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Sustainability Issues In Energy Efficient Manufacturing Systems - A Review

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Abstract

Since birth the mankind had to struggle and compete for their very survival. By virtue of relentless efforts and innovations, the human population left other species far behind to reach to the present arena. With the manifold increase of human population and their consistence dependence on natural resources for fulfilling various needs, it has been gradually felt that there will be a likely shortage of various resources in the near run. The problem got aggravated in the recent past due to the mindless development for short term gains. It is therefore expected that the present generation should take immediate measures so as to be able to reduce the burden on the earth's natural resources. Fulfillment of our ever increasing demand for various products will only be possible by efficient and optimum use of all types of natural resources. Our Manufacturing Plants use raw natural resources and convert them to produce finished products by using various machines and manufacturing processes. As energy in some form or the other is must to carry out manufacturing operations, it is imperative to say that an in-depth analysis of the manufacturing process and the energy used for carrying out these processes are very much essential in order to achieve a development that will be truly 'sustainable'. This paper stresses the importance of energy in manufacturing processes for a global sustainable development.

1. Introduction

The exponential growth of human population had an increasing demand for various types of goods and services for their use. This was possible to be met through a rapid industrialization. The giant manufacturing industries aggressively

used various raw materials to deliver varieties of finished goods as per market demand by using energy in various forms. Increased production and consumption had resulted in augmented use of raw materials as well as energy that led to the depletion of natural resources. The aggressive manufacturing also caused an alarming level of pollution and generation of waste and emission that further degraded our environment. The Present manufacturing activities are leading towards a situation where natural resources would have depleted completely and manufacturing activities will come to halt.

Moreover apart from depletion of natural resources there are allied problems which are likely to occur in the anticipated future are:

- scarcity of natural resources
- deficiency of fossil fuels and energy
- drought of water especially drinking water
- Global warming and climate change
- Increased level of pollution with regards to soil, water and air
- dearth of land fill sites
- increase in chronic diseases etc.

Therefore, there is an urgent need to address to the development activities which are not only sustainable but efficient too. This will accomplish the necessities for the present as well as future generations.

Present work is an attempt to review the existing manufacturing systems in terms of efficiency and sustainability.

2. Manufacturing

Manufacturing is the production of merchandise for use or sale using labor and machines, tools, chemical and biological processing, or formulation. The term may refer to a range of human activity, from handicraft to high tech, but is most commonly applied to industrial production, in which raw materials are transformed into finished goods on a large scale. Such finished goods may be used for manufacturing other, more complex products, such as aircraft, household appliances or automobiles, or sold to wholesalers, who in turn sell them to retailers, who then sell them to end users – the "consumers".

Manufacturing is a term that refers to creating or producing some kind of goods using man, machine, energy and raw materials. The term ‘manufacturing’ implies that it involves transformation of raw materials into finished goods on a large scale. This engages human activity which ranges from handicraft to high technology; however it is most commonly related to industrial production.

The inputs given to manufacturing system are transformed into a variety of value-added products called the output under suitable environment. A typical manufacturing process consisting of input, process and output is explained in Figure 1.

