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A Review of Implementation of Green-Manufacturing in Die-Cutting Industry

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Abstract

This research work aims to study Green manufacturing, its earlier utilization and recent developments. This research work also focuses on experimental information about green manufacturing which has various opportunities of utilization. It has been observed that very less research is available in its fully developed form. And therefore, the study of Green manufacturing has a great essence. In this research work various die cutting and printing methods and their impact on the environment is studied. Along with this, how the green manufacturing techniques are useful to reduce the waste are elaborate. This work also includes the earlier research about various methodologies used to reduce waste from industries and techniques of green manufacturing. It also describes the results of various studies and practices in the Industries

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1. Introduction

"Green " is an adjective that is defined as "concerned with or supporting environmentalism and tending to preserve environmental quality (as by being recyclable, biodegradable, or non polluting)". [1] This definition alone is broad, but when applied to manufacturing the general idea of green manufacturing is a process or system which has a minimal, non-existent, or negative impact on the environment.

1.1 Introduction to green manufacturing:

A definition adapted from one proposed by the U.S. Department of Commerce has sustainable manufacturing as "the creation of manufacturing products that use materials and processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers and are economically sound". The term "green" can also be used as a verb which would then refer to the process of reducing the environmental impact of a manufacturing process or system when compared to a previous state.[2] Examples of greening a manufacturing system therefore include reducing the volume of hazardous waste produced, cutting down on the coolant consumed while machining, even changing the energy mix to include more renewable energy sources.

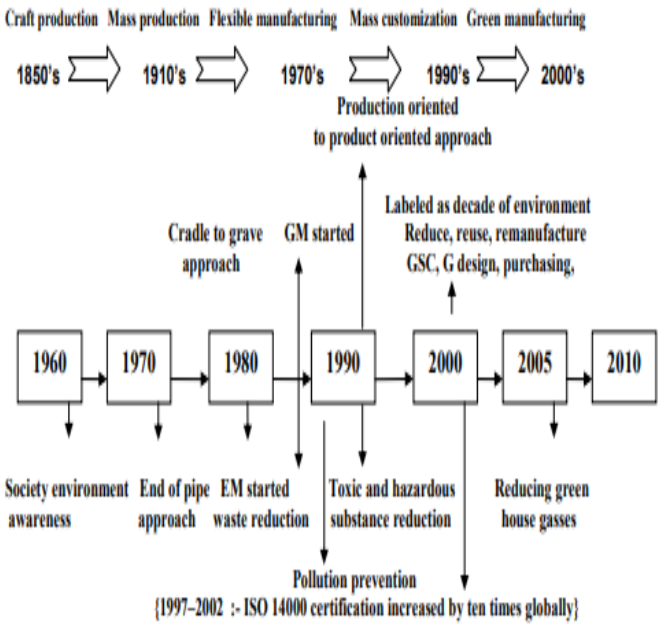

Fig.1. Evolution of GM [20]

1.1.1 Importance of GM

According to Zhang et al. [21] in product life cycle, once it moves from the drawing board into the production line, its environmental attributes are largely fixed. Therefore, it is necessary to support the design function with tools and methodologies that enable an assessment of the environmental consequences in each phase. Liu et al. [22]

Describe that Sustainable development has become the key policy by which environmental control and resource usage can be done, despite continuous development. An understanding of the causal relationship between GM and corporate environmental performance such as Green technology activities is therefore highly important. Rising industrial activities led to the global problem of adverse environmental impact. To protect the world, it is necessary to adopt a preventive approach to environmental problems. Tseng et al. [23] believes that reducing wastes and emissions at source can improve the environmental, as well as economic performance of an organization. Thus, from the above discussion it is come to know that GM is an important issue and it needs to be explored in detail.

1.1.2 GM tools

Research dealing with deployment of various GM tools perception includes themes such as application of 4Rs, product/process change and modification, waste segregation, etc. Researchers have developed various approaches to track material, resource use, emissions, and the implied environmental impacts of products throughout their life cycle including; materials extraction, materials processing, product manufacturing, distribution, use, and EOL. Life cycle inventory (LCI) accounts for the type and amount of materials, energy, and natural resources used and the emissions produced. Similarly, LCA tools have been found to be useful in assessing product designs, processes and systems. Assortments of GM tools used throughout the globe are LCA, DfE, environmentally conscious manufacturing and product recovery (ECMPRO) etc. To support this there are various computer programs, software packages, spreadsheets etc. that are in practice. Volvo has developed the environmental priority system, the Dutch developed the eco-indicator (embodied in Simapro software), and the University of Stuttgart in Germany has developed several extensive databases plus software tools for GM.

