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Emerging Green Manufacturing Technologies for the Manufacturing Sector

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Abstract – The study deals with green manufacturing, which is relevant because of how necessary it is and the many ways it cuts down on waste and pollution. The paper focus on the origin and overview of green manufacturing, green manufacturing defined, importance of green manufacturing, types of green manufacturing technologies, operational technologies, green manufacturing tools, strategie green manufacturing, green manufacturing practices, green manufacturing trends, cases, experience, green manufacturing organisational culture, green manufacturing measurement, companies implementing green technologies.

Key Words – Green Manufacturing, Manufacturing, Importance, Green Technologies, Measurement.

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1. INTRODUCTION

Green Manufacturing processes include many production problems such as recycling, conservation, waste management, preservation of the environment, compliance with regulations, pollution controls and other associated difficulties. Green Manufacturing is also known by a variety of names: clean production, environmentally-friendly production, ecologically friendly production, environmentally friendly production and sustainable manufacturing. Regardless of the nomenclature, the objective is always the same: to develop and supply goods that, via their manufacture, use and disposal, minimize adverse impacts on the environment.

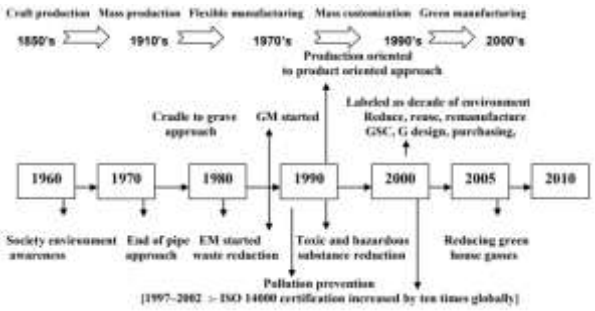

Figure 1: Evolution and overview of Green Manufacturing practices

2. ORIGIN AND OVERVIEW OF GREEN MANUFACTURING

In the late 1980s and the early 1990s, the idea of Green Manufacturing was born in Germany. According to Bylinsky (1995), an effectively worldwide manufacturing standard was introduced that any business that wanted to compete internationally must begin to produce goods that conform to the Green European market norm. In the 1980s, sustainable industrial activity began to concentrate on the decrease in waste generation. After this, the process-oriented parade Green Manufacturing for sustainable production was transformed into the product-oriented one, which is primarily concerned with reducing resources, energy and hazardous chemicals, as well as with developing and using Seliger et al (2008). Fischer et al. (1997), who supported many methods in which organizations, few of which are intended for recycling, reuse, minimizes waste, emissions and consumption of raw materials, handled these questions in a similar manner.

Lele (2009) says that flexible and mass-personalization methods have been used to suit the unique requirements of our customers without jeopardizing productivity and quality. It's now about GM. Gungor and Gupta have previously highlighted in many countries environmental protection legislation, regulations and tax consequences (1999). In reality, environmental and public pressure laws, along with economic and technical reasons, have made the sector more ecologically aware globally, and Green encouraged Shrivastava (2003).

3. GREEN MANUFACTURING DEFINED

The maximum definition of genetically modified organic matter is focused on minimizing the environmental effect by reducing toxicity, waste, pollution, raw material and energy usage

optimization through the use of end of life, cradles and loop approaches. Different definitions of Green Manufacturing are as follows for notable investigators.

