Potential for Improving Performance through Design for Environment (DFE) in a Ferrous Foundry

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Abstract - The study dwelled on how to develop an implementation procedure for design for environment (DFE) management program. A ferrous foundry manufacturing organization was the subject of comprehensive assessment and recommendations in this research. The main thrust of this work was to develop theory on how DFE could be comprehensively and consistently managed in daily business situation of product development. The use of DFE for foundry industry would go a long way in preserving the environment and improving plant performance.

Keywords - DFE, environmental, green, foundry, competitiveness, performance, ferrous

I. INTRODUCTION

The introduction of market-based instruments of control, such as environmental producer responsibility and environmental labeling, and the growing importance of green consumerism have strengthened the incentive for Design for Environment (DFE) as a business strategy at the corporate level. The reasons behind this growth are probably that DFE gives companies an opportunity not only to decrease business risks due to evolving legislation and to increase product competitiveness but also to cut costs and find new products and market segments [1, 2].

In Zimbabwe, many organizations do not include environmental issues in their product development activities in the environmental management system. This study seeks to study how Design for Environment (DFE) could be integrated into ISO 14001. As a result, DEF would be conducted in the ISO 14001 cycle of plan-do-check-act (PDCA) with environmental objectives and DFE tools integrated into the traditional process of product development [5, 8].

II. LITERATURE REVIEW

A. Definition

Design for Environment (DFE) is the systematic consideration during design of issues associated with environmental safety and health over the entire product life cycle [3]. DFE can be thought of as the migration of traditional pollution prevention concepts upstream into the development phase of product before production and use. DFE is applied to the design of new and modification of existing products, processes and facilities.

B. DFE and product life cycle (PLC)

As global markets are undergoing continuous and rapid change, every company’s ability to innovate and be flexible will be critical to its profitability [7, 8]. DFE strategy can stimulate product innovation in areas of choice of material, production techniques, finishing technologies and packaging methods. Also partnerships with suppliers/distributors/recyclers can open up new market areas and improve product quality. While most companies do not control the whole product life cycle, their design decisions do have an impact on upstream and downstream processes, from selection of materials to product service and end-of-life options.

C. DFE and (EMS) [3]

EMS such as 14001 is an organizational approach to facilitate environmental evaluation and management. The core requirement of EMS is that a firm should have a reasonable amount of information on environmental effects of its products and processes, and seeks continuous improvement. Pollution prevention is typical part of EMS concept.

Motivation for DFE program arises from need to reduce Non Product Output (NPO). The cost of NPO includes cost of material, warehousing, manufacturing as well as internal collection, treatment and external disposal or recycling. Hence, DFE seeks to minimize NPO or create valuable by-products from them. Typically for iron processing the NPO adds up to 15 to 15% of total output by weight [3, 8].

The other tools mainly used in DFE are Life Cycle Analysis (LCA) and Environmental Conscious Program (ECP). These tools seek to design for cleaner production, recycling and safe waste disposal.

It is important to note that high level of
environmental performance can only be improved by regular reviews of related scientific information and existing environmental legislation.

III. METHODOLOGY
The study was done at the case study foundry to assess the environmental aspects of product throughout its life cycle. Effort was also made to identify the environmental priorities to be delay with by the DFE process implementation. MET – matrix was used to evaluate the priority areas [6]. Any other process inspections and interviews with operators were complementary to data collection to get more insights about the operations. Utility bills and purchases records provided the data required on resource consumptions for the various foundry sections.

IV. CASE STUDY
Foundry Company is a ferrous foundry establishment which manufactures iron castings. It is ISO 9002 certified. It has two cupolas with capacity of 750kg. A general manger heads the foundry with supervisor below him and then operators. It is mainly a green sand-molding foundry with some core made from CO2 sand. The key sections of the foundry are the pattern shop, molding area, green sand reclamation, fettling section, cupolas, machine shop and the quality inspection.

A. Pattern shop
The pattern shop receives orders from customers with some bringing their own patterns with description of product they require and the dimensions. Some bring drawings from which patterns can be made.

The patterns are made from wood, aluminium, resin and grey cast iron. Also in this section bond fillers, vanish and hardeners are used. This mainly carpentry operation produces dust from wood shavings and sawdust, the dust is also from the adjacent sand blasting. Hence there is need to use protective clothing like respirators and goggles by the operators in this section of the operations.

B. Molding area
The major raw material used in this area is green sand for molding with other raw material being silk blacking (refractory material), bentonite, starch, water and coal dust. There are seven molding machines which during operation produce lots of noise. The use of green sand has been emphasized since it can be reclaimed against carbon dioxide sand process, which uses sodium silicate, and silica sand cannot be reclaimed on the background that silica sand is very expensive.

C. Green sand reclamation
The process of reclaiming the sand has its environmental impacts where the dust created goes into the atmosphere because the dust extraction plant is not functioning. There are also leakages from the pipes that transport the sand to be reclaimed. The dust has an adverse effect on people in the molding area. The sand is then mixed with new sand to improve on the quality. The sand is tested for quality before being used in the molding process.

D. Fettling section
This is where the cast is removed from the molds and the gating system is machined off. The area has noise from the grinders and the workers are recommended to put earmuffs.

E. Cupolas
The raw material fed into the cupola are large coke pieces to facilitate air movement, limestone, pig iron, cast iron scrap, NI hard, white iron and steel. The cupola should have uniform pressure so preparation is made to remove slag to maintain a uniform diameter of 92 cm. the refractory used is firebricks, side arch or standard.

F. Machine shop
The machine shop is the final area in the production of cast production. In this section a lot of swarf material is produced and sold as a by-product to other industries. Each operator cleans their work space at the end of the shift. Of concern is the high noise level, and there is need to use earmuffs by operators.

