completion of the machine (Tang & Li, 2011).

**1.5 Fundamentals, Purpose, Principles and classifications of machine design**

![Figure 1: The different phases of machine design formalize concepts and impressions into definite information (Tang & Li, 2011).](image_url)
The machine element and design procedure commences with the identification of the defined need, the basic problems with synthesis, optimization analysis, evaluation and the decision to make productive application of the machine. After many stages of evaluation, the procedure completes with the designed plans to satisfy the eventual needs. On the basis of the situation and the nature of the designing task, the stages can be reproduced to finalize the design. The design process is mentioned in Figure 1, indicating design iterations, processes and phases (Sharma & Aggarwal, 2014).

1.6 Types of Machine Design and Design Basics

The machine element design is the most exiting and innovative manufacturing stages, when all the aspects of the final machine looks, material used, functions and so on are formulated and designed. Only after understanding the fundamentals of the final product and design process, the exciting stage of designing starts. The manufacturing technology involves complexity and creativity of machine design where the fundamental aspects of engineering come in and they are measured in three categories, like Adaptive machine Design, Developmental Designs and New Designs.

1.7 Factors to be considered in machine elements and machine design

Adaptive machine Design is like reinventing a wheel. Mostly, there are design elements and machine components adapted to suit the purposes. It uses basic features and make slight alterations to suit a particular application. By modifying the proven technology, the engineers can save time and money to make the product far more effective than to try and design the element from scratch.

Developmental Design uses existing concepts, but includes new machine components and elements to create a unique design of the component with improved technology. For example, the motorcycle is an innovative progress in manufacturing technology in machine design. However, it mainly relies on preexisting components and mechanical elements to help in the building the assembly for a new motorcycle.

New Designs where designers and engineers come up with entirely new, unique and original designs. It needs a large amount of money, time and research. By applying shared technology
and knowledge, the engineers can become more efficient and productive by modifying the
designs, which already exists. However, with the correct ideas and the appropriate experience,
the New Design elements can prove to be extremely beneficial and lucrative in the entire
manufacturing world.

By understanding the basics of Mechanical Design, Stresses and Forces, knowing the right
material, Understanding the technology and techniques, the components can be created from
scratch, while the engineers must consider all aspects of functions and forms to ensure the
product is manufactured as specified and operates as expected (Das, Lashkari & Sengupta,
2006).

1.8 Machine Design Purpose and Procedures

Mechanical engineering encompasses the design, construction, development, and engine
operating processes, machines and power plants. They are related to all the mechanisms that
move and reposition. A categorization of mechanical engineering common procedure is by the
application of machine design and available energy utilization, that involves creations,
applications and distribution of air conditioning, refrigeration, boilers, heat engines, and so on.
Machine Elements and machine design are concerned about hardware components, to include
machinery, which make use of heat processes (Schreiber, et al., 2020). The Machine Design
assists to understand the basic designing fundamentals and the most commonly utilized and
essential elements, units, components, parts of various machines. By congregating various
components to form a small machine, bigger machines are made. Hence, the machine is the basic
assembly structure of properly designed several individual elements and components (Schreiber,
et al., 2020).

In the prevailing circumstances, the new science and technology includes the fundamental
concepts related to software skills to operate while designing a machine. Surely, no machine,
element, component or product can be manufactured or made without properly and accurately
designing it. The following measures have to be taken while designing:
• Understanding the basic Requirements.
• Analyzing and Evaluating the Mechanism of Design.
• Analyzing all the mechanical Forces involved.
• Designing the Elements, components, parts and so on.
• Making Material Selection and Analysis.
• Making mathematical and computational Design procedures for Manufacturing.
• Creating Comprehensive and Meticulous Mechanical Drawings (Alex Muir, 2020).

2) Problem Statement

The machine elements and design of components is concerned about the fundamental application to certain particular machine parts and components. In the engineering exercise, the main problems are involved with the design, application and analysis of all the machine members. They can rarely be solved by using the fundamental principles of application alone. Therefore, it is critically vital subject of knowledge of the essential sciences, which is not sufficient to solve the designing problems. Often, certain empirical information is utilized along with proper engineering judgment applied to process the work. The basic problem of engineering design cannot have only one precise answer. For instance, the competent engineering staff of the company performs various innovative product designs to find the final solution to the same major problem. These inventive techniques and solutions bring changes as new and novel technologies, with new manufacturing methods, new materials, and new marketing techniques under the prevailing conditions. These basic concepts can provide the primary and foremost experience to deal with further professional mechanical engineering problems (Juvinall & Marshek, 2012).

3) Literature Review

3.1 Machine Design modern Objectives and techniques

The Additive Manufacturing objective is to develop an articulate roadmap to address the needs of technological advances and opportunities to design; control process modeling; machines,
materials, and processes; energy with sustainability; and specifically for biomedical applications (Bourell, Rosen & Ming, 2014).

The main focus of Machine design is on the fundamental principles of the three sections:

- Machine elements of the major mechanical parts of any machine and they involve bearings, gears, springs, fasteners, couplings, seals, and so on;
- Mechanical behavior of the machine like static, dynamic, vibrations, strength of material, fatigue and reliability;
- Manufacturing procedures involve certain computerized machine system control, ergonomics, quality control, engineering statistics, and life cycle analysis (Philip Kosky & George Wise, 2013).

