

Towards sustainable development in Indian small-scale industries: A green manufacturing initiative

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ABSTRACT

This study explores the impact of green manufacturing practices—specifically green activities, investments, and product types—on the economic performance of firms. Using survey data from Indian small- and medium-sized enterprises (SMEs), the research employs self-determination theory to analyze how the number of green activities, the extent of green investments, and the product type influence economic outcomes. The results reveal that a greater number of green activities enhances economic performance, while the relationship between green investments and economic performance follows an inverted U-shaped pattern. This dynamic is further strengthened when firms offer both green and non-green products. The study advances the understanding of green manufacturing's role in business performance and provides practical guidance for managers seeking to optimize the benefits of green initiatives.

Keywords: Green Manufacturing, Plan Do Check and Act (PDCA), Environment Management System (EMS), Environmental Impact Assessment (EIA).

1. INTRODUCTION

The society's increasing focus on the "green" initiatives of companies stems from rising concerns about environmental issues that pose significant threats globally (Centobelli et al., 2020). Environmental challenges are among the most urgent and unresolved global objectives that need addressing (Cappa et al., 2022). Since it became evident that human activities significantly contribute to environmental degradation and depletion of natural resources, these issues have become a top priority for governments, organizations, and individuals (Michelino et al., 2019). In this context, the Government of India (GOI) has set various emission targets and regulations aimed at reducing the environmental impact of small-scale industries. These targets are part of broader initiatives to combat climate change and improve air quality. As per NCAP-2025 scheme, the aim set by GOI to reduce the particulate matter (PM10 and PM2.5) levels by 20-30% by 2025, compared to 2017 levels (Government of India, 2017).

Due to various factors, manufacturing companies are increasingly adopting green manufacturing practices. These practices aim to benefit the environment, enhance brand image and reputation among consumers (Fercoq et al., 2016), and appeal to customers who favor eco-friendly businesses, ultimately boosting companies' economic performance (Verrier et al., 2016). Green manufacturing involves environmental awareness in production, including the use of renewable energy sources and participation in sustainable supply chains (Dieste et al., 2019).

With the rising interest in green manufacturing, there is growing attention to how these practices impact different aspects of company performance, such as environmental, operational, and financial outcomes (Ye et al., 2023). Previous research indicates that green initiatives positively influence various aspects of economic performance (Li et al., 2021). However, while some green initiatives, such as waste reduction, hazardous material minimization, and reverse logistics, have a positive effect on financial performance, others, such as environmental collaboration with suppliers and eco-friendly purchasing practices, as well as ISO 14001 certification (which certifies effective environmental management systems), do not necessarily lead to improved economic outcomes (Gandhi et al., 2018). Additionally, detailed assessments of the impact of green manufacturing on operations in small scale industries are still limited, and research has yet to fully explore the effects of green initiatives in process and products, which are not designed to minimize environmental impact throughout their life cycle (Liu et al., 2024). This research gap is occupied by conducting the present study towards sustainable development in Indian small-scale industries via green manufacturing initiatives.

Objectives of the study

The present work is planned to achieve the following objectives:

1. To study on qualitative implementation of green manufacturing.
2. To study on quantitative environmental performance of forging furnace stack emission.

2. LITERATURE REVIEW

In this section, the literature on implementation of green manufacturing with respect to environment performance has been discussed through literature review approach. During this approach, the articles have been downloaded from various reputed database like web of science, google scholar, emerald, Elsevier, Springer etc. using keywords such as Green Manufacturing, Environment Impact Assessment. In literature, it was observed that the literature review conducted from various journals and other textbooks to know the process, adverse environmental impact, and problems during study. The green manufacturing refers to the environmental protection for sustainable development without compromising the ability of future generations(Singh, Singh, et al., 2023). An expectation of society for sustainable development, transparency and accountability evolved with legislation, pressure on the environment from pollution, inefficient use of resources, climate change, improper waste disposal, loss of biodiversity and degradation of ecosystems(Goyat et al., 2020). The successful implementation of the environment system depends on commitment from all levels of the organization with focus of top management(Singh et al., 2019). The top management can address its risks and opportunities by integrating the environment system to the business process model and strategic direction with incorporating environment governance.

