Develop the Mathematical Model to Measure Economic and Environmental Sustainability of Machining Process: A Review

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***Abstract*— This review paper gives the information of economic and environmental impact of the machining process used in industry. Also it gives the information that sustainability has no longer remained a choice in manufacturing sectors. Indicators of sustainable manufacturing considering environment friendliness, reduced power consumption, reduced cost, reduced waste, enhanced safety and personnel health factors. Sustainability issues in a conventional machining process.**

***Index Terms* — Sustainability, Economic, Environmental, Machining.**

I. INTRODUCTION

The industrialization represents prosperity of any country; however environment is at risk with this rising industrial development. Environmental degradation means depletion and contamination of natural resources of earth. Sustainable development cannot be achieved unless sustainable environment is thought of. One has to uphold equilibrium between development and overall sustainability. We must understand that the cost of environment is higher than any other objective (personal or of nation) for our better future (CPCB, 2010).

Manufacturing industry is the core and strategic industry of a country. It is a benchmark for measuring the competitive power of a nation and an important constraint in determining the country's status in international market. In recent past the performance of organization is measured by the quality of product and its profitability. There is a considerable change in the world around us over the past two decades. Technology has proved to be one of the key factors of economic and social development. The environmental consciousness developing amongst the organizations and increased awareness in the society makes green business means of making profit. Survey amongst OECD countries suggests that increasing number of countries is considering the environmental/climate change as a new opportunity for increasing competitiveness rather than barrier to their growth (OECD, 2009).

The manufacturing industries possess the potential to lead as a powerful means for the creation of sustainable society. In the recent years, manufacturing industry is exploring sustainable product development through sustainable manufacturing. This shift is a result of increased awareness among the manufacturer and the users (Averam et al., 2011). All countries are being compelled to reduce negative environmental impact of manufacturing process. The environmental concern and focus is above the interest of any individual, organization or country. For a better and safe environment we must not compromise (CPCB, 2010).

A manufacturing process converts raw materials into finished products resulting in physical and/or chemical changes. Environmental wastes and emissions are simultaneously generated by the consumption of energy, excessive materials and other resources in the manufacturing system. Mechanical Machining is most important and popular processes of manufacturing the products. As reported by many previous researchers it is the most energy consuming and waste generating manufacturing process amongst all. Turning is one of the basic and widely used machining processes for removing material from the external surface of a rotating work piece. Thus machining industries have a great potential to contribute socio economical development and upliftment of the society.

Sustainability has no longer remained a choice in manufacturing sectors. According to the United Nations world commission on environment and development, sustainable development can be defined as the ability to meet the needs of the present without compromising the ability of future generations to meet their own needs. One of the best ways to define sustainable manufacturing according to U.S. department of commerce is

"The creations 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."

The definition covers and it is now agreed in almost all literature that the sustainability should include economic aspect, Environmental aspect and social aspect.

Manufacturing organizations have always been conscious about optimum machining parameters and bring sustainability aspect in machining process. The issues in Indian Machining industry are different than the developed countries. Because of profound availability of skilled manpower, conventional machining is still being used by large. Majority of workers in such small scale industry lacks proper training and hence it is very difficult to make them understand the concepts of mathematical model and outcomes. While Most of the methods are being developed and applied for CNC machining, sustainability assessment of a conventional machining process at small scale industry is rarely focused. Thus, there is a need of developing a simple model which

will be easy to understand and can be easily incorporated in small scale industries working on conventional machining (Smith & Ball, 2012). Motivated by this problem the study addresses sustainability issues in a conventional machining process.

II. LITERATURE REVIEW:

Various methodologies have been used by researchers to understand the sustainability of a machining process. A three dimensional system approach **Yuen, F. K, (2012)** [1] highlighted sustainability issues of manufacturing from pollution prevention point of view. Three key components of process; namely technology, energy and material were considered for the study. Supported case study shows the effective use of methodology in a nano-scale manufacturing unit.