1.1.3 Green process planning

Green process planning does not defy traditional process planning, but is a supportive method to make the manufacturing process more benign. The objective of the process planning for Green design is to improve the Green attributes of the manufacturing process by optimizing process elements. A web-based Process database support system which has the function of distributed processing and storage of the data is developed by Jiang et al. [24] this process database can provide required digital information of relevant criteria and consulting data such as processing methods, machining parameters, Green material, process equipment, etc. Román and Bras (2005) proposes an approach for storing and reusing environmentally-related process information of similar component process plans via environmental process model templates. Similarly, the process planning support system for GM (GMPPSS) was developed by Yan et al. (2007) which deal with the problem of optimization of Green process planning. The GMPPSS consisted mainly of three function modules and related model repositories including: selection of process elements, optimization of process courses, and evaluation of process projects for GM.

Fig. 2. Green Computing [23]

1.2 Introduction to die cutting and printing industries:

1.2.1 History of the printing industry.

"In 1440, a German called Johannes Gutenberg invented a printing press process that, with refinements and increased mechanization, remained the principal means of printing until the late 20th century. The inventor's method of printing from movable type, including the use of metal molds and alloys, a special press, and oil-based inks, allowed for the first time the mass production of printed books" (GREAT@2007). Gutenberg gave birth in 1436 to "an art" that played and important part on the industrial revolution and today is one of the most advanced and technological developments. "He was German, his press was wooden, and the most important aspect of his invention was that it the first form of printing to use movable type" (GREAT@2007).

It is important to make clear that printing is not an invention of only one brain. It is an aggregation of multiple theories and technologies from before Gutenberg. Even today, the printing technology and industry are changing very fast, with facilities and results not expected before. Nowadays it is possible to do amazing things. One of the best results in the industry is coming from the digital image with the development of different kinds of software, making possible real-printed pictures, touched up works, effects, editions, etc.

No matter what is cut with die, there will be sections of the part that will be wasted. Be it a hole or an odd-shaped piece, that waste won't stay with the web. Scrap removal is the process of disposing of those slugs and scraps. [3] It can either be done manually or the process can be automated with a part or add-on to your rotary die machine.

Printer ink is toxic to human beings, but in most cases, you would need to directly ingest it to see the effects. However, there are chemicals in printer inks that can be harmful to the environment, as well as petroleum oil and non-biodegradable plastic casing found in some ink and toner cartridges. The negative impact of simply

throwing an old ink or toner cartridge into the garbage are plentiful. The volatile organic compounds (VOCs) and heavy metals in ink can lead to soil and even water pollution when left in landfill, while plastic can take thousands of years to degrade and even then, they will continue to pollute the soil. [5]

1.2.2 Die cutting process.

The die cutting process involves the use of metal dies3 to give paper or substrate products specific shapes or designs that cannot be accomplished by a straight cut on a web press or a guillotine cutter. By using knife-edge cutting blades formed into a pattern or die, a machine presses the die into the material to produce the desired shape. Almost any shape can be created and applied to a diverse array of raw materials. Labels, envelopes, folders, cardboards, and documents are only a few of the many printed products that can be die cut. Web presses often have a rotary die unit that is utilized for die cutting paper and label stocks. Although there are limitations on the types of dies and paper selections that can be provided, rotary die cutting serves as an effective method for longer run quantities of printed materials requiring some type of die cut area. Single sheet products require the use of a flatbed die and a flatbed cutting press to cut the shape into the paper stock. The speed of this process is slower than a web press, but it does provide die cutting capabilities to a wider variety of paper stocks and printed products" (INTERNATIONAL@2007).

Fig..3: Example of die cutting [24]

In high-volume die cutting operations, fully automatic machines are used. The material to be cut is automatically fed into the press and located in the proper position. The steel die is pressed through the material and the pressure is released. The cut piece is removed along with any scrap material, and the next piece is indexed to repeat the process. (Flexographic, 1980, 26)

There are different kinds of dies used during the die cutting process (it depends of the kind of machine) (Flexographic, 1980, 26):

• Mallet Handle die: This was the first kind of die created. They were originally fashioned by a blacksmith to the desired configuration of the product to be produced. After the cutting edges were hand-sharpened and heat treated, a handle was attached to the back of the die which could be struck with a mallet to force the die through the material to be cut.

• The clicker die: As the Mallet handle dies, the Clicker die's blade is bent or fabricated to conform to the design configuration. No external support is required to prevent the cutting knives from bending.

• The steel rule die: This is probably the most commonly used with most of the web and sheet fed equipment. Here the cutting knives are flexible and relatively thin. They must therefore be embedded in or otherwise supported by a thicker, solid material such as plywood.

