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Evaluate the computer-Aided System for Life Cycle Assessment of a Pressure Die-Casting Process using score Method

Manmohan Singh[1], Rupinder Singh[2], Daljinder Singh[3]

[1]*Assistant Professor in Dept. of Mechanical Engineering, Chandigarh Engineering College, Landran, India*
[2]*Assistant Professor in Dept. of Mechanical Engineering, Chandigarh Engineering College, Landran, India*
[3]*Assistant Professor in Dept. of Mechanical Engineering, Chandigarh Engineering College, Landran, India*

Abstract — *To analysis the environmental impact, score method is used. The weightage is given to each indicator in the form of matrix. The matrix is evaluated to find the environmental performance of the values. The method is applied on the results of software, for further validation of computer aided system [30]. A case study is used to illustrate how the evaluation of system software and to demonstrate its applicability.*

Keywords - *Computer-Aided System, Sustainability Indicators, Score Method, Environmental Impact, Pressure Die-Casting.*

I. INTRODUCTION

Industrial sector is in huge demand of casting parts and is widely used in manufacturing and assembly units globally. The scoring method developed by Jiang et.al. [11] is used to check the computer-aided system developed by Singh et.al. [30], for life Cycle Assessment of a Pressure Die –Casting Process. Pressure die-casting process is one of the keys to realize a successful sustainable manufacturing strategy. To decrease the energy consumption and other miscellaneous sustainability analysis is performed on life cycle of manufacturing process. The development of an appropriate assessment method for evaluating the environmental performance of a manufacturing Sustainability of a manufactured part is represented using sustainability indicators. A number of indicators are available for sustainable manufacturing and broadly classified into social, economic and environmental indicators [13].According to the flows in the manufacture they are divided into input and output indicators. Present work focuses on validation analysis of pressure die casting process system. The sustainability indicators used are energy consumption, solid waste, cost and other miscellaneous consumption.

Energy is the primary driving indicator for study. To enhance the effectiveness of the study and better development of the system some other indicators are also taken under consideration namely flux consumed, solid waste, die-coat lubricant, and fuel consumed.

II. RELATED WORK

Previous work related to sustainability analysis of manufacturing processes is discussed in this section. Choi et. al. [5] developed assessment model for manufacturing process to evaluate the product design in terms of environmental impact. Robert et. al. [27] Suggest changes to decrease the environmental impact of aluminium die-casting process. By analyze the life cycle inventory using air emission and material use. Indirect emission caused by the process is not considered. Krajnc et. al. [13] proposed the indicators for sustainable production. Indicators are based on commonly measured environmental aspects of sustainable production. Tanet. al. [21] used Life Cycle Analysis (LCA) to investigate the environmental performance of zinc cast product. Direct and indirect air emission that arises from zinc smelting, casting, recycling and during transportation has been measured. The results confirmed that the major air pollution occurs during smelting 65-70% of overall air pollution during the process. Gutowski et. al. [7] performed the system level environmental analysis on pressure die-casting process. Environmental impact is evaluated by examining the life cycle of the process considers the die preparation, metal preparation, casting and trimming. Narita et. al. [17] proposed an environmental burden analyzer for machine tool operation. Analysis is based on tool wear information and cutting conditions from the viewpoints of environmental burden due to electric consumption of machine tool components, coolant quantity, lubricant oil quantity, cutting tool status, metal chip quantity and other factors. Neto B. et.al. [18], developed a model (MIKADO) that can be used to evaluate the environmental performance. Methodology used to develop the model is based on life cycle assessment of the part and environmental system management. This model does not consider the indirect air emission. Jiang et. al. [11] proposed the method to evaluate the environmental performance for manufacturing process plan. A matrix is used whose row corresponds to process and column is associated with environmental performance criterion and the normalized inventory values are used to create a score for each process and criterion. The method has been encoded into the software. It evaluates the environmental performance as waste emission and energy consumption only. Singh et. al. [29] Proposed sustainability analyzer for die-casting process is presented using three sustainable indicators (air emission, energy use and solid waste). It helps the die-casting industry to improve the energy efficiency and to reduce the air emission and solid waste. The proposed system uses analytical method to calculate the sustainability indices and is compared with shop floor data. The proposed system is limited to three indicators to analyze the sustainability. Balogun et. al. [2] Develops a new mathematical model for predicting direct energy required for machining. By study the effects on electric current consumed during machining due to machine modules, auxiliary units and machine code and evaluate the tool path to makes them more efficient. The number of studies on the environmental performance of the metal casting is limited.