In the research by A.A. Munoz et al. [2] objective was to find waste stream generation due to cutting fluid usage which is evaporated from cutting point, deposited on chips, work piece and expended tools. Model is proposed to find waste stream due to Scrap, Lubricant and their environmental impact was found. Using AHP weighting factors were calculated. The proposed methodology gives information about the waste stream generation in real time through a model if objectives like processing time and quality is known. The energy utilization in machining depends upon part design, set up parameters. Waste stream, production & processing time is function of operating (Speed, Feed) and design parameters.

Jiang, Z., Zhang, H., & Sutherland, J. W. (2012) [3] described a new method for environmental assessment of manufacturing process for entire process plan. The weights for process plan parameters were obtained using Analytical hierarchy processing (AHP) approach. Life cycle Assessment (LCA) is widely considered for understanding the environmental impact of a manufacturing process. It is an authoritative instrument to analyze the manufacturing process.

Branker, K., Jeswiet, J., & Kim, I. Y. (2011) [4] presented new economic model based on LCA methodology. Theoretical and experimental results were used to validate the model for carbon emission and cost sensitivity. Use of LCA methodology demands the knowledge of LCA study.

Joung, C. B., Carrell, J., Sarkar, P., & Feng, S. C. (2013)[5] gives the information that many of the industries may not have recourses available for the same. Also the availability of environmental data of the country is a major concern. Large numbers of parameters namely economic, environmental and social need to be evaluated for sustainability assessment of a machining process**.**

In any analysis it is important to define the boundary of the study first **Smith, L., & Ball, P. (2012) [6]**. Multi criteria decision making approaches like Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) etc. can be applied for the assessment. The outcome of such analysis will be based on the judgment of the decision maker, which in turn, depends on his/her experience and knowledge.

Kara S. and Li W. (2011)[7] concludes that higher the MRR results less energy consumption and improved environmental performance The study proposes empirical approach to know the relationship between unit energy consumption and process variables like Work piece Material, Speed, Feed Depth of cut and cutting environment. Using DOE the experiments were designed and relation between specific cutting energy and MRR is obtained. The generic model was validated using data from turning and milling process.

According to **Pusavec F., Kramar D., Krajnik P. and Kopac J. (2010)[8]** the new technologies reduce Solid Waste, Water usage, GWP, and increased energy use for CLF production. Presented work highlights alternative machining namely Cryogenic Machining and High Pressure Jet assisted Machining, their merits and demerits over conventional machining based on Cutting and Lubrication Fluid usage is discussed. It is proposed that with use of these technologies the consumption rates, environmental burdens and health risks can be reduced. It was based on LCA of machining process. It is proposed that In conventional machining the cost of disposal of CLF, part cleaning and drying cost, chip cleaning and drying cost etc should be considered before making comparison with the alternative machining processes.

Another study by **Pusavec F., Kramar D., Krajnik P. and Kopac J. (2010) [9]** proposes cost aspect of conventional and alternative machining process in view of sustainability. Although the cost of Labor and energy consumption will be higher than conventional machining but if we consider overall impact considering energy, labor, cleaning of part & chip due to CLF usage, disposal cost etc, the alternative machining process costs are slightly higher for cryogenic machining and HPJAM. This is basically due to the higher investment in alternative machining process. With increase in cutting speed beyond 60 m/min it is observed that the new technologies are more economical.

Vijayraghavan A., Dornfeld D. (2010) [10] focuses on the direct energy monitoring of the machine tool using M-Connect which is possible for NC machines. End milling operation is selected for the purpose. A simulated energy profile is developed based on the actual data gathered from M-Connect. It signifies relationship between the energy use & operational performance of a machine tool. Architecture is developed to study characterization of process and equipment energy use during LCA. The data can be utilized in decision making to improve the environmental performance of machine tool.

Jayal A.D., Badrudeen F., Dillon Jr O.W.. and Jawahir I.S. (2010) [11] focuses on indicators of sustainable manufacturing considering environment friendliness, reduced power consumption, reduced cost, reduced waste, enhanced safety and personnel health factors. 6R approach is presented to achieve sustainability. Analytical model of turning operation is expressed for cutting fore in 3D. Challenges of sustainability at product process and system level are discussed. Alternative process like Near Dry turning and cryogenic Machining is discussed. It concludes that overall sustainability requires holistic view spanning entire supply chain including manufacturing process and systems and involving multiple product life cycle. There is a need of improved product performance models, predictive process models optimization of manufacturing process as well as entire closed loop supply chain.

