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Review on Recent Trends of Zero Waste Management in Mechanical Fields

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Abstract— *Resources which exist in abundant in nature are being wasted have made the researchers to focus on the reduction of waste. The word waste refers to unused products or inefficient or non- essential goods.Large amount of waste are produced every day which not treated properly. Lean Manufacturing conveys waste as any activity that consumes resources but adds no value. Wastes are classified into 1.Over production: Producing more than demand 2.Waiting: Long cycle time 3.Transport: Unnecessary movement 4.Over processing: Poor product design consumes more process which adds no value 5.Excess inventory: poor planning 6.Unnecessary movement of workers 7.Defective product.*

Zero Waste is a philosophy that encourages the redesign of resource life cycles so that all products are reused. The goal is for no trash to be sent to landfills or incinerators. Recycling and reuse can be eliminated by zero defects. Expenditures for both producers and consumers can be reduced with the help of zero waste. ZWM can be achieved with the use of Lean optimization tools and Sustainable manufacturing theories. The review discusses the current trends in forming, foundry and machining areas. Many references were made on the properties and applications have been cited in this review.

I. INTRODUCTION

Lopez, [1] concluded that manufacturing of Goods and services in today's industrial world has expanded drastically to meet up with the global demand. Crocker, [2] classified the products which are essential for day to day activities includes:household needs, electronic accessories, automobiles, eatables, etc. One has to sacrifice his resources at each and every stage even when the production of all goods and services is highly complex. These sacrificed resources are unable to recover or to reuse, hence moved towards manufacturing waste. As the result, Dumping of waste is the critical problem the globe is facing every day. Zaman, [3] concluded that big challenge for decision makers is controlling the diversity of the waste. Curran and Williams, [4]described that zero waste aims to 'eliminate' rather than 'manage' waste. Zero emissions process explained wastes from one system acts as input material for another. It minimize the wastage on the natural resources. Zero-waste can be categorized into followings sub-systems; (i) administration and manufacturing; (ii) resources; (iii) emissions; (iv) product life and; (v) toxics. Excess amount of waste are being dumped in the lands, it may cause unhygienic, and potentially disastrous to our environment. This also requires the allocation of space and incurs costs related to the consequences of the waste disposal. Ngoc and Schnitzer, [5] suggested that Suitable landfill sites are becoming more difficult to find and large cost is involved. The rate of waste generation is un-manageable to locate proper landfill sites because it is very fast.

Batayneh et al., [6] described the flow of waste as due to advancement of technology waste generation was increased and this leads to disposal of larger amount of goods which are considered as waste.

Figure 1. Hierarchy of waste

Reuse or recycle can be used to treat the waste produced. Reuse is using the obsolete goods for some other purpose. For example, use of hard disk can be used for other purpose at some other place. Material recovery and synthesis operation through thermal, chemical or mechanical means is called as re-cycling.Kerbside recycling company in Australia through waste recycling obtained a net benefit of $72million. Environmental efficiency improvements will have greater benefit due to material, energy and waste costs rise. Even after obsolete from primary application, some methodologies should be adopted for product once produced can satisfy multi-utility. Thus, manufacturing plays a prominent role in waste generation.Kumar et al., [7] considered the major barrier as conventional manufacturing processes. In order to tackle such barriers, various countries have started joint research projects. RIE2020 is the major thrust plans in Advanced Manufacturing and Engineering, planned by Singapore's Research, Innovation and Enterprise plan. Many countries have planned according to the ideas and innovations provided by the institutions.

Advanced Manufacturing Initiative program was launched by America i.e. digital manufacturing (DM), sustainable manufacturing and ZWM. DM purpose is to model, design, simulate, and analyze machines, tooling, and input materials in order to optimize the manufacturing processes and produce customized products. Usage of resources effectively and productivity improvement are the benefits of DM. Optimal utilization of materials, energy and water in the manufacturing of products, thus eliminating pollution and reducing costs is called resource efficiency. This leads to ZWM. ZWM involves designing of products and processes in which no trash is sent to landfills or incinerators.ZWM can be achieved in two ways, 1.To redesign products and materials selection suitable for reuse,2. Recover resources from the used products and to manufacture them as new products. The objective of this review is to discuss the re-cycling and reusability of the waste in foundry and machining.Overall, this review article is designed in a way to motivateengineers/scientist/researchers to adopt ZWM strategies.

