A CONTRIBUTION TO THE LIFE CYCLE MANAGEMENT APPLICATION TO MOULD MAKING BUSINESS

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Abstract

The Life Cycle Management (LCM) concept defines a new wide open type of management. With this concept the managers must see a product in its entire life cycle, regarding typical managerial subjects, environmental issues like air emissions generated, and all massic and energetic streams. With this approach, managers will be able to predict the total cost of a product, the natural resources consumed, the energy spent and the environmental impact associated to a specific product. The application of these concepts in the mould making sector will enhance significantly the competitiveness of the currently called Eastern World manufacturers since this kind of tools are considered the key factors to compete with Asiatic companies. In this paper is presented a LCM model structure that can be used in the future by the sector. The model is applied to three different case studies in order to demonstrate the importance of this approach and the type of analysis and knowledge upgrade it can support.

Introduction

The Life Cycle Management concept defines a new wide open type of management. With this concept the managers must see a product in its entire life cycle, regarding typical managerial issues (costs, time, among others), environmental issues like air emissions generated, and all mass and energetic streams. With this approach, managers will be able to predict the total cost of a product, the natural resources consumed, the energy spent and the environmental impact associated to a specific product.

A product life cycle starts when raw materials are extracted from the earth, is followed by manufacturing, transport and use, and ends with waste management including recycling and final disposal. At every stage of the life cycle there are emissions and consumption of resources. In a world of life cycle thinking and life cycle economy, all the environmental impacts from the entire life cycle need to be addressed [1]. In this context the concept of Life Cycle Assessment (LCA) appears as a management tool that allows the evaluation of an environmental impact, of a product or service, in its entire life cycle.

To achieve a sustainable development it's crucial to use some kind of management that gives the deserved importance to the environmental issues. Nevertheless a company can not only use the information given by LCA for the project of a product. The companies must keep the usual approach with the technical performance, economic aspects, among others issues associated with the product manufacture. Even in an idealized scenario, where the environmental performance is the only goal for the project, the economic issues must be part of the analysis, once the natural resources needed to achieve the project goal are limited in Nature. With these arguments it became clear that we must integrate LCA with other technique whose objective is the economic analysis. This bridge is made connecting LCA with LCC (Life Cycle Costing).

Several authors have developed several studies about the connection between the economical and environmental aspects [2][3]. Every one of them shows potentialities and limitations of their methods. Nevertheless, a joint initiative in USA created a Manual for the complete bridge between the economical and environmental aspects. This study develops a method which is called TCA (Total Cost Assessment) and all kind of costs are taken into account, regarding also the environmental costs and those associated to the degradation of human health due to pollution (E&H costs).

The application of these concepts in the mould making sector will enhance significantly the competitiveness of the currently called Eastern World manufacturers since this kind of tools are considered the key factors to compete with Asiatic companies.

In this paper a model is presented that allow the managers to choose the best scenario for a specific mould, taking into account every aspects mentioned above. Three case studies are presented to illustrate model application. The integration of recycling and reusing practices are being studied in a case study that will be presented in future.

LCM model methodology

The model is supported by the main ideas from Life Cycle Management concept. In other words the model will make the bridge between LCA information and TCA methodology for the product: Injection Mould. The diagram of figure 1 shows the life cycle stages for this product.

Gathering information for the mould life cycle we should be able to create a parametric regulation for all LC stages. The model will use the parameters to perform the simplified LCA (the relevant streams are considered), cross this information with costs databases and retrieve a Total Cost for each stage. The model also gives information about natural resources and energy consumption. The diagram of figure 2 shows the global approach used by model for each stage.

The first step to perform LCI is the complete identification of all entries and all exits of a particular process. This identification allows the construction of a diagram that shows every stream involved in the process, the diagram is named I/O Diagram (input/output diagram). After identifying the relevant streams they must be quantified. To perform the quantification there are algorithms created by several authors [4] [5] that shows how the parameters are related to each other for some technological processes.

Based on TCA methodology the total cost will be divided into five different categories (table 1).

Category	Description
E&H Costs	Environmental costs associated to the impacts cause by gas emissions to atmosphere
Natural Resource Consumption Costs	Costs associated with the consumption of resources from Nature
Waste Disposal Costs	Costs associated with removing and treatment of wastes
Energetic Costs	Costs associated with the total amount of energy consumed
Production Costs	Usual costs considered in industry (machine and human costs)

Table 1 – Costs categories

Life Cycle stage – Mould manufacturing

This particular stage of mould life cycle includes the resource to several technological processes. In this case we should deal with them separately because the production stage is the most susceptible to parametric representation. The main technologies for mould production are: EDM, Milling (including HSM) and Hand Polishing. The I/O diagrams shown in figures 3, 4 and 5 respectively do the characterization of each technology.