• The male-female die: It is made of two distinct (upper and lower) sections. Each section is made of hardened steel blocks which must be mated with extreme accuracy in order to accomplish the scissor type cutting action inherent to this form of die cutting. It is most useful in the production of tags and labels.

• Rotary dies: Because of their curve configuration, they are more difficult and time consuming to build and therefore more expensive. They are normally used on a web press.

The die is fixed to a metal roller. The function of any die cutter is to operate the die and to control the flow of material as it enters and exits from the die area.

2. GM practices (Country specific)

Global challenges can only be met by simultaneously considering social, economic, ecological, and technological criteria urge Southworth (2008). Initiatives taken with respect to GM practices and initiatives are diverse in various countries. GM initiatives taken by major countries are as under

• European Union (EU):

directives issues to member states with regard to GM. Each EU member state will adopt its own enforcement and implementation policies using the directive as a guide. According to Gutowski [25] EU focuses on product EOL, DfE, elimination of toxic, implementation of directives like waste electrical and electronic equipment (WEEE), end of life vehicle (ELV) and takes back legislation. Allen et al. [25] and Durham [25] believe that, still there was no perfect solution for integrating GM throughout the business in EU.

• Germany:

it is the country where the 'Green movement' started, Germany has imposed the strictest European standards on its industry. Germany already imposes drives like Green taxes, eco-labelling advocates Fisher [26]. German environmental legislation is considered to be the most stringent in the world and emphasizes the use of best-available technologies for the environment. The Principle of Anticipatory Protection looks toward anticipating and preventing the development of future environmental problems advocates Klassen and Angell [28] also environmental investment positively impinges upon production growth as a productivity driver claims Böhringer et al. [29].

• USA:

Factories practicing various GM philosophies very fast from reducing energy use and recycling water to implementing ISO 14001 and reusing packaging, claims Brown [19]. According to Allen et al. [25] it also focuses on existing material and processes, international firms responding aggressively to EU directives like WEEE and ELV along with traditional recycling.

• Japan:

Allen et al. [25] states that Japan strongly emphases on recycling along with ISO 14000. Focus on developing lead free solder and other similar applications. The other focus is on restrictions of hazardous substances (RoHs), hybrid cars, and purchasing guidelines for the entire government

agency. DfE is strongly correlated to a culturally ingrained sense of avoiding waste and conserving limited resources. Lack of space is a key motivator in Japan advocates Gutowski [26].

• **China:**

They are having RoHS like law (information electronic production pollution control and management), WEEE directives (under preparation), GSCM for automotive industries are going on claims Hicks and Dietmar [29], Nowadays, most of the iron industries in China make efforts to improve their traditional manufacturing. In these years some Chinese iron enterprises have already started to practice GM and get benefit from it, claims Zhang et al. [21].

• **India:** major industries focusing on reducing energy consumption, water consumption, hazardous substances, waste, emission claims Ramakrishnan [30]. Green purchasing network is also spreading its wings in India. According to Mukherjee and Kathuria [31] efforts are taken by leading firms for Prevention of potential hazards to the environment as well as getting ISO 14001 certification. Few of the manufacturing firms had ensured to comply with the RoHS directive. Green machining based on cryogenic cooling makes use of liquid nitrogen type highly cooled gases under high pressure to cool the machining zone to minimize the frictional heat generated between tool and part being machined by providing a cushion of gas layer [16, 17]. Another important green machining technique is minimum quantity lubrication (MQL), where micro-droplets of green lubricants mainly fatty acids, synthetic esters, and vegetable oils are supplied to the machining zone and due to their uniform distribution at the tool chip interface improved machinability is obtained [16,18]. MQL has been found to be a suitable alternative to conventional hydrocarbon oil-based coolants. Moreover, MQL produces almost equal machinability to that obtained in conventional wet machining. Dry cutting is yet another green machining technique that extensively minimizes the negative effect of harmful cutting fluids (or coolant/lubricant) due to their complete elimination [19]