I. RESEARCH TRENDS

2.1. ZWM in machining scraps and mechanical wastes

Ay and Unal, [8] recycled waste tile by mixing in the cements and investigated the pozzolanic properties, setting time, volume stability ,particle size, density, specific surface area and strength of waste tile and found that it can be used for the purpose of cost reduction because of its properties. Rapoprt et al., [9] mixed a steel fiber in the reinforced concrete and done the permeability test to conclude the steel fiber reduced permeability. Ismail and Al-Hashmi, [10] predicted that the overall strength can be increased by combining waste glass mixture with concretes when observing its strength and ASR expansion.Abbas, [11] conducted compression and workability test by recycling steel solid wastes and mixed in reinforced concrete and showed its strength increased whereas workability decreased. Shende et al., [12] investigated the mechanical properties of recycled lathe waste, soft drink, bottle caps, empty waste tins and waste steel powder by mixing it with the concrete and showed the improvement in its overall strength. Murthi et al., [13] done ultra-sonic pulse velocity testing and compressibility test in the recycled natural coarse and steel slag aggregate and fly ash materials. Alwaeli, [14] analysed mechanical properties of the scale and steel chips mixed with concretes. Taha et al., [15]experimented on ceramic products and concluded its fluctural strength increases and in firing temperature porosity and water absorption decreases.Shukla, [16]determine the mechanical properties of the CNC waste by examining the concrete mix recycled with CNC waste. The author varied the CNC waste proportions by 1% and 2% were subjected to several tests. The various test carried out for the mechanical properties like workability test, compressive strength test and bulk density. The results inferred that compressive strength was gradually increased by 50% with the addition of 2% of CNC waste with the concrete mix. Vijayakumar et al., [17] used the lathe scrap as fiber reinforced concrete and concluded that the strength of the concrete increased.Bignozzi and Sandrolini, [18] recycled the tire waste and examined the mechanical and microstructure behaviour of tire. The experiment was done with different amounts of rubberized concrete. The experiment explains that high compressive strength was obtained. Sengul, [19] investigated the mechanical properties of the scrap tiers mixed with the concrete at different percentages by conducting the carious experiments. The results obtained from the experiment are compressive strength, splitting strength and flexural strength was determined. The mechanical behaviour of concrete was affected by the steel fibers recovered from scrap tires.

II. ZWM IN SUSTAINABLE MANUFACTURING

Mahdavi and Danesh, [20] considered waste management as the challenging issue in the competitive world because the quality of the manufactured products plays a major role in the market. Manufacturing process required a strong countermeasure in the reduction of waste and energy conservation. In the last couple of years, environmentally conscious manufacturing has received increasing interest in manufacturing processes.Foster, [21] minimizes the trash and depletion of natural resources by educating on the reducing the wastage of parts and reusing the components. The manufacturing issues were covered under '6 Rs' i.e. Reduce, Reuse, Recycle, Recover, Redesign and Remanufacturing (Jawahir et al., [22] ; Jawahir et al., [23]). Europeans who initiated the "Product Take-Back" from the customers, was very useful for the American industries to recycle the components used. King and Lenox, [24] explained the positive side-effectstowards waste reduction and the cutting back of pollution by describing green as 'the good public spill over of Lean'. This concept green explains the eco-friendly design of products, raw materials, packing and reuse after end of life of product. Franchetti et al., [25] stated the difference between lean and green and their effect on the environment. Todd, [26] explained the goals of sustainable manufacturing. The goals are to reduce the waste in human effort, inventory, time to market and to meet the customer demand. Optimization tools such as

- Kaizen- continuous improvement of working practices
- One-piece flow- is an approach to discrete manufacturing that contrasts with batch production
- Cellular manufacturing- produces families of parts within a single line or cell of machines
- Synchronous manufacturing- time-based competitive strategy that reduces manufacturing lead times and inventory while accelerating the flow of materials
- Inventory management-specifying the shape and placement of stocked goods
- Pokayoke-mistake-proofing
- Standardized work- most efficient method to produce a product (or perform a service).

Russell and Taylor, [27] suggested that manufacturing waste can be reduced by the Lean manufacturing tools. George et al., [28] described quality and waste improvement can be performed with Six Sigma and Lean, which is also a well-known methodology for quality and waste improvement. Motorola Company improved the problem solving byfive phases i.e. Define-Measure-Analyze-Improve-Control usually referred to by the acronym DMAIC. Sustainable development has become an important part of approaches to integrate economic, environmental, and social aspects. The concept of sustainable production was emerged at the United Nations conference on environment and development in 1992, and was concluded that the major source for environmental degradation (Veleva and Ellenbecker, [29]). Jayal and Balaji, [30] proposed a sustainable manufacturing approach to minimize the use of energy, material and to maximize the part life. The cost savings, product quality improvement, and increasing market share was obtained with the sustainability and economic performance are the information gathered with previous studies.