III. METHODOLOGY OVERVIEW

A part is produced through a number of operations and manufacturing processes. During the transforming process the number of by-products like waste. The pressure-die casting process is described with the help of input/output diagrams. It is proposed to deploy some steps to conduct this evaluation. (1) Collection of inventory for all the operations, (2) selection of environmental indicator, (3) evaluate the indicators and improvement.
According to Jiang et.al. the first step in this method, is to list the inventory for each operation in the process plan [11]. To collect the data on electric energy consumed, flux consumed solid waste, die-coat lubricant and fuel consumed for pressure die-casting process. The results from computer-aided system are compared with shop floor data for validation of system software [30]. The pressure die-casting process inventory framework developed to show the input and output for the process.

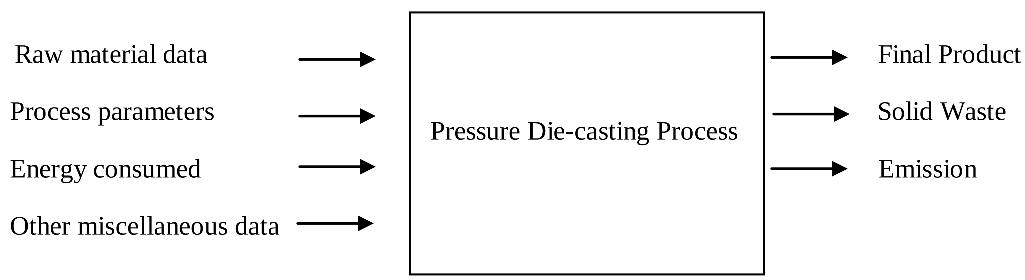

Fig.1 Input/output diagram for Pressure die-casting process

IV. CASE STUDY

4.1 Case Study: Electric Iron Sole Plate

Electric iron sole plate is made from aluminium alloy (A307) by pressure die-casting process. The raw material for the electric iron sole plate is ingots of metal and no scrap raw material is used.
First of all Aluminium ingots is melted to about 720-750 ^oC in furnace oil fired reverberatory furnace. Flux is added to the molten metal which makes the impurities to float on metal surface in the form of slag and is collected and separated out.
After melting the molten metal is transferred to electric holding furnace using fork lifter. Which holds the molten metal at about 760-770 ^oC. Molten metal is then injected into the pressure die-casting machine under high pressure. After specific time the casting solidifies and taken out.
Results obtained from sustainability analyzer for case study 1 are shown in table 1.
Number of parts: - 460

Table 1 Pressure Die-Casting Process Analyzer Results

Sub Process	Electric energy consumed (kWh)	Flux consumed (Kg)	Solid Waste (Kg)	Die-coat lubricant (Liters)	Fuel consumed (Liters)
Melting	0	0.4	10	0	42.5
Holding	304	0	3.4	0	0

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Pressure Die-Casting	179.2	0	0.6	2.13	0
Macro-level activities	42.59	0	0	0	0.832
Total	525.76	0.4	14	2.13	43.34
Indicator /part (U_{max})	525.76/460 =1.14	0.87	0.03	0.0046	0.094

U_{max} is the largest realizable value for the inventory measure. U_{max} is the theoretically calculated values.

Table 2 Inventory data of value Pressure die casting

Process	Electric energy (kWh/part)	Flux consumed (g/part)	Solid waste (kg/part)	Die-coat lubricant (L/part)	Fuel consumed (L/part)
Melting	0(=u)	0.761(=u)	0.016(=u)	0(=u)	0.111(=u)
Holding	0.65(=u)	0(=u)	0.005(=u)	0(=u)	0(=u)
Pressure die casting	0.33(=u)	0(=u)	0.001(=u)	0.004(=u)	0(=u)
Macro level activities	0.086(=u)	0(=u)	0(=u)	0(=u)	0.0026(=u)
U_{max}	1.14($=U_{max}$)	0.87($=U_{max}$)	0.03($=U_{max}$)	0.0046 ($=U_{max}$)	0.94($=U_{max}$)

dij =umax/u
Where, u is the inventory value and U_{max} is the largest realizable value for the inventory measure.