The environmental assessment of aspect-impact identifies the economic, environmental and social factor of a project activity in the manufacturing and gives up the potential impact on the environment(Singh and Rathi, 2024). The Indian industries manufacture a multiple variety of products by latest manufacturing techniques(Singh, Rathi, et al., 2023). However, this neglects the role of aspect-impact during and after the production which results many environmental issues have been constituted. Installation and commissioning of plants can be safe and environmentally sustainable if environmental risks manage effectively by qualitative and quantitative methodology for aspect-impact assessment(Singh et al., 2024). The process-based model for environment management system is shown in figure 1.

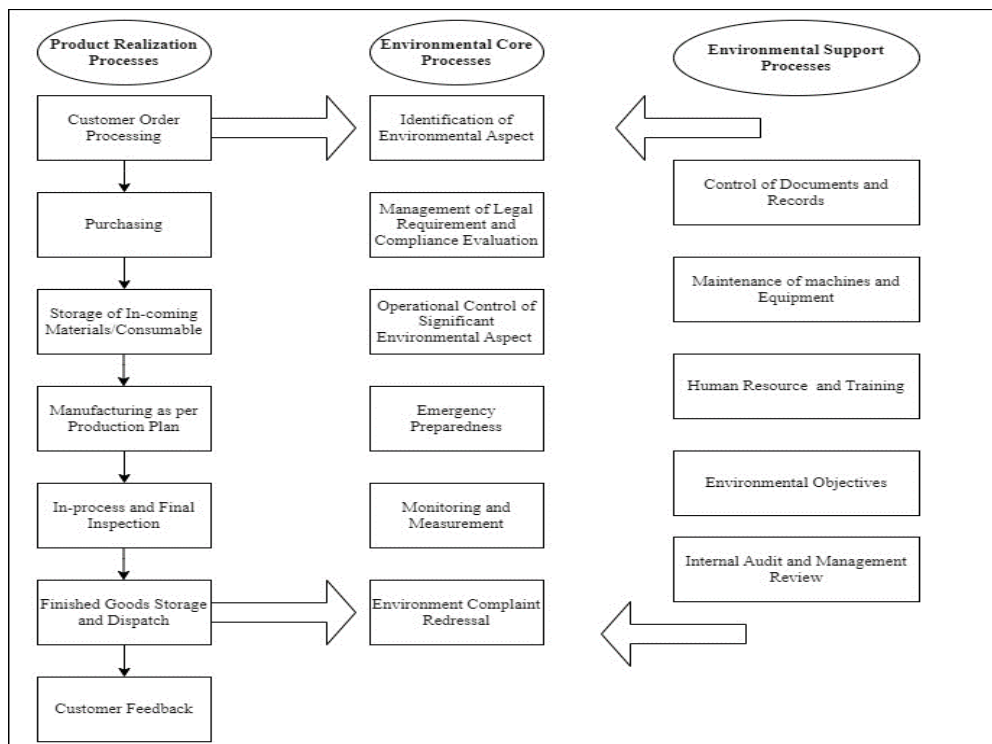


Figure 1. Model of Process-based Environment Management System(Source: Constructed by authors own)

3. RESEARCH METHODOLOGY

This study was conducted in the manufacturing unit of drop forged spanners located in North India. The spanners are manufactured by hot forging process through closed die with other manufacturing processes as illustrated in the flow diagram. The proposed work was carried out based on the methodology which is described in the figure 2. This study was carried out for an evaluation of the green manufacturing in the drop forged hammer with heating furnace wherein low-density furnace oil is being used for the required heat of raw material and environment parameters of stack emission are measured as per the norms.