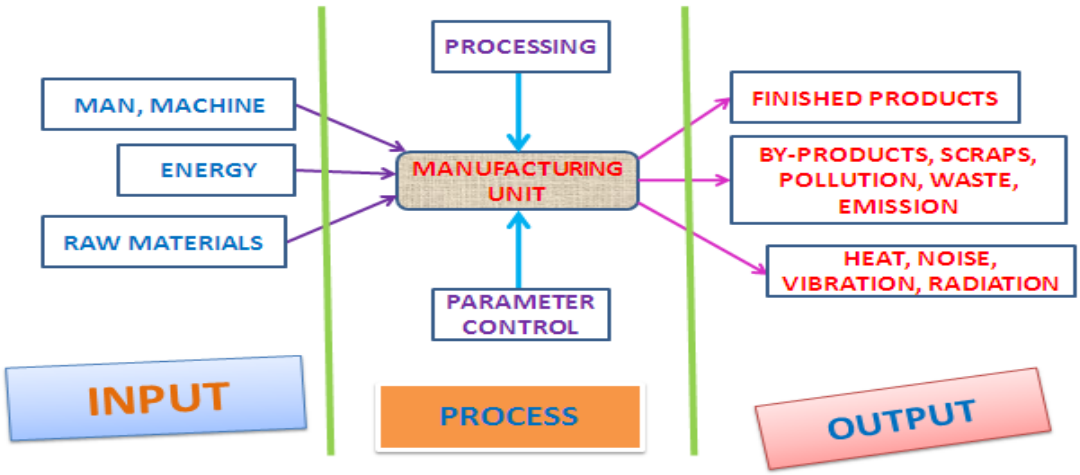

Figure 1. A Typical manufacturing process

3. Energy Efficient Manufacturing

Energy-efficient Manufacturing is the need of the present time as discussed in the previous paragraph to utilize the available resources optimally to cater the needs of the present and future generations.

The Energy-efficient Manufacturing is a broader term which engulfs production process phases as well as product development with maximum energy efficiency in production. It is achievable if and only if all of the components work together impeccably and in tandem.

An energy-efficient manufacturing environment has a faster repayment period. The existing energy saving impending must be acknowledged and optimization if any existing in the system must be precisely analyzed. The potential measures so optimized be incorporated in the existing manufacturing system and must be updated from time to time.

Such system is key to a sustained manufacturing system for a longer duration.

4. Sustainability

Stakeholders (including consumers, investors, employees, retailers, non-profit organizations, and NGOs) increasingly expect companies to implement sustainable manufacturing practices through using "processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers, and are economically sound".

Adopting sustainable strategies may seem detrimental to a manufacturer's efficiency; however, changes that improve the environmental and social impacts of manufacturing practices can reduce operating costs, improve risk management, and strengthen a company's market position (Blus, 2008).

The World Commission on Environment and Development (Report of the Brundtland Commission, 1987) defined sustainable development as *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"*.

Sustainable development comprises of ecological, *economical and social dimensions*.

As per Westkamper E., et al. (2001) there is five typical drivers for sustainability. These are:

(i) The shortage of natural resources
(ii) The dramatic increase of world population
(iii) Global warming
(iv) Pollution and
(v) An unstoppable global economy.

5. Literature Review in Manufacturing

5.1 Some Recent Trends In Manufacturing

The present day manufacturers are under pressure from the society and the government to maintain a clean, safe and healthy environment. The stricter environmental regulations do not allow them to continue the rampant activities and malpractices that they were enjoying till recent past. Some of the recent manufacturing practices that will be helpful for them to attain the goal of sustainability are:

- Development of alternative materials and better design
- Development of clean and efficient technologies
- Adoption of Macro, Micro and Nano manufacturing technologies
- Efficient use of natural resources
- Recycling for Sustainability
- Near-net shape forming technology
- Digital technology and Automation
- Research and development for developing new and innovative materials, technologies
- Energy saving and emission reduction technologies etc.

As per E. B. Brousseau, S. S. Dimov & D. T. Pham (2010) the current trend towards product miniaturization has great demand for advances in micro- and nano-manufacturing technologies and their integration in new manufacturing platforms. These platforms must enable both function integration (i.e. combination of different functions) and length-scale integration (i.e. mixing of the macro-, micro- and nano-dimensions) in existing and new products and at the same time their cost effective manufacture in a wide range of materials.

5.2 Sustainable Manufacturing

The aim of any manufacturer is to make and deliver products that have lowest possible cost and at the same time the highest possible quality. This will be possible only when the manufacturer is capable of optimizing various parameters involved in the manufacturing operation. It is quite evident from figure 1 that the finished outputs are associated with one or more kind of waste, scrap and by-products. Generation of pollution, emission, heat, noise, vibration, and radiation are also inevitable in most of the manufacturing systems. These undesirable outputs surely cause some form of environmental pollution and damage. It is therefore essential to adopt better and efficient technologies that can reduce these undesirable effects to a great extent. Development of a sustainable manufacturing system can be of great help in this regard.

