SUSTAINABLE MANUFACTURING SYSTEMSAND PROCESSES: A REVIEW OF ENVIRONMENTAL PERSPECTIVES

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Due to fast population growth of the world, the worldwide demand of useful products is increasing rapidly day by day. Fulfillment of such demands results in depletion of natural resources and generation of wastes at an alarming rate and improper disposal of wastes, also disturbance in our ecosystem. There are so many factors (social, economic, and environmental) found responsible for the disturbance. One of them is the conversion of raw material into the usable/ marketable form of products. Such conversion directly relates to the different manufacturing processes and systems. In the past researches, it has been found that manufacturing processes and systems presently used for production are not perfectly sustainable. As a policymaker, we should make policies/ rules to encourage sustainability in every field of life. As a manufacturer, we should try to use such sustainable manufacturing processes and systems to save the environment. As a consumer, one should prefer to use the sustainable products. In Rio summit 2012, 17 sustainable development goals are fixed. Sustainable consumption and production is one of them. In this paper, a detailed review of available literature on sustainable manufacturing systems and processes has been conducted.

Keywords: Environment, sustainable manufacturing, natural resources.

I. INTRODUCTION

Manufacturing is a very vast and challenging field since the early ages. In a manufacturing system, raw material is processed to form useful products along with byproducts and waste. Such raw materials are extracted from nature. Nature has a natural phenomenon to balance itself under normal circumstances. The problem with nature arises when the rate of extraction of raw material from the natural resources exceeds the normal rate. The high rate of consumption of natural resources (minerals, fossil fuel, forest, potable water etc.) in last few decades resulted in the unbalanced ecosystem of the earth. It means that if harnessing of the natural resources is continued at the same rate for manufacturing and other purposes then these natural resources will not be available to our future generations. Therefore, to save the nature for the future generation this is the right time to take some necessary steps to secure our natural resources. Keeping in view such facts we have to think for the term sustainability in the field of manufacturing processes also so that we will take only a little from nature for the production of useful/ marketable products/goods with minimum waste without disturbing the ecosystem of the Earth.

The prime factor behind the present environmental crisis is the high rate of increase in our population since 18th century, which triggered the demand of products necessary for survival as well for luxury also. For meeting such demands, modernization of manufacturing processes was started at a very fast rate on one side whereas on the other side the harnessing of natural resources is still at a much higher rate which causes unbalancing of the Earth's ecosystem. This unbalance ultimately results in bad effects (air pollution, water pollution, soil contamination, and global warming) on our environment. It is observed that we ourselves are destroying our environment for fulfilling the present demands. It is also observed that we always act/think after the damage/crisis has happened. Generally, there is no common practice till today to analyze the pros and cons of any act before its initiation. We always think over it only after facing the ill effects of that particular act i.e. the damage has been already done before we initiate to rethink over it. The 'use and throw' policy of manufacturing firms result in further deterioration of our environment. For keeping the customer satisfaction on top priority, the manufacturing units always put more emphasis on replacing the defective part with a new one instead of repairing it, which further results in an increase in solid waste and hence deterioration of the environment. Nowadays it has become a common practice that as a customer we insist on replacing the parts rather than repairing it. Many of us always try to purchase the products of the single-use type so that we will purchase the new product again like purchasing of a sachet of shampoo, tomato ketchup, and pen etc. for a single use only instead of the large packing for multiuse. Such use and throw packaging/products deteriorate the environment more. It will take a long time for the peoples of this world to understand that the present modernization, high living standards, and conventional as well-advanced manufacturing processes has made the life easy but simultaneously has caused a bad impact on our environment. In the Paris Agreement on Climate Change (2016) all the participating nations agreed to finalize a roadmap to restrict the global warming (greenhouse gases effect) up to 2° C by 2020. Rogelj et al. (2016) suggested that a combined effort of all is required to achieve the target of keeping the global warming well below 2° C. Different kinds of measures (sustainable manufacturing, waste management systems etc.) have been taken to curtail this problem of the eco system disturbance of our earth so that a healthy environment can be secured for the future generations.