Green Manufacturing satisfies today's generation's demands without jeopardizing the capacity of future generations to satisfy their own needs, says Mendler et al. (2005). GM, which minimizes waste, pollution and depletion, slows down the depletion of natural resources, and lowers the large volumes of garbage entering the settlement, according to Cortellini (2001). Further to the new packing package, distribution and EOL use in Florida et al. (2000). Similarly, Atlas and Florida (1998) said that Green Manufacturing includes efficient manufacturing procedures that include the reduction of sources, recycling and green design. Gutowski (2002) requires manufacturers to address environmental effect via resource conservation and component recycling at all stages of the manufacturing process. While Zhang et al. (1997) view Green Manufacturing technology and design approaches as making trash a lucrative product for businesses. The green manufacturing technologies conserve energy and reduce reliance on non-replaceable raw materials by means of sustainable product design and process design according to Chien and Shih (2007). green manufacturing is more than the use of Green resources according to Bylinsky (1995) and Norberg-Bohm (1999); it is built on reuse production, decommissioning, etc. Ramakrishnan (2006) notes that green manufacturing deals with the creation of goods with environmental design (DfE), their eco-efficient processes, their environmentally friendly customer experience and the use of "countrybuild" methods to EOL product handling. The emphasis on minimizing hazardous waste is on Mohanty and Deshmukh (1999) and Southworth (2008). Melnyk et al. (2002) focus on environmental waste management, with the aim of reducing the effect on the environment and also maximizing the efficiency of resource use. Hicks and Dietmar (2007) emphasizes the design improvement, renewable energy and raw materials use, modern technology and equipment procedures. The definition of green manufacturing for various individuals typically depends on discipline and training, according to Pojasek (2008). Green should be seen as a journey, not as a goal or as a static condition. It is inferred from the explanation above that green manufacturing is a method that minimizes environmental impacts via the reduction of waste, pollution and harmful substances during manufacturing. By adopting the DfE, it optimizes the use of the raw materials and energy, slows natural resources by using EOL, cradles and loops, thus increasing production and maximizing profit. It also improves.

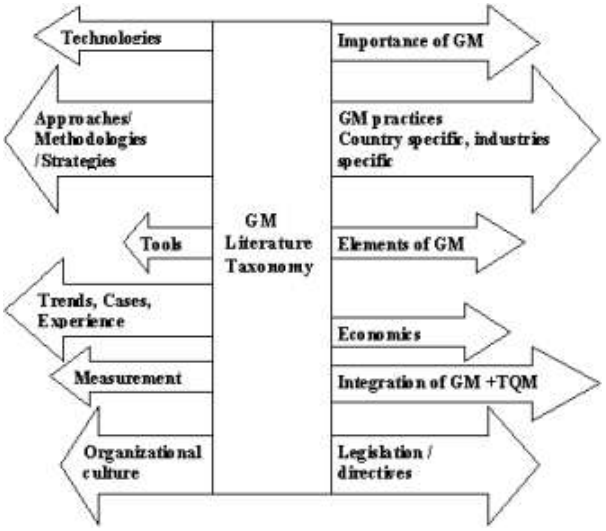

Figure 2: green manufacturing literature taxonomy

4. IMPORTANCE OF GREEN MANUFACTURING

In the lifecycle products according to Zhang et al. (1997), its environmental characteristics are essentially fixed as soon as it goes from the drawing board to the manufacturing line. The design function must thus be supported by tools and methods which allow the environmental impacts to be evaluated at every stage. Liu et al. (2005b) insist that sustainable development has, despite the continuing growth, become a major strategy for environmental management and resource use. It is thus very essential to understand the causal connection between green manufacturing and environmental performance in companies, such as Green Technology. The worldwide issue of negative environmental effect was driven by the rise of industrial activity. A preventative approach to environmental issues is essential to preserve the planet. To remove it from the very source, Rivera-Becerra and Lin are currently pursuing the demands of GM, DfE and the life cycle analysis (LCA) (1999). Forcing businesses to enhance their environmental performance urges Zhu et al. to do better than ever in terms of their environmental globalization (2007). Therefore for today's industrial situation green manufacturing is the only obvious option. Many manufacturers see environmental governance as an essential element of economic growth and the necessity for company to stay competitive. Green strategies have progressed from a control of the pipe alone to an integral consequence of Sawhney et al's process improvements (2007). Allen et al. (2002) emphasizes that an effective action program is needed. It also addresses numerous issues, including: hazardous substances, trash, pollutants, greenhouse gases, energy consumption, and the recycling of products.