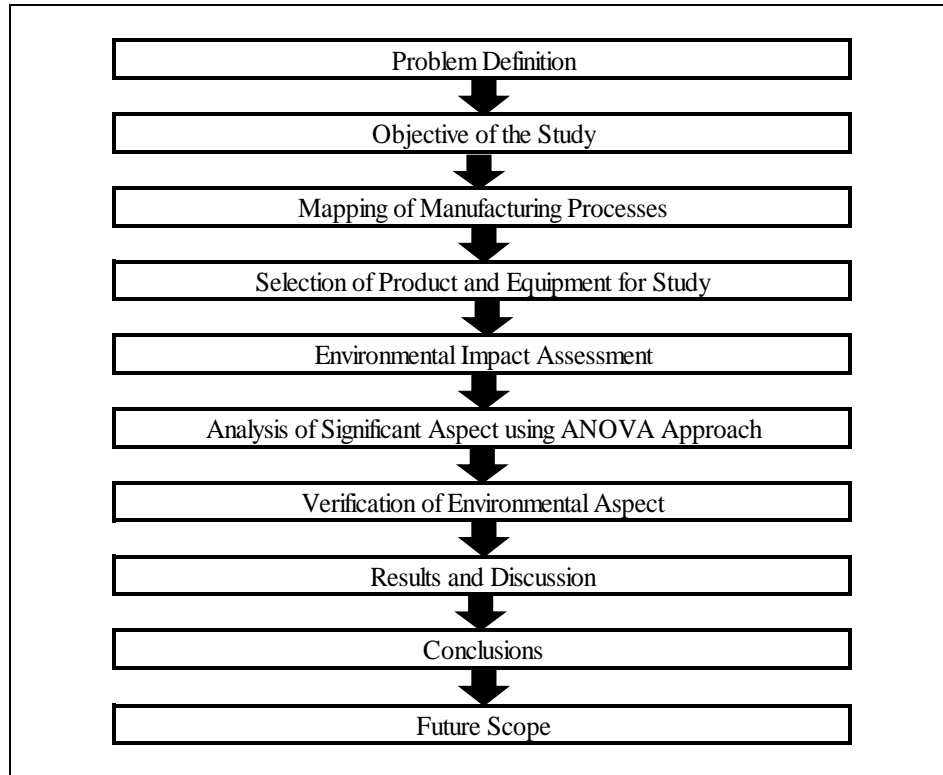


Figure 2. Research Methodology

4. Case Study

4.1 Problem statement

The purpose of this case study is to present the view of the industry for green manufacturing to maintain sustainable development. The aim of green manufacturing is to enhance the environmental performance to maintain the ecosystem for sustainability. Green manufacturing is essential for identification of significant environment aspect to reduce the adverse environmental impact. The environmental performance can also be enhanced to recycling of process materials. The aim of study to identify the problem and fulfilling the gap. Due to this there was an essential need for assessing the green manufacturing for sustainable development. The study involved for the assessment of implementation for green manufacturing in the engineering industry and environmental performance of the installed equipment.

4.2 Assessment of environmental metrics

In the Engineering Industries, small and medium scale Industries are in North India. In these types of Industries, the traditional system works and there is need for study of implementation of green manufacturing and environment performance. Out of these, one of Engineering Industry was selected for the study, which is located in Punjab. The Company is manufacturing multiple products wherein major products are drop forged Combination Spanners and Double Open-Ended Spanners. Double Open-Ended Spanners is selected for the study of green manufacturing which is produced on drop forging hammer capacity of 2 ton with furnace. The flow diagram of manufacturing is illustrated in figure3 for more understanding.

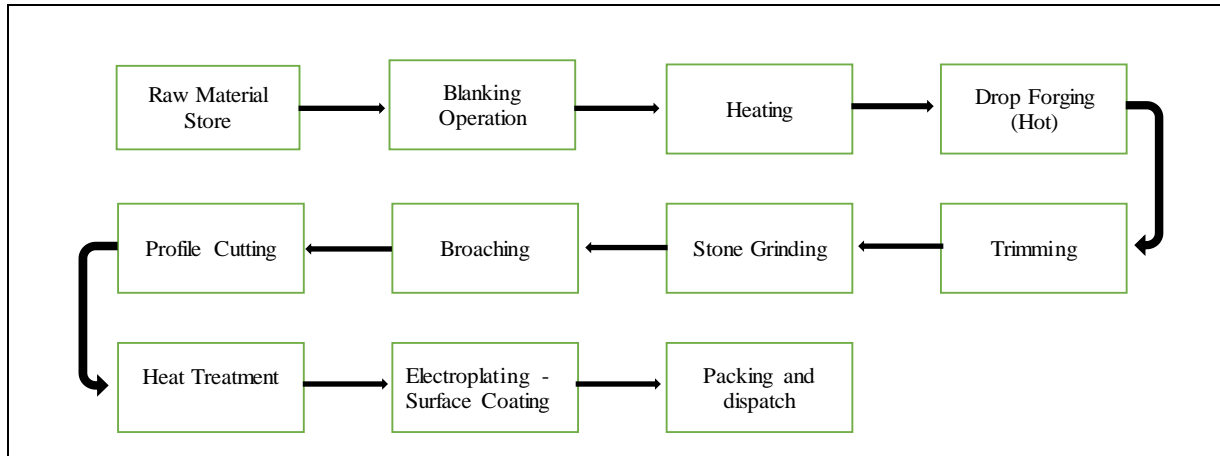


Figure 3. Manufacturing Processes

Initial environmental review was conducted by the core functional team of the company which comprises of competent managers and engineers. The primary data is collected through site round observation, records, monitoring and measurement. The external source of data is publications, journals, articles, and books.