3.2 The importance of Machine Design & layout

- The plant operators consider all the physical properties along with clearances of the machine made as per the design;
- They consider proper sanitation in plans while designing the equipment;
- The design is made for proper and requisite ventilation and airflow in the process plants.
- While making the final design and installation, equipment design is very critical to uphold the safety and efficiency (Tang & Li, 2011).

3.3 Impact of AM- Additive Manufacturing in Mechanical Engineering

Several products that we observe on the shelves are designed, processed and influenced by a team of mechanical engineers. They provide more than design aspects to provide an outstanding physical product, by modeling, production and analysis to make sure that these products function the way they should. The proper exposure of designer tools can turn out to be an added value approach to various product designs and that can become a groundbreaking concept in product functionalities and geometries, leading to the complete exploitation of the additive technologies. The AM- additive manufacturing systems can generate tremendous impacts on education and knowledge of future mechanical engineers, by taking advantage of implementing AM technology at different stages of education, for diverse disciplines and purposes. The innovative nature created by AM and its impact can be evaluated (Minetola, 2015).
There is a positive connection with adopting AM devices with perceived motivation, interest, and for ease of gaining knowledge of mechanical engineering. The additive technologies provide a hands-on experience in academia, by fostering the technical knowledge acquisition (Minetola, 2015).

4) Methodology

4.1 AM- Additive manufacturing methodology for of Machine Design

Additive manufacturing encompasses the design, manufacturing method, postprocessing techniques, quality assurance and various activities useful for 3D design printing to operate in a production environment. AM is facing several hurdles and harsh realities. Starting from the machine cost, material feedstock, technological risks, uncertainties, lack of allowable design standards, challenging tool chains and workflows, AM has hurdles, which are hindering its industrialization (Simpson, 2020).

The AM introduction opens the possibilities for creating better, lighter and customized products. But, to take possible advantage of AM, there are challenges. The general method of design process to create complex products is evaluated. The method is to aid the design procedure, wherein, the TO- Topology Optimization is applied to concept development, and interpreted into a MM- Master Model to support design evaluation during the elaborate design stage, when MM is created, and manufacturing information is stored in the database. This automatically generates and export designed models for further CAE analyses and manufacturing. It uses KBE- Knowledge-Based Engineering tool to realize the methodology development. The tool has a special quality for the structural elements and component creation and they connect to other assembly components. For example, the aircraft door was used to evaluate the tool to interpret the topology design optimization. The methodology, results showed the parametric CAD model that allowed quick changes, coupled database for the export of models for different purposes (Wiberg & Andersson, 2019).

4.2 Effects of AM on engineering education

An engineering technology of Additive manufacturing pertains to the machine elements, designing, and manufacturing field and it minimizes the production time considerably, resulting
in high production rate. It is also known as the most economical, efficient, accurate and qualitative method. The most vital feature and attribute of this technology is that, it helps in design flexibility, freedom of geometrical intricacy, and overcomes many shortcomings in the prevailing conventional methods (Hari Prasad & Suresh, 2019).

The fundamental aspects are to understand the standards, industrial applications, methods, and materials by applying AM technology. Its new trends in technology are effectively shaping the engineering education together with machine element applications and design (Verma, 2020).

### 4.3 Impact of AM- Additive Manufacturing on Machine elements and machine design

The AM- additive manufacturing procedure is evolved from quick prototyping towards the product manufacturing, end-of-use process. The manufacturing constraints are mainly alleviated while the design freedom is significantly broadened, processing and managing material complexity, functional complexity, shape complexity and hierarchical complexity. Inevitably, the DTM- theory of conventional Design and Methodology, particularly the lifecycle oriented objectives are challenged (Yang & Zhao, 2015). There is a positive impact of AM on conventional DTM- Design Theory and Methodology and it is analyzed through the machine DFM- design for manufacturing, DFA- design for assembly, and DFP- design for performance. There is plenty of evidence to specify that the conventional method of DTM cannot embrace these fresh opportunities and hence, underline the requirements of a new set of design principles using AM to obtain a better quality design. Another aspect concerning the design methods of AM, and they are classified after reviewing into three main categories, involving design guidelines, customized DTM used for AM, and DFAM- design for additive manufacturing. The principles and related design method for every category was studied comprehensively to gather drawbacks and benefits. The new and better design method applied was partially improving the drawbacks by combining structure optimization and function integration to obtain better performance. The designing tools as a requisite part to support design and they are possible areas for the future research (Yang & Zhao, 2015).
5) Conclusion

There is an increasing demand for the quality materials, machine components and elements in machine tool product supply chain. There is also an increasing technological complication, hurdles and challenges for superior and innovative designing methods in the product manufacturing and development procedures. The research review suggests the integrated tool with proper application to formulate an effective model of the preliminary stages of the machine element development process. The AM- additive manufacturing process is mainly concerned with quick prototyping of elements to suit specific product manufacturing, and also applicable at the end-of-use process. AM designing procedure provides an essential prototyping, an open architecture issue, interactive modeling, while AM is completely involves smart and intelligent devices to solve complex designing procedure with 3D figures for the real-time virtual monitoring. It includes proper diagnosis, control procedures of the designing process. The latest AM process application advances with smart manufacturing techniques with necessary alterations and any improvement in the middle of manufacturing all the previous conventional designs and it can be made with a new AM approach as specified (Cho & Kim, 2005).

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