Seliger et al. (2008) argue the present highly relevant problems for governments and industrial sectors globally on GM, their usage, Green treatment, and resource recovery. He now reports that the science methods also concentrated on DfE and recycling at material level. Tseng et al. (2006) think that decreasing waste and emissions at source may enhance an organization's environmental and economic performance. From the debate above, it became clear that green manufacturing is an important topic and must be studied in depth.

5. DIFFERENT TYPES OF GREEN MANUFACTURING TECHNOLOGIES

1. Energy audits - The key step for an industry to comply in terms of environmental protection is to carry out daily energy audits and monitor where significant quantities of energy are used and replace it with green technology facilities. For instance, the replacement of conventional light bulbs with compact fluorescent light bulbs (CFLs). Consumer changes are not reported at immediately, but energy use will alter in the long term. Since fossil resources are declining and the global ecological equilibrium is likewise disrupted, the only strategy of survival is to reduce energy usage. This applies to both an industry and a person. Green goods, with reduced energy consumption, would improve the reduction of carbon emissions when used in manufacture and production.

2. The requirement of an hour is shifting to traditional energy consumption provided by fossil fuels in the energy generated by sun, wind, tides and biomass. The on-site construction of an own eco-electric power source is always a superior choice to meet requirements and decrease emissions. For the generation of electricity from green technology many countries offer incentives and tax free manufacturing. If such a power source cannot be built, it may be bought from an external source that is somewhat more expensive than normal electricity. The expense of building green power sources may be large, but this would be a significant long-term success in comparison with ecological advantages and energy optimisation.

3. Application of 3 rs (reduction, recycling, and recycling) - Recycling production waste and recycling plant development would also be a means of reducing the waste disposal costs.

4. Minimize water use — Many businesses pollute water primarily in manufacturing, textiles, leder and building applications. Its effects on humans and other animals are immediately felt.

5. Select alternate methods of manufacture

6. Telecom utilization 6.

7. Instead of paper, use electronic mails

8. Shift towards hybrid cars

6. GREEN MANUFACTURING OPERATIONAL TECHNOLOGIES

green manufacturing technology assist clients reduce their environmental impact and help them make sustainable profits. These technologies encompass a range of techniques involving material waste reduction, including recycling, replacement of less dangerous alternatives, internally consumed waste, and re-production. Operational technology research includes GM, for example decreasing or eliminating the use of hazardous substances, undesirable by-products, non-value-added operations, etc. The light review shows that a greater focus is placed on minimizing environmental effect, including reduction of sources, minimization of the use of natural resources, and increased intensity of use through reduction, reuse, restoration and recycling technologies.

The focus will be reduced resources, such as energy conservation, reduced packaging techniques like green design, supply chain (GSC), investment recovery, sales and acquisitions, etc. GM's main spirit is to transmit ecologically friendly and economical technology. In-process preventive, end-of-pipe and interorganisational type technologies may include green manufacturing technology. green manufacturing technologies. This technology range from conventional to more sophisticated closing systems, incorporated into regular operations of manufacturing. Some of these technologies are problematic since they are typically adapted to a certain facility or line of production. In circumstances like remanufacturing and dismantling another element of environmental technology would arise. Due to the complexity of these reverse supply chain operations, these technologies are not readily developing.