The processes of green manufacturing are given below:

- a) Identification of environmental aspect
- b) Management of Legal and Compliance Evaluation
- c) Operational control of manufacturing and contracted services
- d) Emergency preparedness
- e) Environmental monitoring and measurement
- f) Maintenance of machines and equipment
- g) HRD and Training
- h) Management Functions - Internal audit, Management review, corrective action
- i) Control of documented information

Environmental Manual, Procedures, Documents and Formats: After conducting the literature review, the Environmental Manual, along with the Operational Control Procedures, Documents, and Formats, were examined. The manual addresses the interpretation and reference of these processes and is authorized by the organization's Director. The operational control procedures outline the steps for executing and overseeing environmental processes. The formats serve as records to provide evidence of the activities performed. The environmental management system is structured into four tiers:

Tier-1: Environment Manual: The manual provides interpretations of the standard requirements, addressing the organization's context concerning internal and external issues. It outlines the needs and expectations of interested parties, which are regularly monitored. Processes are defined, and criteria are applied to maintain operational control. Objectives are set to guide achievement, while resources, operations, and performance evaluation are thoroughly covered.

Deployment of Environment Process Matrix was prepared for the ownership of process to demonstrate the ability to do the effective operation and shown in Table 1.

Table 1. Deployment of Environment Process Matrix

Sr. No.	Process	Process Owner (Responsibility)
A) Core Processes		
	Identification of Environmental aspects	Management Representative
	Management of Legal and Compliance Evaluation	HR/Admin Manager
	Operational Control of manufacturing and contract services	Management Representative
	Emergency Preparedness	HR/Admin Manager
	Environment Monitoring and Measurement	HR/Admin Manager
B) Support Processes		
	Maintenance of machines and equipment	Maintenance Head
	Control of Documented Information	Management Representative

	HRD and Training	HR/Admin Manager
C) Management Processes		
	Corrective Action	All Functional Heads
	Internal Audits	Management Representative
	Management Reviews	Head of Plant Operation

The responsibilities and authorities of key personnel are prepared and documented. The same is communicated to all concerned and understood within the industry. The detail matrix for the same is documented and shown in Table 2.

Table 2. Responsibilities and Authorities of Key Personnel

Sr. No.	Personnel	Responsibilities and Authorities
1.	Director	Overall, in-charge of the operations related activities. Overall guiding force behind all environmental activities. Approval of Environmental Manual. Provision of resources required for the effective functioning. Review of environmental performance at defined intervals. Overall authorize to take all decisions related to all operational aspects. Approval of Environmental Objectives.
2.	HR/Admin Manager	Responsible for the identification of legal & other requirements applicable to the organization. Ensuring compliances to legal & other requirements. Implementation of On-site Emergency Plan. Authorized to obtain resources as per On-site Emergency Plan. Liasoning with the external agencies for the Environmental related aspects. Authorize to interact with the legal / Govt. officials.
3.	Head Production / Manufacturing	Responsible for production planning. Overall responsible for production activities. To provide required support and guidance to production personnel. Analysing of Environmental Non-Conformities and implement corrective actions. Review and Control of Non-Conformities. Implementation of operational control for manufacturing processes.
4.	Head Maintenance	Overall responsible for preventive, breakdown and shutdown maintenance of the plant & machinery ((including machinery associated with operations related to significant issues). Preparation of maintenance schedules and their execution.
5.	All Heads	Control of Records including their Retention. Internal Communication within department / section. Identification of training needs of the department personnel. Maintaining relevant QMS process effectiveness to achieve key performance results. Action on audit non-conformities.
6.	Management Representative	Overall Responsibility for establishing, implementing and maintaining Environment Management System Reporting to Management for review Meeting on performance and need for improvements. Document Control. Internal communication within organisation on effectiveness. Ensuring awareness within the organization. Co-ordination of the conduct of Internal Audits & Management Reviews. Compilation and review of Environment Risk Assessment.

Environmental Objectives

Company's overall objectives have been framed for continual improvement in the performance with respect to Environment aspect based on the customer requirements, significant aspects / risks, legal

requirements and other requirements to which the organization subscribes, technological options, its financial, operational requirements, business requirements and the views of interested parties.