The term 'sustainability' was coined by Brundtland Commission (1987) in the World Commission on Environment and Development report 'Our Common Future'. Kahle and Gurel-Atay (2013) have defined the term 'Sustainability' as the practice of maintaining processes of productivity indefinitely- natural or manmade – by replacing resources used with resources of equal or bigger value without degrading or endangering natural biotic systems. Before introducing sustainability in the field of

manufacturing, the top-level management of a firm always worries about the recovery of huge investment to be made in the adoption of sustainability in its manufacturing unit. In the present scenario, almost all the manufacturing firms are concerned about the customer satisfaction instead of the harmful effects of products on the environment in which we live today and our future generations will have to live. There is no effective mechanism developed in the world till date which will ensure that a product after completing its useful life will be taken back by the manufacturer itself. In simple words, there should be an effective and attractive buyback policy of the products like in industries using Lead metal. As given in the annual review (2013) on life cycle assessment of Lead metal, Lead has the highest recycling and reuse rates among all the metals. The recycling rate of Lead based batteries is above 95%. Davidson et al.(2016) has found that with the highest end-of-life and highest recycling rate of Lead and Lead based products, the impact of Lead and Lead based products on the environment significantly lowered. But still environmentalists are not satisfied with the use of Lead metal due to its high toxicity nature. Before the inception of pet bottles, all the usable/eatable liquid items (medicines, liquor, soft drinks, milk etc.) were packed in glass/metal bottles/containers, which was circulated back to the same or other manufacturer for further use through different channels, but now a days the scenario has totally changed as all these usable items are packed in plastic bottles and even in poly packaging, which are very convenient for both consumers as well as for the manufacturing firms. But disposing off such plastic bottles/products is very harmful for our environment because there is lack of effective recycling mechanism. In sustainable manufacturing system, there should be a proper mechanism for the disposal of the product after completing its useful life similar to selling mechanism of new product. The manufacturer should develop its own mechanism for the collection of products after completing its useful life using the 6 R's (recyclability, reusability, reducibility, re-manufacturability, Redesign ability and recoverability) policy so that not only the disposing off of the product will become easy and cheap but also lower the environmental hazards to a much great extent. The term 'Sustainability' is only a matter of discussion in closed loop systems where manufacturing subsystems are treated as an integral part of society and nature. According to Haapala et al.(2013) sustainable manufacturing is a philosophy which cannot be recognized independent of broader environmental and socio-economical systems. Keeping in view these environmental and socioeconomic issues at global as well as local level, manufacturers are being compelled, by the different environment concerned regulations and competition in the market, to achieve sustainability goals. The initiation of these regulation agencies brought a significant progress in manufacturing scenario during last few decades. This paper basically reviews such developments in context of sustainable manufacturing processes.