7. GREEN MANUFACTURING TOOLS

Research on the use of different green manufacturing instruments Perception covers topics such as application of 4R, alteration and modification of product/process, separation of trash, etc. Researchers have developed different methods, including material extraction, materials processing, product production, distributed, used and EOL, to monitor materials, resource usage, emissions and the environmental effect of goods

throughout their life cycles. The Life-Cycle Inventory (LCI) is responsible for the kind and volume of resources and emissions utilized for energy and natural resources. In the case of evaluation of product plans, processes and systems, LCA techniques have also been shown to be helpful. The LCA, DfE, environmentally sensitive manufacturing and product recovery (ECMPRO) etc. are several green manufacturing instruments utilized throughout the world. There are many computer programs, software packages, Tables, etc. in practice to enable this. Volvo has created the priority system for the environment; the Netherlands has produced a Simapro software eco-indicator; and many large databases and software tools have been developed for green manufacturing in Germany by the University of Stuttgart.

Two methods, audit and LCA, are specified within ISO 14000 series but the tools and techniques outside the scope of the standards are becoming more and more extensive. Even DfE, environmental audit, other green manufacturing instruments and procedures are hardly implemented or integrated. green manufacturing tools like as remanufacturing and dismantling remain at an early stage. While there has been considerable development in the area of green manufacturing practice and research over the last several decades, numerous tools and methods are still needed to facilitate operational integration in companies. Due to high expense, unless they are forced by governmental constraints or substantial community concerns, companies cannot implement these practices. The several green manufacturing tools and their references are provided as shown below.

8. STRATEGIE GREEN MANUFACTURING

Strategic approaches show how green manufacturing methods are used and how they are accepted and implemented in the market. In general, there may be a variety of objectives, environmental awareness methods and management policies. Developing a strategy plan needs participation, collaboration and technological knowledge of all stakeholders. Benchmarking provided by trade organizations and governmental bodies may help to raise technological knowledge. Some writers have developed green manufacturing methods including replacement of raw material, reduced source and stock, product innovation, manufacture of closed loops. In order to minimize an environmentally friendly business, a sustainable strategy includes a planning. This involves efficient and effective resource use, product categorization for 4R, optimization of raw material utilization and energy savings. Through a statistical approach to GM, companies may create differentiated green manufacturing strategies. GM's strategic results include the integration of environmental thinking into product and process design, the creation of new products and selection of materials etc. Some of the strategic levels concentrate on cumulative for green business practices such as green manufacturing implementation, integration of green design, the integration of the supply chain, marketing, sales and acquisition issues in GM. Studies that use a qualitative and quantitative green manufacturing methodology are more important green manufacturing requires a system-level strategic plan that starts with a strategic plan to define goals, objectives and progress monitoring because to the complexity of regulatory, technical, economic, social, biological and other factors. green manufacturing methods/methodology/tactics things and references.

9. GREEN MANUFACTURING PRACTICES (COUNTRY SPECIFIC AND INDUSTRY SPECIFIC)

Only social, financial, ecological and technical factors push Southworth to address global problems at the same time (2008). There are different efforts in various nations in regard of green manufacturing practices and projects. Major nations have adopted green manufacturing measures as they are

- **European Union (EU):** Member States' guidelines on genetically modified products. Using the Directive as a guidance, each EU member state will establish its own policies on enforcement and implementation. The EU's emphasis on product EOL, DfE (End of Life Vehicle), hazardous removal, application of guidelines such as waste electrical and electronic equipment (WEEE), and takes laws back, according to Gutowski (2002). Gutowski says. Allen et al. (2002) and Durham (2002) think that the integration of green manufacturing across the EU industry still does not provide a perfect answer.

- **Germany:** the nation of origin of "the Green Movement," Germany placed on its industry the most stringent European requirements. Germany implements initiatives such as green levies, Fisher proponents of eco-labeling (1997). German environmental law is regarded as the world's strictest and highlights the use of the finest possible environmental technology. Klasse and Angell (1998), which supports environmental investment also has a beneficial impact on the expansion of production, are predicting and avoiding the development of future environmental issues, like Böhringer et al (2008).

- **US:** plants that apply different green manufacturing principles extremely rapidly, from energy reduction and water recycling to ISO 14001 implementation and packaging reutilization, Brown says (2009). It focuses also on existing materials and processes, according to Allen et al. (2002), multinational companies aggressionously react to EU regulations such as WEEE and ELV, along with conventional recycling.