1. To reduce the overall energy consumption.
Present Level: 3153 Units/Ton of Production (Jan-Dec 2022); Next Target: 3050 Units/Ton for Jan-Dec 2023
2. To reduce the overall water consumption.
Present Level: 2100 Litres/Day of Production (Jan-Dec 2022); Next Target: 5% reduction for Jan-Dec 2023
3. To reduce the furnace oil consumption.
Present Level: 116.42 Litres/Ton of Forging Production (May 22-March 2023); Next Target: 5% reduction for Jan-Dec 2023
4. To improve the sapling/tree plantation.

Present Level: 140 Nos (Jan-Dec 2022); Next Target: 150 Nos for Jan-Dec 2023

Tier-2: Procedures: The procedures prepared for the activity being carried out. The list of procedures is shown below in Table 3.

Table 3. List of Procedures

Sr. No.	Title
	Procedure of Internal Audit
	Procedure of Management Review
	Procedure of Monitoring of Environmental Objectives
	Procedure for Aspect-Impact Analysis
	Procedure for Management of Legal Requirements and other requirements
	Procedure for Operational Controls of manufacturing and contract services
	Procedure for Emergency Preparedness
	Procedure for Monitoring & Measurement

Tier-3: Operational Control Procedures: The operational control procedures prepared for the control of environmental activity for effective operation to have positive impact on ecosystem. The following operational control procedures are mentioned in Table 4.

Table 4. List of Operational Control Procedures

Sr. No.	Title
1	Operational Control Procedures for Compressor
2	Operational Control Procedures for Diesel Generator Set
3	Operational Control Procedures for Power Management
4	Operational Control Procedures for Electrical and Mechanical Maintenance
5	Operational Control Procedures for Hazardous Chemical Storage and Handling
6	Operational Control Procedures for Hazardous Waste Management
7	Operational Control Procedures for Battery Management
8	Operational Control Procedures for Scrap Management

4.3 Analysis

Environmental Impact Assessment: The environment impact assessment for the core and supporting activities is reviewed with a focus to find any adverse impact to the environment.

Appendix - A

Environmental Impact Assessment is given in the appendix for detail study.

As per the significance level of environment impact assessment, stack emission of forging process was selected for the study which operates with furnace oil and known as low density oil.

Criteria for Identification of Environment Aspect-Impact

A review of aspect for the manufacturing processes as per flow diagram was conducted by the Core Team which is consisting of all the Functional Heads at a frequency of once in a year wherein forging process was selected for the study to determine the significance level/issue as per the details given below:

1. Consider operations of the forging process.

2. Consider the process flow of each such operation & divide it into different activities, so that each activity can be considered separately for identifying the releases & discharges. Record activities in the 'Environmental Impact Assessment Report'.

3. While dividing operations into activities, consider:

Activities which include handling of hazardous materials, receiving activities, storage, forging processing, disposal activities.

Services which are Maintenance and cleaning.

Products are use of raw materials, consumable, packing materials, finished products and bye-products.

4. Classify activities into 'Direct' and 'Indirect':

Direct: Those which are under the direct control of the organization

Indirect: Those which are not under the organization's direct control, but over which it can be expected have an influence of the activities performed by the contractors, sub-contractors, or suppliers.

5. Identify Aspects of each activity by considering the following:

Inputs:

Use of raw materials, consumables, natural gas, Use of Water, Use of Energy.

Outputs:

Releases to Air, Discharges to Water, Solid Waste, Discharge / releases to Land, Noise, Nuisance (Smoke, Odour, Dust, Vibration, Light, Heat, Radiation), Visual Impact, Finished Products, Bye Products

6. Identify issues under all the following conditions for each activity:

Normal running conditions of the activities, Abnormal conditions which can be start-up & shut down/breakdown activities, Emergency conditions are possibility of fire hazard, leakage of hazardous gas.

7. Use following documents and reports as potential source for identifying aspects:

Permits and consents from regulatory authorities, Material Safety Data Sheets of materials, Reports of previous environmental incidents.