According to **Ameta G., Mahesh M., Sudarsan R., Feng S. C., Sriram R. D. and Lyons K. W.,.(2009) [12]** tolerancing approach can be used in calculating Carbon Weight during part manufacturing and assembly. It employ the principle of mechanical tolerancing which states tolerances of individual parts are accumulated during assembly. The carbon Weight of entire parts is calculated using proposed model. Total carbon weight is then sum of CW of all the parts in the assembly. Data for developing the

model is taken from earlier researchers. The study focuses on redesigning the parts based on targeted reduced carbon weight thus calculated.

Lanz M., Mani M., Leong S., Lyons K., Ranta A.,. Ikkala K and Bengtsson N. (2010), [13] explores and discusses impact of energy measurement as an indicator for sustainable manufacturing. A turning and drilling operation is selected for the purpose. Using M-Connect the data related to energy consumption of a CNC tool is gathered and expressed as a function of MRR, Spindle revolution and cutting speed. The data gathered by M-Connect is not validated by independent measurement as it cannot give the value if machine is idle or not.

Shao G., Kibira D. and Lyons K. (2010) [14] provides a virtual model to measure sustainability of machining a part. The reference data related to cutting parameter, tool, work piece is taken from database. Input in the form of NC program is provided. Based on Energy consumption, Coolant lubricant oils, cutting tool usage, MRR it provides simulation statistics. By comparing various scenarios optimized machining strategy can be derived.

Experimentation on a conventional lathe were carried out by **Rajemi M.F., Mativenga P.T. and Aramcharoen A (2010) [15]** to find relationship between Energy consumption, Tool Wear and Tool life from sustainability aspect. Taylor's tool life equation is used to derive optimum toll life from minimum energy. It is observed that the flank wear increases with increase in cutting speed. It advocates that the traditional minimum cost criteria may not satisfy the minimum energy requirement criteria. The optimum cutting speed was found to fall in the range provided by other researches.

Jayal, A.D., Balaji, A.K.[16] focuses on the effects of different CF application methods on tool wear during machining of AISI 1045 steel under prevalent machining conditions were found to have an interaction with the tool/coating material system and the presence/absence of chip breaking grooves. No lubrication was observed under MQL, or any other CF, application condition, rather, forced attempts at achieving reduction in friction through the use of CFs with EP additives actually led to enhanced tool wear through chemical attack under conditions where the tool substrate was exposed, and accessible to the CF.

According to **Domnita Fratila [17]** to achieve an accurate assessment and more detailed environmental impact of machining processes the extension of the analysis to micro-level is necessary. The future work will consider those elements which contribute to the good progress of the machining process, that were not included in the macro-level analysis of the process such as: the preparation of tools, the building of machine tools, the waste, the used tools, and the cleaning substances.

According to **Vishal S.Sharma , ManuDogra, N.M.Suri [18]** some unresolved issues described Investigation of the optimization of flow rate/mixture quality (air and gas mixing) and its impact on tool wear, surface quality and air quality in the atmosphere. To achieve chip breakage and control over chip formation in HPC turning, study of variation in pressure level and flow of the jet is essential.

III. CONCLUSION

The studies cited uses cutting force as a means to calculate the energy consumption to decide the impact. Other focuses on the alternative way of machining the product. Use of alternative methods will bring huge investment in the organizations. For a small and medium scale industry it may not be feasible to change the process because of economic constraints. The studies were carried on CNC machines in controlled environment. In our country still the conventional way of machining is preferred because of availability of skilled labor. Hence there is a need to develop a model and framework which will provide information about the impact of the machining process on economic, environment and social parameters. Indian Machining industry scenario is slightly different from other developed countries. Because of profound availability of skilled manpower, conventional machining is still being used by large organizations. Majority of workers found in such small scale industry do not have proper training and hence it is very difficult to help them understand the concepts of mathematical model and outcomes. While most methods are being developed and applied for CNC machining, sustainability assessment of a conventional machining process at small scale industry is hardly given sufficient attention. Thus there is a need of developing a simple model, which could be easy to understand and could be easily incorporated for small scale industries working on conventional machining .