- **Japan:** Japan's emphasis on recycling alongside ISO 14000 is stressed by Allen et al. (2002). Concentrate on the development of free lead solder and other related applications. The other emphasis is on limits on dangerous chemicals (RoH), hybrid vehicles, the whole government agency's buying guidelines. DfE correlates significantly with a culturally established attitude of waste avoidance and resource conservation. Space lack is an important motivation for Gutowski in Japan (2002).

10. ELEMENTS OF GREEN MANUFACTURING

1. Green design (design for the environment)
2. Green process planning
3. Green supply chain
4. Reverse logistics
5. Green marketing
6. Green productivity

11. GREEN MANUFACTURING TRENDS, CASES, EXPERIENCE

Client pressure costs for raw materials, market pressure, globalization and regulatory pressures push genetically, it is discovered that client emphasis is on necessity. It also shows that trends in big, medium and small sectors differ in terms of GM. The motivations and methods in each region/country are different to handle green manufacturing too. Concurrence among technology advancement organizations resulted to GM. It offers up new business possibilities, increases environmental efficiency and performance and reduces accident and liability risks. The participation of suppliers and product development will assist to raise knowledge about green manufacturing and therefore improve productivity and social welfare. During case studies on different genetically modified trends, remanufacturing is widely utilized worldwide. It is discovered. Reproduction market/yr in Germany is at Around 140 billion. While in China, the most reproduced sectors are cars, tyres, and electronics, the increasing regulatory pressure in China may be attributable to this situation. According to an Australian study, barely 1/4th of the small industries know about green manufacturing. green manufacturing awareness must still be emphasized. The different green manufacturing trends, instances, problems of experience and references are provided as follows.

12. GREEN MANUFACTURING ORGANISATIONAL CULTURE

The greening of the Organization led to the creation of the green corporate image, which improves market value and acts as a driving force among organizations. Companies that incorporate green manufacturing into their corporate culture benefit by reducing cost, changing culture, improving industrial functioning and increasing production. Researchers argue that there are a number of elements like employee empowerment, dedication and participation in the management of a strong Green culture in the company that may stimulate employee morale via growth and training. Most studies would want to engage consumers in the delivery process of products and services, feedback and integration of providers. For Green culture to be effective, stakeholder action at various levels is essential, staff performance must be assessed, organizational obstacles removed, management approach integrated. A committed team is essential for achieving and sustaining sustainable change to lead this Green Organization Culture project. Assemble a Green team that includes members from several organizational divisions responsible for the development and implementation of green manufacturing policies. The different questions and references to green manufacturing organizational culture are provided as below.

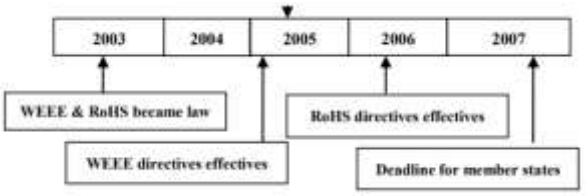

Figure 3: various directives with deadline for implementation

13. GREEN MANUFACTURING MEASUREMENT

For the evaluation of how green is produced, different measurements may be included, an analysis, a computational assessment or statistical techniques may be used. The creation and execution of green concepts and aims are part of a sustainability effort. The creation of metrics to assess performance is essential to this process. Most study focuses on different methods for assessing green manufacturing components and assessing them. Nick Johnstone et al. (2004)