G. Quality inspection
There is limited inspection on the scrap material because of shortage of equipment like spectrometers. There are also checks done on patterns for tolerances. A prototype cast is made and verification is done on dimensions in liaison with customers. After verification then mass production is done as per requirement.

V. RESULTS AND DISCUSSION
Foundry Company is a ferrous foundry and has not taken any step towards EMS, making it a big potential for DEF opportunities. It being a foundry it deals with sand molding with its two cupolas being coke fired hence lots of dust is generated from the sand reclamation plant and sand blasting section. The foundry depends on raw materials which are fast depleting, and the aspect of recycling becomes a handy option for the organization. Foundry Company gets its major raw material as pig iron from a local producer. The organization has not attempted to adopt the process that leads to the certification to ISO
14001.

A. Yield Analysis

Yield analysis that shows the need for DFE

<table>
<thead>
<tr>
<th>Date</th>
<th>Changes</th>
<th>Weight Charge</th>
<th>Meta Loss</th>
<th>Runners</th>
<th>Cast Scrap</th>
<th>Total Good</th>
<th>M/Shop Scrap</th>
</tr>
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<tr>
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<td>20</td>
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<td>200</td>
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<td>250</td>
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<td>6750</td>
<td>373</td>
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<tr>
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<td>32</td>
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<td>500</td>
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<td>200</td>
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<td>665</td>
</tr>
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<td>250</td>
<td>672</td>
<td>6048</td>
<td>574</td>
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<td>11250</td>
<td>13000</td>
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<td>165750</td>
<td>15087</td>
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</table>

The above Table II shows that scrap rate is too high, which is causing an environmental burden and hence the need for implementation of DFE as way forward for the business and environmental protection.

B. Energy

There was a lot of high powered machinery which has high demand for power in the plant, meaning there existed poor load factor i.e maximum demand was higher than energy demand.

C. Casting area

There was a lot of high powered machinery which has high demand for power in the plant, meaning there existed poor load factor i.e maximum demand was higher than energy demand.

D. Fettling process

Fig. 2 gives the inputs and outputs flow of the Fettling section to produce cleaner casting by removing the sand cast. Here water is extensively used. Waste is generated in form of swarf, effluent, and scrap castings. Table IV below summarizes the
adverse environmental impact of the mentioned waste produced by the processes in this section. Scrap casting is re-cycled back into production.

Table IV
ENVIRONMENTAL IMPACT OF FETTLING SECTION

<table>
<thead>
<tr>
<th>Affected element of the environment</th>
<th>Impact / effect</th>
<th>Significance Rating (1 to 3), I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface water</td>
<td>Potential spillage lubricant contaminating the storm water drains &amp; sewer</td>
<td>3</td>
</tr>
<tr>
<td>Underground water</td>
<td>Potential contamination if effluent seepage occurs</td>
<td>3</td>
</tr>
<tr>
<td>Land</td>
<td>Waste sand is alkaline and contaminates the water when washed away</td>
<td>3</td>
</tr>
<tr>
<td>Natural resources</td>
<td>Depletion of natural resources</td>
<td>2</td>
</tr>
<tr>
<td>Flora</td>
<td>Destroys vegetation</td>
<td>2</td>
</tr>
<tr>
<td>Fumes</td>
<td>Affects aquatic life</td>
<td>3</td>
</tr>
</tbody>
</table>

F. Tool room
Fig. 4 gives the inputs and outputs flow of the tool room to produce tools for use in the plant and repairing them. Also waste generated in form of fumes, swarf, scrap steel and used oil spillage effluent was noted. Table VI below summarizes the adverse environmental impact of the mentioned waste produced by the processes in this section.
It was noted that use of carbon dioxide, heat, lubricants, water and sand resulted in generation of fumes, effluent spillages and waste water effluent to the detriment of the environment. This also posed a high risk to operators if they inhale the fumes or get injured when the work without protective clothing like gloves. The environmental review of operations at the foundry has revealed a number of shortcomings such as the uncontrolled exposure to and release of substances potentially hazardous to health. Poor in-plant containment and management of waste products which were contaminating land. Also noted was ignorance of requirements relating to effluent discharges, and contamination risks to surface water drains and sewers arising from inadequate storage of materials. Air pollution resulted in neighborhood nuisance from fumes, dust and odor emission.

VI. RECOMMENDATIONS

High power demand could be reduced through load shedding and staggering the times of switching on equipment in the plant. As well as sub-metering various sections of the plant with view to closely monitoring major consumer sections as well as maintaining a good load factor for key equipment.

There is extensive use of lubricants for machining and lubrication and oil interceptor has to be installed as well as used oil to fire up the furnaces by burning it for environmentally friendly disposal. This measure would effectively reduce the possible contamination of storm water drains.

On the input raw material, recycling is used to handle the high scrap rate of 20.7% in Table 2, this can be cause for high level of electricity consumption through re-working of scrap castings. It is recommended that the scrap rate is reduced to 6% for cost effectiveness in the plant.

Processes like sand reclamation and sand blasting produce a lot of dust, hence it is recommended to use dust extraction fans to reduce dust inhalation by operators.

VII. CONCLUSION

The analysis of the case study has shown that in Zimbabwe, most organizations are not aware of DFE and have not taken EMS as a competitive advantage. Some of the DFE techniques adopted so far at the case study organization as part of their best practice initiatives, have yielded significant benefits. The areas identified for DFE implementation are designing for resource conservation, low-impact material, biodiversity conservation, cleaner production, reuse, recycling and safe disposal in the ferrous foundry. The issue now would be to implement companywide DFE and constantly evaluating and reviewing progress through guidelines of ISO 4001 or full benefits to accrue to the organization.

has to be to the whole life cycle of the products.

REFERENCES