The algorithm of figure 6 represents the model approach for this particular stage.

Life Cycle stage – Mould in use

The utilization of this particular product, the mould, is associated with the production of plastics parts by injection moulding. For the sake of simplicity conventional injection moulding is the only that is going to be considered.

The I/O diagram for this stage is represented in figure 7.

Life Cycle stage – Final Disposal

This stage refers to what happen with the mould when its life reaches the end. There are several ends for an injection mould: storage, landfill, component recycling or reutilisation or even recycling the entire mould by melting the material. But for a better understanding of the rules adopted by the industry in the mould Final Disposal some visits were made to companies of mould makers and plastics moulders. The information gathered allowed the development of three end-of-life scenarios. These scenarios and the combinations among them cover every kind of identified end-of-life practice.

In the case studies presented in the paper this particular stage is not yet included. Another case is being developed already with all life cycle stages.

Case Studies

The following case studies will illustrate how the model works and explain some simplifications introduced.

Case Study 1 – EDM

This case study is about machining a mould cavity by ram EDM. The plastic part to be injected is in figure 9. The table 2 shows all the data required. The information is gathered by groups according with the diagram of figure 6. Table 3 shows the main results, provided by model application, for this case. Figure 10 shows how the total cost is divided by categories, the total cost rounds 1800€. A remark must be made to the E&H costs, the value obtained is so small that allow us to neglect him in future analysis without lack of accuracy. It's a very useful result to optimise the model.

Time Info	******
Process time [seg]	**180000**
Process Info	******
Machine tank volume [dm^3]	**200**
Maximum Current Intensity [A]	**96**
Machine Nominal Power [kW]	**5,4**
Gap Voltage [V]	**200**
Room Temperature [ºC]	**25**
Dielectric Fluid	-------
Fluid Type	**kerosene**
Density [kg/m^3]	**2700**
Specific heat – Cp []	**2,89**
Raw Material Info	******
Material	**steel**
Density [kg/m^3]	**7850**
Melting point [ºC]	**1400**
Volume to be removed [m^3]	**0,000942**
Tool Info	******
Material	**graphite**
Density [kg/m^3]	**2250**
Melting point [ºC]	**3826**
Block volume [m^3]	**0,001431**

Table 2 – Inputs for CS1

LCI Mass Streams	
Raw Material	6.75E-5 kg / seg
Electrode	2.61E-7 kg / seg
Dielectric Fluid	3.33E-4 kg / seg
Gas Emissions	
Impact Category	---------
PAH's	7.59E-10 ton
VOC's	1.84E-10 ton
Nickel	3.77E-14 ton
Chromium	2.83E-12 ton
LCI Energetic Streams	
Process	1077165 kJ
Dielectric fluid processing	219752 kJ
Electrode processing	253671 kJ
Electrode machining	18000 kJ
TOTAL	~1640 MJ

Table 3 – Result summary for CS1

Case Study 2 – EDM vs. HSM

This case study is about machining a mould cavity for an electronic component. This cavity could be done by HSM or by ram EDM. The model will be used to show how different choices of manufacturing can be compared based on the LCM concept. The major cavity dimensions are *117.77 mm x28.30 mm x 5 mm*, and it's made of AISI 420 MOD (steel).

Doing this cavity by HSM it takes: roughing – 15 minutes; semi-finishing 1 (corner) – 23 minutes; semi-finishing 2 (whole cavity) – 17 minutes; finishing – 28 minutes. And no cutting fluid is required. Table 4 shows the main results for HSM choice. Figure 11 shows the cost division, the total costs is approximately 120€.

Mass Consuption		
Roughing	*Raw Material*	0.127 kg
	Tool	0.001 kg
Semi-finishing 1	*Raw Material*	0.126 kg
	Tool	0.001 kg
Semi-finishing 2	*Raw Material*	0.126 kg
	Tool	0.001 kg
Finishing	*Raw Material*	0.126 kg
	Tool	0.001 kg
Energy Consuption		
Roughing		129 MJ
Semi-finishing 1		148 MJ
Semi-finishing 2		134 MJ
Finishing		105 MJ
TOTAL		~516 MJ

Table 4 – Result summary for CS2 – HSM

Doing this cavity by EDM it takes: roughing – 182 minutes; finishing – 210 minutes. And no cutting fluid is required. Table 5 shows the main results for EDM choice. Figure 12 shows the cost division, the total costs is approximately 250€.