All identified Environmental Aspects related to products, activities and services was assigned an Impact Rating of Quantitative technique for each of the factors which are Quantity, Probability of Occurrence, Severity and Control as per the criteria defined in Table 5 below:

Table 5. Quantitative Environmental Rating Criteria

Quantity (Q)		Probability Of Occurrence (O)		Severity (S)		Control (C)	
Score	Criteria	Score	Criteria	Score	Criteria	Score	Criteria
5	Excessive	5	Continuous	5	Fatal to human life	5	Absence or not effective controls
4	High	4	Several times a day	4	Long term Human health effect	4	Mechanism in place but not reliable
3	Moderate	3	Once a day	3	Affects flora/Fauna, global issue, resource use, short term health effect etc.	3	Needs human intervention
2	Low	2	Once a week	2	Causes discomfort, Acid rain or Nuisance	2	Has in-built secondary control
1	Negligible	1	Once a month or less	1	Slight Impact or negligible visual impact	1	Available

The total Impact Rating of an Aspect is calculated as per following formula and listed in Table 6:

1. Total Impact Rating is multiplied of Quantity, Probability of Occurrence, Severity and Control.
2. All aspects having Total Impact Rating equal to or more than '81' are considered 'Significant Aspects' based on the criteria of all factors of more than 50 percent or severity is rated as 5 which can be fatal to human life wherein operational control for the significant aspects was taken.
3. All aspects covered under legislation are considered as 'Significant Aspects' and compliance to legal was ensured for control of the significant aspects.
4. All emergencies' situations considered as 'Significant Aspects' and control ensured through 'On-Site Emergency Plan'

Table 6. Environmental Impact Assessment

ENVIRONMENTAL IMPACT ASSESSMENT																Review Date : 11.12.2022			
Sr No.	Activity	Environmental Aspect	Environmental Impact	Control			Condition			Qualitative			Quantitative				Score	Remarks	Control Method
				Direct	Indirect		Normal	Abnormal	Emergency	LC	IPC	BC	A	B	C	D			
1	Forging	Process Gas Emission	Air Pollution	Y		Y				Y	Y		3	5	3	3	135	S	Process Stack Monitoring
		Use of Lubricants	Resource Depletion	Y		Y					Y		2	2	1	2	8	NS	
		Spillage & leakage of lubricant oil	Land contamination	Y			Y			Y	Y		2	2	2	2	16	NS	
		Generation of Noise	Noise pollution		Y	Y				Y	Y		3	3	3	3	81	S	Monitoring Plan & Use of PPE
		Use of Electrical Power	Resource depletion	Y		Y				Y	Y		3	3	3	2	54	S	Plan for control of Electricity consumption
		Use of Furnace Oil (LDO)	Resource depletion	Y		Y				Y			3	2	2	2	24	NS	Monitoring of LDO consumption
		Leakage & Spillage of LDO	Land Depletion	Y			Y	Y			Y		3	3	2	2	36	S	Storage license, Emergency plan, Secondary containment.
		Scaling waste	Land pollution	Y		Y				Y			2	2	2	2	16	NS	
		Cooling Water	Resource depletion	Y		Y				Y			2	2	2	1	8	NS	Recycling through cooling tower
		Raw material (Steel)	Resource Depletion	Y		Y					Y		3	2	2	2	24	NS	
		Waste oily Clothes	Land pollution	Y		Y				Y			2	1	2	2	8	NS	
2	Blanking	Use of Lubricants	Resource Depletion	Y		Y					Y		2	2	1	2	8	NS	
		Spillage & leakage of lubricant oil	Land pollution	Y			Y			Y	Y		2	2	2	2	16	NS	
		Use of Electrical Power	Resource depletion	Y		Y					Y		2	2	2	2	16	NS	
		End wastage	Resource Depletion	Y		Y				Y	Y		2	2	2	2	16	NS	

LC-Legal Concern, IPC-Interested Party A-Quantity, B-Severity, C-Probability of Occurrence, D-Control

Appendix - B

ANOVA calculation is given in this appendix and listed in Table 7.

Now ANOVA study is applied to know the effect of stack emission of forging furnace as below:

Step 1 - The hypothesis is formulated to test the significance of forging stack emission between different period which is selected the last two cycle of November 2021 and October 2022.

Step 2 - Introducing null hypothesis and alternate hypothesis.

Step 3 - Collection of data for study of two cycles of period.

Step 4 - Calculation the relationship between different sum of squares which is formulated as Total sum of squares (SS total) = Sum of squares of treatments (SS treatments) + Sum of squares of errors (SS error).

Step 5 - Calculation of F Test based on source of variation, degree of freedom, sum of square, mean sum of square for result of significance level.

Step 6 - Inference of the ANOVA approach which shows the null hypothesis accepted and there is no significant difference in terms of forging stack emission between different cycle of period.