3.1. Advances of ZWM in foundry

The contribution of this industry to the world over is vital and crucial. Foundry industry provides products which are highly used in agricultural, mining and manufacturing industry, as well as other industries. Serious contaminations were caused in our environment due to consumption of large amount of water, energy and produce numerous organic pollutants. Khatib and Ellis, [36] mixed foundry white fine sand without the addition of clay and coal, foundry sand before casting (blended) and after casting(spent) in the concretes and found strength of the concrete gets decreased when the quantity of foundry sand is increased. Backhouse et al., [31] made Boustead life cycle analysis by reducing the weight of the casting and analysed the fictive automobile suspension component and stated that it reduces the foundry’s environmental impacts. Vijayaram et al., [32] suggested that in order to achieve the quality and to avoid the rejection and scrap in metal, motivation has to be done for the employees.Indian Foundry Industrygenerates approximately 1.7MT waste foundry sand (WFS) per year and is the 4th largest casting producer in the world. Pal et al., [33] developed an energy efficient divided-blast cupola furnace for pollution control by investigating and conducted experiments in foundry. The cleaning process like extraction and filtering of dust may be undertaken to limit the load on the environment. Neto et al., [34] observed the environmental impact in terms of pollution and used fabric filters, wet scrubbers as a alternative agents because it has (up to 99.9%) large metal emission reduction potential also modified the process of combustion, new die casting moulds and reduced the scrap rate even the usage of electrical equipment and proved it is possible to change the mass flow rate or input through the system. Siddique et al., [35] recycled waste foundry sand and analysed the Leachate characteristics. Bauer et al., [40] used Titanium(as-received and re-cast) in Dentistry after observing the microstructure, mechanical properties like tensile and micro hardness also did fractography. Guney et al., used recycled waste foundry sand in high strength concretes and investigated about the tensile strengths, compressive strengths and elasticity modulus and noted the reduction in the properties. Sahmaran et al., mixed foundry sand and fly ash for the development of green self-consolidating concrete and stated 0-70% of Portland cement was replaced with fly ash and 0-100% sand was replaced with WFS. Siddique and Singh, [38] mixed waste foundry sand with concrete and tested compressive strength, splitting tensile strength, modulus of elasticity, freezing-thawing resistance and shrinkage which results in increase of concrete strength. Quijorna et al., [43] mixed waelz slag and waste foundry sand in the red clay bricks and analysed physico-chemical and mechanical properties and concluded extrusion properties during forming and reduction of water absorption of sintered brick due to connected porosity. Santurde et al., [44] mixed recycled green sand core and clay and bricks evaluated physically and mineralogically and stated when clay or green sand bricks is fired at 105 degree Celsius it shows better values of physical properties also mineralogy is not significantly affected. The manufacturing cost and fuel cost can be reduced by 30% and 58%, by introducing CO_2 hardened the moulds during pouring and solidification which is considered as the major pollutant. The development of technologies can improve performance and reduce or eliminate waste at the same time will greatly enhance the future success.

3.2. Advances of ZWM in machining

Machining has a big potential for environmental impact as it is the major manufacturing operation. The factors having environmental impact are tool life, usage of coolant and lubricant, waste chips and energy consumption. Thus the analysis has been made on the machining system. The analysis of machining systems and their optimizations has significant implication in sustainable manufacturing.Leão and Pashby, [45] studied the impact of EDM operation in environment. It is concluded that oxygen can be used for next generation machining applications because of the higher material removal rates.Tsuda et al., [46] performed the process of aluminium foam from machined chip waste by using the precursor manufacturing processes. By performing the experiment he studied the effect of TiH_2 content and the addition of ceramic particle were examined. The author concluded that TiH2 has 3% more mass and it was not the effective way to produce the aluminium foam. Sreejith and Ngoi, [47] suggested that dry machining is also a sustainable method to follow.Aoyama et al., [48] used the process of milling by the method of MQL and Direct oil drop supply system (DODSS). He also investigated the coolant consumption and concluded that DODSS had the possibility of reduction in total amount of oil consumption by decreasing the diameter of oil drops. Fratila, [49] investigated on the life cycle assessment of the scrap processing, the use of lubrication and the energy consumption by using the gear milling Process. The author found that NDM is the best method to reduce the consumption of the coolant and energy. Tao et al., [50] used the process in turbine cylinder using the methodology of Energy saving and Emission reduction life cycle assessment. Measurement of energy consumption is investigated and concluded that Energy consumption is reduced. Chauhan et al., [51] investigated the process time using the Lean Manufacturing Principles in the conveyor pulley. It resulted in 76.55% reduction of idle time. Gupta and Sood [52] investigated the cutting forces, tool wear and surface roughness using the dry, wet and MQL machining using the process of turing of titanium (grade 2 and Inconel 800 alloy. It was concluded that MQL machining is the most cost efficient and clean method having highest potential.