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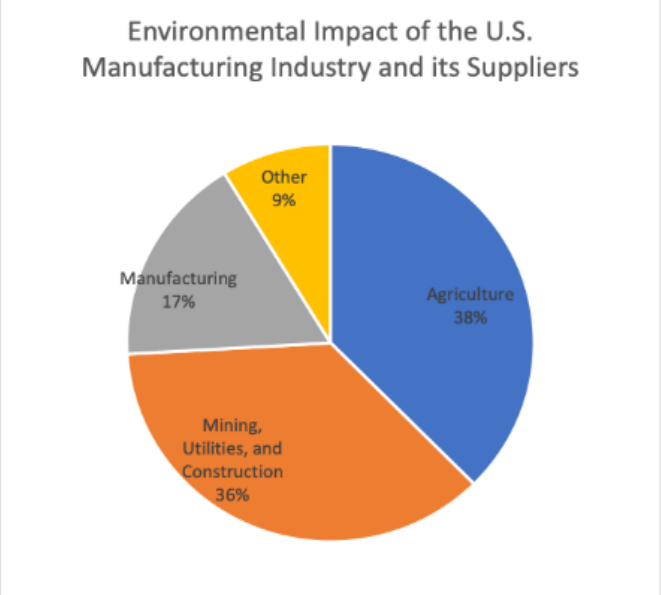

Fig. 4. Environmental impact [25]

3. Literature Review of Die cutting and Green Manufacturing

The overview of earlier research work is summaries in following table

Sr. No	Author Name	Journal/ Conference	Year of Publication	Methodology	Findings/Suggestions
1	Jeffrey B. Dahmus and Timothy G. Gutowski	ASME International Congress	2004	Machining processes, Energy used, Cutting Fluid	Cutting fluid preparation and cleaning, the focus shifts from one of energy to one of liquid and gaseous emissions.
2	M. Dänhardt	International journal	2006	Explosive Penetration" and "Explosive Separation	Problem of dust and loose fiber
3	Ugurulu M, Karaoglu	International journal	2006	Initial pH, activated carbon (AC), NaCl amount and airflow	Removal efficiency significantly depends on the applied cell voltage, airflow, time, salt amount and ph.
4	Daeyoung KONG, Sushrut PAVANASKAR	International Conference	2010	Energy consumption and CO2 emissions	Component of both machine tools that required the greatest energy to manufacture.
5	Agneta Ghose	International journal	2013	Pulp and paper industry	Reduction of climate change impact by increasing the fraction of fillers in newsprints.

6	Siddharth Kale	Procedia CIRP	2014	Positioning speed and accuracy	High-speed high-precision machine tools.
7	Srebrenkoska Vineta	International Conference	2014	Dye stuff, mordant and reducing agents like sulphides, acetic acids etc.	Large volume, strongly colored, fairly high BOD (6% of total)
8	Shivnarayan Singh	International journal	2015	The dissolved and suspended solids	pH, alkalinity, chlorides, Sulphur, and other inorganic pollutants
9	Petchporn Chawakitchareon	International journal	2017	Ink tank, Water from plate washing, Paper dust	Guideline for good waste management
10	Pelin Hayta	International journal	2019	waste ink, ink sludge and solvents	Pre-Printing, printing and post printing processes
11	Chinaza Godswill	International journal	2019	chemical additives, phthalate	Use of biodegradable plastics
12	Diego Lima Medeiros	International Conference	2019	Front and back adhesive label	Polyethylene terephthalate (PET) and glassine paper.
13	Awuchi, chinaz	International journal	2020	Chloroform , furans, COD, Electronic waste, plastic waste	Pyrolysis, Incineration, Sanitary Landfill
14	K. Gupta	International Conference	2021	Frictional heat generated between tool and part, minimum quantity lubrication, hydrocarbon based dielectric fluid	Replace types of traditional dielectrics, green vegetable oils, glycerin and biodiesel,
15	Ricardo Jara-Ruiz	International Conference	2021	Parameterization in industrial machines	Parameterized design of a die cutting machine

4.Conclusion

Some basics about die cutting and green manufacturing were explained. A comprehensive review for various green methodologies with different types of machining techniques is presented. The causes of waste generation are described, and minimization methods arising from various parameters are considered.
Depending upon the review work, certain methodologies can be chosen. Determining the various techniques for reducing waste and implementing green methodologies for further work. A GM process involves a comprehensive and holistic approach that encompasses everything a business does that impacts the environment. Thus, it assists companies in making systematic changes in areas like product design, emissions, tools, trends, energy, transportation, water and waste. Past research focuses on 'End of pipe' treatment like waste reduction, pollution prevention etc. In Present situation, manufacturers or designers are forced to adopt regional environmental directives.

Available resources should be used effectively and efficiently so as to achieve total Green productivity with overall socio-economic development that integrates continuous improvement and overall process modification. Industrial culture to be changed in the perspective of GM. Need arises to think beyond the conventional end of pipe treatment. GM should be within the reach of manufacturers. Effort should be made in such a way that GM should come at no additional cost. For this environmental benchmarking of the manufacturing process is needed. Management must establish priorities, make the required trade-offs and implement an effective management control system. Need arises to market the benefit of GM through various information bodies. More research and analysis is needed by utilizing various tools for exploring GM.

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