The concept of sustainability can be applied in the field of manufacturing as well. The U.S. Department of Commerce (*www.trade.gov*) defined Sustainable manufacturing as the creation of manufactured products that use processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers and are economically sound.

As per Marc A. Rosen, Hossam A. Kishawy (2012) improving environmental stewardship and sustainability, while maintaining profitability and productivity, are increasingly viewed as strategic goals of manufacturing companies. They were of the opinion that the Key contributors to sustainable manufacturing are the followings:

- Sustainability indicators, policies and procedures
- Company procedures, culture and conditions for sustainability
- Sustainable design
- Supplier attitudes and support for sustainability
- Customer attitudes and support for sustainability
- Environmental controls, monitoring, remediation
- Community engagement for sustainability.

Zhuming Bi (2011) was of the opinion that the various transition phases in manufacturing were:

- Mass production
- Lean manufacturing
- Mass customization
- Re-configurable manufacturing
- Sustainable manufacturing

He also concluded that manufacturing companies are forced to change their system paradigms to accommodate the new needs of sustainability.

5.2.1 Advantages in Sustainable Manufacturing

Manufacturing processes can be broadly categorized as:

- Casting
- Forming
- Powder processes/ Powder metallurgy

- Plastics
- Ceramics
- Machining

J. Kopac (2009) in his study showed that sustainable machining provides the followings advantages:

- Enhanced environmental friendliness
- Reduced cost
- Reduced power consumption
- Reduced wastes and more effective waste management
- Enhanced operational safety
- Improved personnel health.

Sustainable manufacturing through innovative product and process design can meet the increasing demand and expectations of the consumers in terms of their quality, cost, functionality, increased lifespan, safety, aesthetic value, repair and maintenance and so on. At the same time there should not be any adverse consequences on the environment during the entire "product life cycle." It is therefore desirable that the concept of sustainability be inbuilt in all aspects of manufacturing including processes, methodologies and techniques. It can be said that implementation of sustainable manufacturing practices with the active participation of the suppliers, manufacturers, end-users (Customers) and the government will definitely give rise to a true sustainable development.

5.3 Sustainable Energy

As per Marc A. Rosen, Hossam A. Kishawy (2012) energy sustainability involves the provision of energy services in a sustainable manner which implies that energy services to be provided for the present and future generation must be affordable as well as acceptable to the society and should not be detrimental to the environment.

As per Robert K. Dixon, Richard M. Scheer and Gareth T. Williams (2011) Renewable energy (RE) technologies reduce environmental emissions including Green house gases and air, water pollution. They emphasized that by harnessing local renewable and distributed energy sources, local employment opportunities can increase and substantial investment in upstream electric transmission and distribution systems can be deferred or avoided.

Ji Han, Psyche Fontanos and Kensuke Fukushi (2012) are of the opinion that efforts must be made to develop alternative energy resources such as hydropower, solar energy, wind power, biomass energy and geothermal so as to make a soft landing to a sustainable energy system.

Rapid growth of population is demanding more and more energy for fulfilling their various needs that will continue to grow exponentially. The conventional sources of energy are also depleting very fast. Manufacturing sectors are therefore required to design and develop more energy efficient machines and equipment for a sustainable future.

6. Conclusion

To meet the ever increasing demand of the world population rapid industrialization is essential. But the rapid industrialization over the last few decades has highlighted the fact that over exploitation of natural resources has caused severe damage and degradation to our environmental. This paper has highlighted the importance of future progress and development as a result of uncontrolled manufacturing activities. The future of our planet is uncertain unless the manufacturing activities are sustainable. It is therefore desirable that the concept of sustainability be inbuilt in all aspects of manufacturing. Various steps like use of renewable energy, developing technologies that are more energy efficient and focus on the reduction and optimization of waste, emission and toxic substances while manufacturing are the need of the hour. An active participation of public, government and the industry for developing sustainable manufacturing practices will definitely lead towards a true sustainable development.

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