A case study has been performed on the usage of minimum quantity lubricant in CNC for turning operation. Here, some turning experiments have been performed under dry, wet and MQL conditions. The machining aspects for dry, wet and MQL machines were tabulated in the Table 1.

Table 1. A framework for evaluation on machining aspects

Machining Aspects			
Performance Measures	**Dry machining**	**Wet Machining**	**MQL Machining**
Surface Finish	Poor	Medium	High
Tool Wear	High	Medium	Low
Cutting Temperature	High	Medium	Low
Cutting Forces	High	Medium	Low

The environmental aspects were also considered for the dry, wet and MQL machining. The complete details of the setup required are presented below (as shown in Fig. 2):

- CNC Turning center
- Lathe Tool dynamometer: Dynamometer
- Tool wear measurements: Tool maker's microscope
- Surface roughness measurements: Surface roughness tester
- Cutting temperature measurement: Infrared thermometer
- Work piece material: Titanium (Grade-2) alloy
- Cutting tool: Uncoated carbide inserts
- MQL system: Mini cool system
- MQL flow rate, air flow rate and air pressure: 0.8 ml/min, 60 l/min and 5 bar
- Cutting speed, feed rate, depth of cut, approach angle: 250 mm/rev, 0.10 mm/rev, 0.5 mm and 90°.

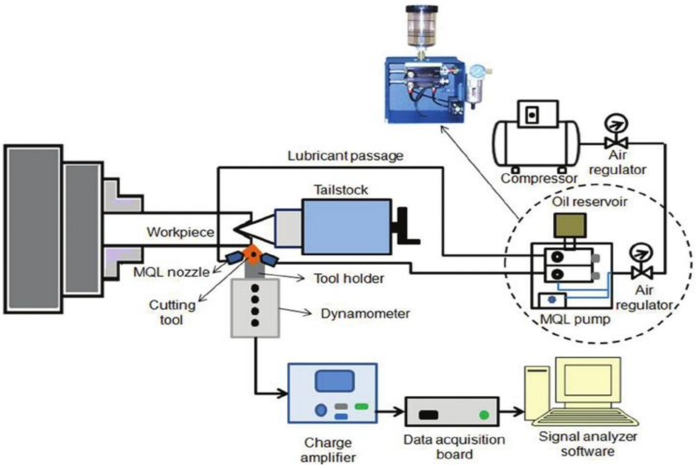

Figure 2. Schematic diagram of experimental procedure

The result obtained suggested that in terms of tool wear, cutting temperature, surface finish and cutting forces, the MQL condition is found to be a best option. Initiative for ZW machining should be taken by the machining industry in order to reduce the excess wastage of the scrap. The ZW should be encouraged to follow in the machining industry. Even the minimum quantity of lubricant can be reduced with more efforts.

III. CONCLUSION

The research review on zero waste has a wider scope in the future due to the pollution caused and the environmental impacts due to landfills. Major hazardous wastes are dumped in the land and water, polluting them affecting the livings. Manufacturing waste is produced in larger quantity and the barriers for their treatment are technologies, knowledge and resources available. Manufacturers should try to minimize the waste by using the available optimization tools and techniques. The initiative should be taken by the industry management by giving the response to a person and making him as a representative to form a team and communicate ideas. Thus waste can be reduced by communicating ideas and progress up to senior leadership and down to department employees. Additionally, companies should establish the software's and methods to minimize the use of materials, energy and resources. This usage of software may help the company to use the material which can be recycled anytime. This usage of the recycled material creates greater demand for recycled materials. The government agencies should take up actions against the over dumping of the goods and it should start up waste treatment plants to reduce the wastage. Michael Braungart said the ZW movement is a path from "cradle to grave" to "cradle to cradle". The complexity for maintaining ZW manually is very high, so advanced methods should be used for maintaining the zero waste. Till now, manual studies and ideas help in the reduction of waste. Due to the advance methods are still in the developing phase, it cannot be used. The advance techniques like digital technologies such as sensors, industrial internet of things, big data analytics, algorithms, artificial intelligence, and cloud computing can be used for reducing and maintaining the zero waste.

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