Hence, the null hypothesis (H0) should be accepted.

Table 7. Analysis of Forging Furnace Process Stack Emission

Test Parameters ↓ Period →	Unit	November 2021	October 2022
Particulate Matter	mg/Nm ³	71	134
Sulphur Dioxide (SO ₂)	mg/Nm ³	203	269
Oxides of Nitrogen (NO _X)	mg/Nm ³	188	211
Carbon Monoxide (CO)	mg/Nm ³	149	151
Carbon Dioxide (CO ₂)	percentage	56	7.8

Inference

This mean that there is no significant difference in terms of forging process stack emission of different parameters between different monitoring period.

Hence, Environmental parameters does not give any adverse impact to the environment as per the permissible limit of norms set by regulators. It is advised to the management of the company that natural gas can be used for heating of workpiece before the drop forging for which the output of the smoke will be environmentally friendly for release to atmospheric air.

To decrease the lower limit of environment parameters for enhancement of environmental performance, an autonomous maintenance plan and schedule is suggested which will be carried out by machine production operator on daily basis. The maintenance check list points are described below:

1. Clean burner as per the defined frequency
2. Lubricate the forging hammer
3. Check heating furnace for any abnormal function
4. Check draft fan is working properly for pre-heat of workpiece to save energy.
5. Check any leakage of furnace oil (LDO), if detect immediate inform to maintenance department.
6. Check consumption of furnace oil and ensure optimum efficiency of the same.
7. Enhance operator working skill based on the latest technology of the day.
8. Identify unsafe condition of the machine and equipment before failure based on working exposure.

It is also suggested that after implementation of these autonomous maintenance plan for atleast one year, the environmental parameters will be reviewed and compared with the previous data to validate the parameters.

The analysis of ambient air quality monitoring was conducted at the location near main gate of the organization to check the environmental parameters meet the standard requirements as set by the Regulatory Body of Central Pollution Control Board of India. The testing of parameters was carried out from the third-party testing agency in the name of Eco Paryavaran Laboratories and Consultants Private Limited which is accredited by National Accreditation Board for Testing and Calibration Laboratories with reference certificate of TC-7477 for authentication of testing. The comparison of last two-year environmental parameters is given in table 8.

Table 8. Analysis of Ambient Air Quality Monitoring

Test Parameters ↓ Period →	Unit	Standard Specifications	November 2021	October 2022
Particulate Matter as PM10	µg/m ³	100	92	91
Particulate Matter as PM2.5	µg/m ³	60	53	51
Sulphur Dioxide (SO ₂)	µg/m ³	80	13	16
Nitrogen Dioxide (NO ₂)	µg/m ³	80	28	32
Carbon Monoxide (CO)	mg/m ³	04	0.71	0.78

Inference: From the table 8 we can find out that the environmental parameters are within the standard limit and does not give any adverse impact to the environment which indicates of green manufacturing in the industry.

Internal Audit

Internal audit is a process of an evaluation of the objectives and effectiveness of environmental processes. The Internal Audit of Environment Management System was carried out as per the programme. The analysis of non-conformity identified in the internal audit of environmental management system is prepared and referred in Table 9 for study of significance level.

Table 9. Summary and Analysis of Internal Audit

Processes ↓ Period →	December 2022	June 2023
Store - Consumable and Waste	2	2
Production - Heat Treatment	0	0
Production - Electroplating	1	0
Production - Forgings	0	0
Environmental Management System - Management Functions	0	0

Legal Compliance	0	1
Total Non-conformity	3	3

It is evident from the analysis of table 9 for non-conformities where the Storage process is the weak area where in corrective action was taken to close out the detected non-conformity.

Non-conformity Corrective Action for June 2023

Store Process -No 01 - Description:Oils and chemical record was not maintained as per procedure, also chemicals name was not displayed in local language on the container.

Root Cause Analysis:

Why 1: Chemicals stock not maintained with name of chemical, receipt detail, issue detail, quantity balance in stock.

Why 2: Standard format provided for chemical record do not have this information.

Why 3: Old controlled format not updated with required information.

Why 4: Lack of awareness for required record & identification.

Correction - Chemicals/oils record maintained with required information. Chemicals/oils name displayed in local language

Corrective Action - Training provided to the concerned persons for the requirement of stock maintenance of chemicals/oils with required information. To check other areas for the same aspect.