REFERENCES

[1] Yuen, F. K. (2014). A vision of the environmental and occupational noise pollution in Malaysia. Noise and Health, 16(73), 427.

[2] Munoz A.A., Sheng P. (1995), 'An analytical approach for determining the environmental impact of machining', Journal of Materials processing Technology, Volume 53, Issues 3-4, September 1995, Pages 736-758

[3] Jiang, Z., Zhang, H., & Sutherland, J. W. (2012). Development of an environmental performance assessment method for manufacturing process plans. The International Journal of Advanced Manufacturing Technology, 58(5-8), 783-790.

[4] Branker, K., Jeswiet, J., & Kim, I. Y. (2011). Greenhouse gases emitted in manufacturing a product—a new economic model. CIRP Annals-Manufacturing Technology, 60(1), 53-56.

[5] Joung, C. B., Carrell, J., Sarkar, P., & Feng, S. C. (2013). Categorization of indicators for sustainable manufacturing. Ecological Indicators, 24, 148-157.

[6] Smith, L., & Ball, P. (2012). Steps towards sustainable manufacturing through modelling material, energy and waste flows. International Journal of Production Economics, 140(1), 227-238.

[7] Kara S. and Li W. (2011), 'Unit process energy consumption models for material removal process', CIRP Annals-Manufacturing Technology, Volume 60, Issue 1, 2011, Pages 37-40

[8] Pusavec F., Kramar D., Krajnik P. and Kopac J. (2010), 'Transitioning to sustainable production – Part I : application on machining technologies', Journal of Cleaner production, Volume 18, Issue 2, January 2010, Pages 174-184

[9] Pusavec F., Kramar D., Krajnik P. and Kopac J. (2010): 'Transitioning to sustainable production – Part II : evaluation of machining technologies', Journal of Cleaner production, Volume 18, Issue 12, August 2010, Pages 1211-1221

[10] Vijayraghavan A., Dornfeld D. (2010), 'Automated energy monitoring of machine tools' ,CIRP Annals-Manufacturing Technology, Volume 59, Issue 1, 2010, Pages 21-24

[11] Jayal A.D., Badrudeen F., Dillon Jr O.W.. and Jawahir I.S. (2010), 'Sustainable Manufacturing: Modelling and optimization challenges at the product, process and system levels', CIRP Journal of Manufacturing Science and Technology, Volume 2, Issue 3, 2010, Pages 144-152

[12] Ameta G., Mahesh M., Sudarsan R., Feng S. C., Sriram R. D. and Lyons K. W.,.(2009)'Carbon weight analysis for machining operation and allocation for redesign', International Journal of Sustainable Engineering, Vol 2 issue 4, 241 — 251

[13] Lanz M., Mani M., Leong S., Lyons K., Ranta A.,. Ikkala K and Bengtsson N. (2010), 'Impact of energy measurement in machining operations', Proceedings of ASME 2010, IDETC/CIE 2010, August 15-18, 2010; Montreal, Quebec, Canada

[14] Shao G., Kibira D. and Lyons K. (2010), 'Virtual Machining Model for Sustainability Analysis', Proceedings of ASME 2010, IDETC/CIE 2010, August 15-18, Montrea, Quebec, Canada

[15] Rajemi M.F., Mativenga P.T. and Aramcharoen A (2010): 'Sustainable Machining: selection of optimum turning conditions based on minimum energy considerations', Journal of Cleaner Production, Volume 18, Issues 10-11, July 2010, Pages 1059-1065.

[16] Jayal, A.D., Balaji, A.K., "Effects of cutting fluid application on tool wear in machining: Interactions with tool-coatings and tool surface features", Wear, 267: 1723-1730, (2009).

[17] Fratila, D.,"Macro-level environmental comparison of near-dry machining and flood machining", Journal of Cleaner Production, 18 (10-11): 1031- 1039, (2010).

[18] Sharma, V.S., Dogra, M., Suri, N.M., "Cooling techniques for improved productivity in turning", International Journal of Machine Tools Manufacture, 49: 435–453, (2009).