II. SUSTAINABILITY OF MANUFACTURING PROCESSES

Keeping in view the concept of sustainability in manufacturing scenario, the selection of right manufacturing process for a particular product is a major concern before the start of actual production. A number of issues arise like which process is more suitable, economical, where should be it initiated first etc. Development and growth of any geographical region is directly related to the living standards of the people residing there. The global and local development and growth are significantly influenced by the manufacturing processes used in industries set up there. Manufacturing processes generally include: metal casting, metal forming, powder metallurgy, Machining, Finishing, additive manufacturing, cloud manufacturing etc., so that the raw material can be converted into useful/ marketable form. In present situations the manufacturing processes are being considered as the key accused among the factors responsible for the deterioration of our environment in most of the literature available. Mangla et al. (2014) highlighted the importance of maintaining the pollution free environment in today's business scenario. Garg et al. (2014) observed that the societal pressure and public concern is the most critical driver out of nine possible drivers (Societal Pressure and Public Concern; Regulation and Government Policies; Top Management Involvement; Support and commitment; helpful Strategies and Activities towards Socially answerable Manufacturing and Market Trends) for the effective implementation of sustainable manufacturing using Decision Making Trail and Evaluation Laboratory (DEMATEL) Approach. In an exploratory study, on the relationship among the sustainable manufacturing practices (pollution prevention, product stewardship) and outcomes in American commercial carpet industry, Ruskino (2007) suggested to the operation managers that in the industries the competitive outcomes are directly associated with the sustainable manufacturing practices used. Green manufacturing emphasized the use of such manufacturing processes that will not harm the environment and human being. In a case study on an Indian Steel industry,Rehman et al.(2013) highlighted the path for implementing green manufacturing and measured its consequences on the performance of the company. By explaining four different examples of decision tools and methodology for sustainable product development, Kaebernick et al. (2003) insisted to think of environmental aspect at all stages of product development. In the light of social, environment and economical perspectives, Mittal & Sangwan (2014) prioritized the drivers for green manufacturing using fuzzy TOPSIS with the expectations that the government and industries should concentrate on such important drivers while initiating the green manufacturing implementations. Mittal & Sangwan (2014) also prioritized the different barriers to green manufacturing using fuzzy TOPSIS by keeping the environment, social and economic perspectives, with the expectations that the government and industries should be initiated to minimize such important barriers while implementing the green manufacturing processes. Singh et al. (2014) has identified six important factors, namely, Green Product Design, Green Design of Raw Materials, Green Processes, Green Technology, Green Packaging Materials, and Green Packaging Design, of green manufacturing practices using Analytic Hierarchy Process method in context of Indian Micro Small & Medium Enterprises (MSMEs). Theoretical and practical issues of green manufacturing practices were also discussed. On the basis of findings from a workshop in UK, Ijomah et al. (2007) explored the background of remanufacturing practices and its significance as profitable and environment friendly. It is also found that some of the key determinants of re-manufacturability (legislation, demand, fashion, and manufacturer's prohibitive practices) fall outside the remanufacturer control. Gunasekaran & Spalanzani (2012) explored the available literature of sustainable business development in manufacturing and service sector and critically examined the materials for developing a framework for sustainable development and suggested the future directions for research. Based on available literature survey, Singh et al. (2014) identified the different factors (Green raw material, Green Product design, Green Process,

Green Technology) of green manufacturing practices and also discussed the various theoretical and practical issues of green manufacturing in context of Indian MSMEs. The impact of different parameters (stochastic demands and return rates, unpredictable manufacturing and remanufacturing lead times) have been analyzed using a continuous and periodic review system on a closed loop hybrid supply chain operations by Dev et al. (2016) using simulation models of five different cases to enhance the total inventory cost performance by strategically adopting the operational units. Seow et al. (2016) proposed a new strategic approach 'Design for Energy Minimization', in which the energy consumption during design and manufacturing phase has been monitored. The usefulness and benefits of such approach have been proven by the authors considering numerous case studies. Stoffels and Vielhaber (2014) insisted that researchers should have more focus on impact of product development on environment rather than production development and should try to optimize the energy requirement for product development only. The authors have developed a new energy efficient production methodology which lowered impact of production on environment and helped the designers to develop the environmentally friendly products. The influence of various environmental management practices (strategic, operational and tactical) as adopted by manufacturing firms on their environmental technology portfolio (pollution control and pollution prevention) has been investigated by Nath and Ramanathan (2016). The authors found that for long term pollution preventions, the manufacturing firms should improve their level of environmental commitment instead of short-term cost saving pollution control activities. To choose the environment friendly material for construction of reticulated dome structure out of four alternative materials (steel, aluminum, laminated bamboo and laminated veneer lumber), Salcido et al. (2016) has found that laminated bamboo has positive impact on the environment as compared to other materials while the aluminum has the most negative environmental impact. In their study, Fusi et al. (2016) analyzed that the environmental issues related to the fresh cut salad and it was observed that processing phase (use of excessive energy and water) is the major contributor to the environmental pollution followed by agriculture (emission of greenhouse gases) and transportation phase. Adebanjo et al. (2016) has proved that there is no significant impact of external pressure and sustainable management practices on manufacturing performance. A. Y. Zhu et al. (2016) has studied the relationship among the new product development, organizational culture, and product safety on the basis of five variables namely top-level management commitment to safety, concurrent engineering, and design for safety, product safety performance, and product safety culture. The authors found that only concurrent engineering has no significant impact on product safety while the other variables directly affect the product safety measures. Keeping in view the 6R (reuse, reduce, recycle, recover, remanufacture and redesign),environmental and social factors, Bradley et al. (2016) has presented a framework for selecting the sustainable product material selection. Also provide a complete and discrete view on product design which is very helpful in assessing the product design. Golini et al. (2014) focused on the significance of the role of site competence for developing sustainability in the manufacturing network at global level. Site competence helps in adoption of ecofriendly technologies for better environmental performances of manufacturing firms. It was also found that manufacturing plants having higher site competency rate will be preferred for best sustainability practices instead of in lower rated plants.