Store Process -No 02 - Description:Different type of waste found mixed in the waste storage area near barrel section which are empty oil drums, chemical canes, solid scrap found mixed in the same area

Root Cause Analysis:

Why 1: Area is defined for solid iron scrap but some other type of waste was not there.

Why 2: Concerned persons are not aware of different types of waste area.

Why 3: Different types of waste areas are not identified for the type of scrap to be hold in the area.

Why 4: Lack of training to the concerned persons.

Correction - Different type of waste segregated and stored in the specified waste storage area.

Corrective Action - Different types of waste/scrap areas identified with the name of waste/scrap to be stored in the area. Training to all the concerned persons including new appointed for the handling & storage of waste. To check other areas for the same aspect.

4.4 Implementation via management review meeting

The purpose and mechanism of management review meeting is to discuss the agenda points as per defined internal system and align to external National/International standards to address the action plan and to monitor the effectiveness of the implemented environmental management system. The organization is conducting the review meeting at the defined frequency of once in six months. The last management review was conducted on 20th June 2023 and chaired by the Director. All the functional heads were present in the meeting. The agenda points discussed in the review meeting. The review includes

a) the status of previous actions from reviews;

b) changes in internal and external issues, needs and expectations of interested parties, compliance obligations, significant aspects of environment and risks and opportunities;

c) status of environmental objectives, status of environmental performance and monitoring trends in non-conformities and corrective actions, monitoring and measurements results, evaluation of legal compliance and results of audit.

d) resource requirements, environmental complaints and continual improvement.

After discussion of the agenda inputs; the outputs of review include actions on environmental objectives if not achieved, conclusions of environment management system and managerial imprecations.

5. RESULTS AND DISCUSSION

This section indicates the results of the qualitative and quantitative findings of the research work. The study exhibits that the significance level of environment aspect of forging furnace stack emission which was identified and selected for the study. The environmental performance for the parameters of the furnace stack emission was measured and compared with the last two cycle of 2021 and 2022 as per the standard specifications of the regulatory body. There was no significance difference in terms different cycle between the parameters. To further enhance the parameters to the lower limit for positive impact on the environment the autonomous maintenance check list is advised which will be carried out the machine operator on daily basis. On the other hand, the measurement of parameters for ambient air quality was carried out for the last two cycles wherein the results were found within the specifications limits which is the indication of green manufacturing in the company. The necessary documentation to

maintain the environmental performance was defined and assessed which includes environmental manual, operational control procedures, environmental objectives, internal audit and management review meeting. The non-conformities identified in the internal audit were corrected with correction and corrective actions. The effectiveness of the environmental system was ensured in the management review meeting.

6. Managerial Implication

In this research work, a case of engineering industry was studied for green manufacturing in the forging furnace stack emission and implementation of the environment management system. Presently, the company manufactures forged combination spanners of hand tool. The industry is advised to deploy horizontal implementation of environmental management system in the manufacturing processes. The major barrier identified for adverse impact to the environment is lack of awareness of the shop floor employees. Thus, it is imperative to identify the training needs and provide the training on appropriate subject to enhance the skill level for effective implementation. To minimize the adverse impact to the environment, the environment parameters can be measured within the specified and lower limit. Subsequently, the measurement of the environmental parameters, the management of the industry advised to implement the autonomous maintenance plan which will be carried out the machine operator on daily for effective machine and equipment efficiency so that no adverse impact to the environment can release. Secondly for implementation of environment management system, an internal audit is advised at the defined frequency to evaluate the status of environmental objectives and environmental performance. The findings of the audit can be discussed in the management review meeting for sustainable development of green manufacturing.

7. CONCLUSION

The objective of this research work was to study the qualitative implementation of the green manufacturing with respect to quantitative environmental performance of the forging furnace stack emission. The environmental parameters of furnace stack emission were within the specified limit and ANOVA approach was applied for the significance level. The study identified that there was no difference between different cycle of study. To further enhance the environment performance of the furnace stack emission, the autonomous maintenance check list is advised to implement. For the qualitative study of implementation of green manufacturing, the status of environmental objectives was assessed with target and the same was within the limit. The internal audit was carried out to evaluate the effectiveness of implemented system. The identified non-conformities were corrected with root cause analysis and corrective action. Hence the same system is advised to continue for environmental enhancement of the green manufacturing.

The present study was carried out in an engineering industry located in Punjab. The other type of industry can also be selected for research work which can be from Auto, Bicycle, Plastic and Textile Sector.

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