Mass Consuption		
Roughing	*Raw Material*	0.740 kg
	Electrode	0.003 kg
	Dielectric Fluid	3.640 kg
Finishing	*Raw Material*	0.070 kg
	Electrode	0.0003 kg
	Dielectric Fluid	0.530 kg
Energy Consuption		
Roughing		236 MJ
Finishing		275 MJ
TOTAL		511 MJ

Table 5 – Result summary for CS2 – EDM

It can be seen by the results provided that HSM technology presents a smaller cost to make the cavity, although it consumes more energy than EDM. The environmental costs are higher in relative terms, furthermore no cutting fluid was used, this fluid should become the environmental performance worst, and increase the total cost. Nevertheless, this application shows that HSM technology is more indicated to do this particular mould cavity.

Case Study 3 – Injection mould

This case study refers to a mould with a very simple geometry, and it is assumed that the mould is only the moulding zones: Cavity and Core. The injection mould is in figure 13.

The technologies involved in production were: milling, turning and hand polishing. The time spent for the operations of turning and milling for the manufacture of core and cavity was 80 hours equally distributed by elements and operations. For the core polishing were spent 32 hours and for the cavity 20 hours. The cycle time is 35 seconds, and a production of 1000 parts is considered. The mould is made of steel.

Table 6 shows the result summary for the model application. The total cost is about 5800€

and is divided, by stage and by category, according to figure 14.

			CORE	CAVITY
Mass Consumption				
LC stage 1+2 – Raw material extraction + manufacture		*Raw Material*	7 kg	
LC stage 3 – Mould Production	*************		CORE	CAVITY
	Turning	*Raw Material*	2.64 kg	2.15 kg
		Tool	0.001 kg	0.01 kg
		Fluid	0.002 m^3	0.006 m^3
	Milling	*Raw Material*	4.99 kg	6.04 kg
		Tool	0.001 kg	0.01 kg
		Fluid	0.006 m^3	0.006 m^3
	Hand Polishing	*Raw Material*	neglectable	neglectable
		Abrasives	0.03 kg	0.01 kg
LC stage 4 – Mould Utilization		*Raw Material*	31.2 kg	
Energy Consumption				
LC stage 1+2 – Raw material extraction + manufacture			129.55 MJ	
LC stage 3 – Mould Production	********		CORE	CAVITY
	Turning		3030 MJ	3200 MJ
	Milling		3200 MJ	3200 MJ
	Hand Polishing		0	0
LC stage 4 – Mould Utilization			835.74 MJ	
TOTAL			~ 3.87 GJ	

Table 6 – Result summary for CS3

Conclusions

The developed model is capable of providing detailed information on the resources and energy consumption, as well as on the total cost and its distribution for each category. The case studies presented show how powerful the model is for implementing the concept of LCM and how technological alternatives to produce a mould can be compared.

The case study CS1 demonstrates that the environmental impact costs (E&H) are null. This is a very important result because the determination of these costs is laborious and difficult. Thus, based on this result, the model can be built neglecting this cost category without affecting the accuracy of the final output.

Future case studies developed will include all life cycle stages. The relevance of recycling and reusing in the global business of mould making and injection moulding of plastics will be analysed. This will provide a tool and guidelines for the design of cheaper, efficient and environmental friendly moulds.

Acknowledgments

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Keywords

LCM, LCA, LCC, TCA, life cycle; injection mould.

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Illustrations

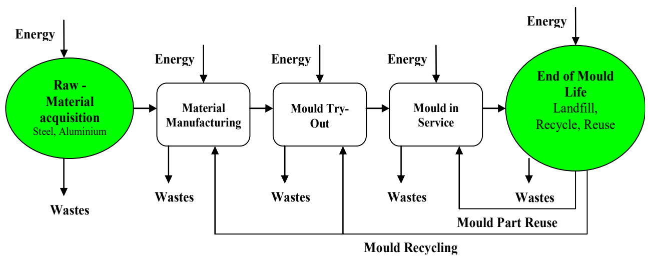

Fig. 1. Mould life cycle stages

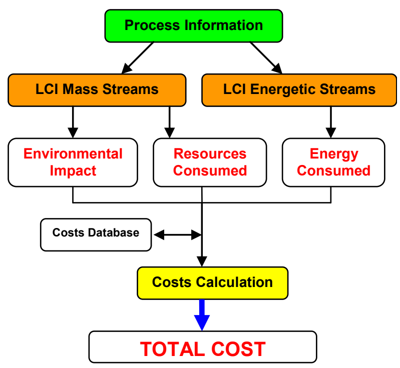

Fig. 2. Model global approach

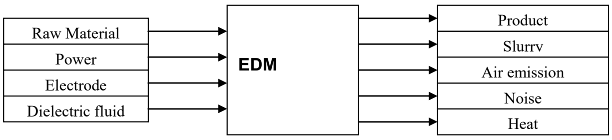

Fig. 3. I/O diagram for EDM

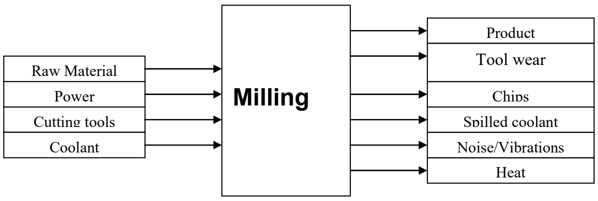

Fig. 4. I/O diagram for Milling (includes HSM)