According to saaty 2003 [28], the pair wise comparison matrix is shown below. Fundamental scale of absolute numbers corresponding for verbal comparisons is as follow.

1for Equal importance
3 for Moderate importance of one over another
5 for Strong or essential importance
7 for Very strong or demonstrated importance
9 for Extreme importance
2,4,6,8 for Intermediate values
Use Reciprocals for Inverse Comparisons

$$
\begin{array}{c c c}
 & \begin{array}{ccccc} EE & FC & SW & DC & Fuel\ C \end{array} & \text{sum } (\sum^{n}_{j=1} aij) \\
\begin{array}{c} EE \\ FC \\ SW \\ DC \\ Fuel\ C \end{array} &
\begin{pmatrix}
1 & 1/5 & 1/2 & 1/3 & 1 \\
5 & 1 & 3 & 2 & 5 \\
2 & 1/3 & 1 & ½ & 2 \\
3 & 1/2 & 2 & 1 & 3 \\
1 & 1/5 & ½ & 1/3 & 1
\end{pmatrix} &
\begin{array}{c} 3.033 \\ 16 \\ 5.83 \\ 9.5 \\ 3.033 \end{array}
\end{array}
\qquad
\begin{pmatrix}
a11 & a12 & a13 & a14 \\
a21 & a22 & a23 & a24 \\
\multicolumn{4}{c}{\dots\dots\dots\dots\dots\dots} \\
an1 & an1 & an1 & an4
\end{pmatrix}
$$

n=5

$$W_i = [(\sum^{n}_{j=1} aij)^{1/n}] / [\sum^{n}_{i=1} (\sum^{n}_{j=1} aij)]$$

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$W_i = (3.033)^{1/5} / [(3.033)^{1/5} + (16)^{1/5} + (5.83)^{1/5} + (9.5)^{1/5} + (3.033)^{1/5}]$

$W_i=0.173$

Where, EE=electric energy, FC= Flux consumed, SW=solid waste, DC=die-coat lubricant, Fuel C=Fuel consumed.
Where, u is the inventory value and u_{max} is the largest realizable value for the inventory measure.
Data in table 3 is calculated using table 2 data and formula dij =umax/u

Table 3 Matrix for environmental performance of the Valve

Process	Electric energy (kWh/part) (w1 = 0.173)	Flux consumed (g/part) (w2=0.241)	Solid waste (kg/part) (w3=0.197)	Die-coat lubricant (ml/part) (w4=0.217)	Fuel consumed (L/part) (w5=0 .173)	Score P_i
Melting	0	1.14	1.87	0	8.47	2.1
Holding	1.75	0	6	0	0	1.48
Pressure die casting	3.45	0	30	1.15	0	6.81
Macro level activities	13.25	0	0	0	361	64.54
Score C_j	18.45	1.14	37.87	1.15	369.47	T=74.93

$P_i= 0×0.173+1.14×0.241+1.87×0.197+8.47×0.173$
$P_i=2.1$
$C_j=1.75+3.45+13.25$
$C_j=18.45$

V. CONCLUSION

The system uses sustainability indicators (energy use, solid waste, cost, and other misc. consumption like flux, die-coat lubricant and energy consumption for other micro-level activities like furnace blower, coolant pump, air compressor, fork lifter, fans and lights) and uses inbuilt database of die-casting process parameters. The user can interacts with system through user friendly GUI and prompts user to select the various choices in the system and enter data for the process plan. The system then process input data and retrieve required data from database and display the results in the form of indicators. The evaluation of this system is done according to score method jiang et.al. [28].The case study is presented for the evaluation of system data by score method [28].
The proposed system can gives results for four indicators (energy use, solid waste, cost, and misc. consumption in pressure die-casting process) in the future it can be extended to includes more sustainability indicators.
The score for holding (1.48) is the smallest of all the operations; this indicates that from an environmental perspective, attention should be devoted to improving this operation. So, the score method helps in selecting the operation for further modification.

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