analyzes 2000 EU businesses and evaluates the influence on the likelihood of an EMS by company characteristics, commercial circumstances, perceived environmental consequences, anticipated advantages and stakeholder pressure. Green design may be evaluated by assessing LCA, which evaluate input and output kinds and quantities, material/energy consumption and natural resources, the use of hazardous substances/toxicity and carbon footprint per product unit. With regard to different components of logistics planning and packaging, a green supply chain (GSC) evaluation may be performed. The environmental audit may assess green production. Green procurement may be assessed by assessing suppliers' environmental audit, internal management, etc. Environmental sensitivity, demand for the Green product may be assessed via green marketing. The compliance by business, environment regulations in export nations, ISO14000 certification etc. may be evaluated by Green laws. The expense of the life cycle may be judged on economic factors. Impact analysis is the evaluation of environmental impacts and hazards posed by waste. It analyzes a range of options and finds actions with larger and fewer environmental impacts, including the proportion of recycled/recycled/disposed trash.

14. COMPANIES IMPLEMENTING GREEN TECHNOLOGIES

1. The steel industry's top product in the world. In addition to its production, its traditional production methods also produce large greenhouse emissions. Every year throughout the globe, about 1.5 billion tons of steel are produced. 2 ton of carbon dioxide in the environment is released by each ton of steel manufacturing! This represents over 5% of global warming and pollution. A method to decrease carbon emissions has been created by experts at theMassachusettsInstitute of Technology (MIT). Professor Donald Sadoway of Material chemistry developed a novel method of manufacturing extremely pure steel with a carbon emission of about 0 percent – rather than oxygen. The method includes the usage of Iridium anode, which utilizes iron oxide in abundance to generate oxygen. In his scientific effort, he proposes this method to produce oxygen on lunar soil with NASA's support.

2. The primary aim of every manufacturing process is the completion of the production with a lower environmental impact, optimized energy consumption and minimum waste generation. Adopting green production technologies has a direct environmental effect - by generating primary secondary products. For example, for Japan's Kao business, the carbon emissions have been decreased by 1.00,000 tons between 1990 and 2008 by adopting energy conservation methods, which directly lower greenhouse gas emissions. Cogeneration - combined heat and electricity utilized in the production of electricity from primary energy sources (oil, natural gas, biomass), at 500 0C and reused as an input in boilers and steam, is one method used by these companies.

3. Production of a polysilicon manufacturing technology for the management of dangerous gas and the use of high power almost 120 KW for one kilogram of silicone in a solar photovoltaic cell composed primarily of silicon this method primarily handles a high risk to employees and the surrounding environment of trichloro-silane gas. The silicon method does not require handling of such gasses, and with just 20 kW to 30KW electricity generates the same quantity of silicone as above. The method involves the smelting of metallurgical silicone with boron and phosphorus impurity of an aluminum smelt at a temperature of approximately 10230 K.

4. One of the leading pollution sources is the construction sector, releasing 4% of the airborne particle pollutants. It helps to pollute the air, pollute water, and pollute noise. Eco-friendly structure building will not only improve the outside environment but will also assist the interior environment to become safer. Conventional building materials and structures have caused many health issues. The major health issues, including asthma, headaches, depression, dermatitis, palpitations and chronic fatigue syndrome, are caused by bio-based pollutants, such as dust mites, chemical pollutants from paint, varnishes, solvents, plastic and composite wood. They are also secondary and tertiary. Many of these issues remove green buildings made of natural and non-toxic materials. Lime has been utilized as a construction material for more than 5000 years.

15. CONCLUSION

To reach an outcome with less of an effect on the environment, industries across the globe should take the lead. Instead of just controlling pollution or recycling procedures, green technologies try to reduce the effect of every step of production, starting with the manufacturing process. The idea of "green production" is held by environmentalists and it is said that it is the responsible thing to do for businesses of all sizes. A green manufacturing approach is concerned with objectives including

minimising emissions, waste, injuries, use of non-renewable resources, total life-cycle cost, and product and service innovation. It is not feasible for an industry which is already established to make the immediate switch from conventional manufacturing methods to green manufacturing techniques because the latter requires substantial startup costs, but it is feasible for a budding industry to do so as the long-term maintenance costs of the industry are reduced and our environment is protected.

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