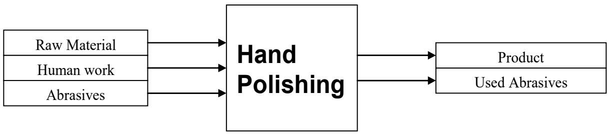

Fig. 5. I/O diagram for Hand Polishing

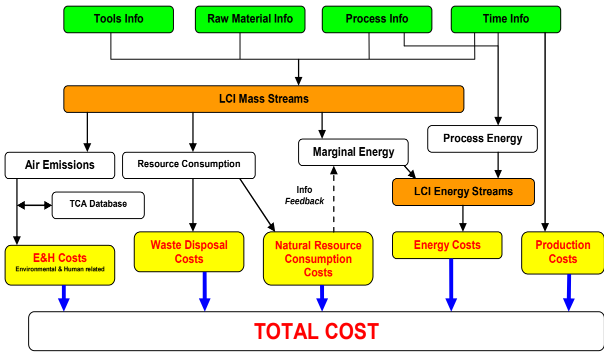

Fig. 6. Model approach for Production stage

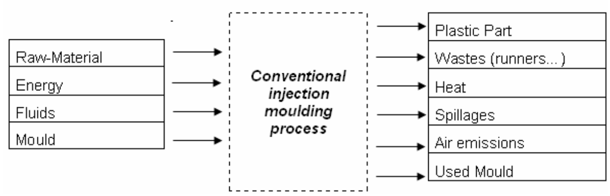

Fig. 7. I/O diagram for Injection moulding process

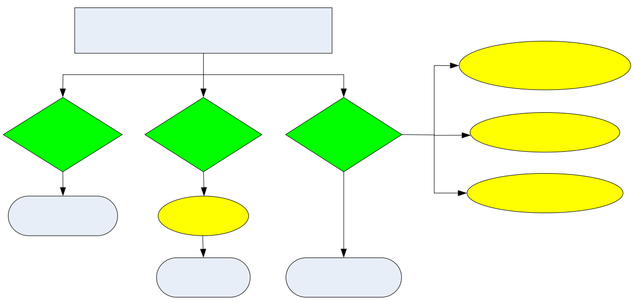

Fig. 8. End of life scenarios

Fig. 9. Motor engine cover

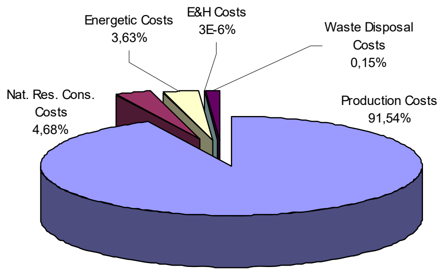

Fig. 10. Costs division for CS1

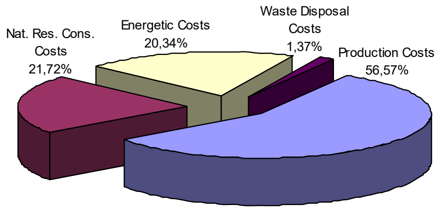

Fig. 11. Costs division for CS2 – HSM

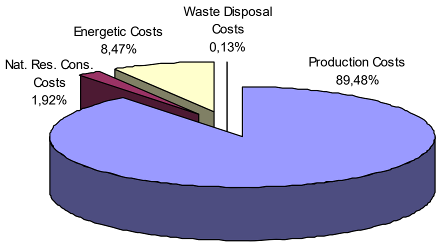

Fig. 12. Costs division for CS2 – EDM

Fig. 13. Injection mould for CS3

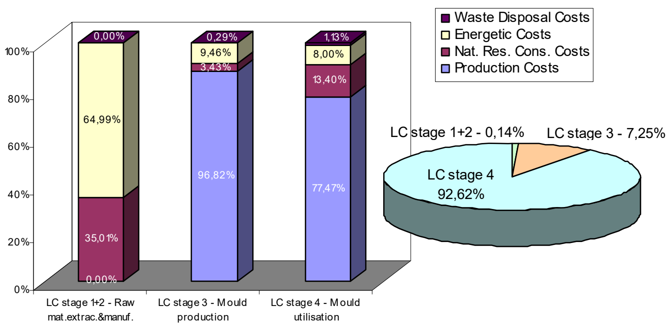

Fig. 14. Costs distribution for CS3