Table 1. Sustainability factors

	FACTORS	REFERENCES
1	Environmental Effect	Adebanjo et al. (2016), Davidson et al. (2016), Gamage et al. (2016),Jindal and Sangwan (2016), Nath and Ramanathan (2016), Salcido et al. (2016), Van Kernebeek et al. (2016), Zhou et al. (2016), Stoffels and Vielhaber (2014).
2	Regional and global Impact	Arnell et al. (2016), Bernier et al. (2016), Fink et al. (2016), Frischknecht et al. (2016), Hansen et al. (2016), Kreidenweis et al. (2016), Zhang et al. (2016), Brizga et al. (2015), Lindqvist et al. (2015), Hoy et al. (2015).
3	Recoverability	Dev et al. (2016), Dwicahyani et al. (2016), Estrada and Romero (2016), Khor et al. (2016), Koskinen and Yang (2016), Kuik et al. (2016), Meng et al. (2016), Mongia and Prakash (2016), Stindt et al. (2016), Shao and Rao (2016), Xin et al. (2016).
4	Recyclability	Andreola et al. (2016), Broadbent (2016),Ma et al. (2016), Mativenga et al. (2016), Meng et al. (2016), Seow et al. (2016), Boonruksa et al. (2015)
5	Redesign ability	Arning et al. (2016), Lindskog et al. (2016), Sakao (2016), Wang et al. (2016), Zhu et al. (2014), Ahmad et al. (2013), Smith et al. (2012),
6	Reducibility	Aborot et al. (2016), Bambusi (2016), Carbone and Pautrat (2016), Dzhafarov et al. (2016), Emam and Ahmed (2016), Fang et al. (2016), Koch et al. (2016), Paturel and Grébert (2016), Sodano et al. (2016), Toledo-Antonio et al. (2016),Tolls et al. (2016).
7	Re-manufacturability	Chari et al. (2016), Fatimah and Biswas (2016), Matsumoto et al. (2016), Xiong et al. (2016), Shi et al. (2016), Rabbani et al. (2016),Denpasar (2016), Zhang and Zhang (2016), Zhenyu et al. (2015), Chen et al. (2015),
8	Reusability	Babaki et al. (2016), Baiocco and Bonnal (2016), Boyaci et al. (2016), Chari et al.(2016), Fatimah and Biswas (2016), Ismail et al. (2016), Shi et al. (2016), Mourtzis et al. (2016)

Based on the available literature (Table 1.), there are eight factors, namely Environmental Effect, regional and global impacts; Recoverability, Recyclability, Reducibility, Redesign ability, re-manufacturability, and reusability are chosen to elaborate the impact of the manufacturing processes on our environment.

III. CONCLUSION

It is lucid from the exhaustive literature study that for meeting our day to day requirements and maintaining high living standards, we ourself destroyed our nature by extracting the natural resources at an alarming rate alongwith improper waste management and by using the unsustainable manufacturing processes. Everyone should try to patch up the damage made to the environment and also expedite some means to stop environmental pollution if possible or to slow down this deterioration rate to a much greater extent. As a manufacturer one should opt the sustainable manufacturing practices besides its cost or profit aspects for developing healthy environment and sustainable manufacturing practices could be prevailed if as a customer we go for sustainable products besides thinking of its cost. This will motivate the manufacturer to produce more sustainable products. The Government Policy maker should make policies and rules favourable to sustainable manufacturing.

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