International Journal of Trendy Research in Engineering and Technology
Volume 9 Proceedings of NCIES-25
ISSN No. 2582-0958

“Life cycle assessment of Electric Motor by using OpenLCA”

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Abstract

The project, "Life Cycle Assessment of Electric Motors Using OpenLCA" covering the cradle-to-gate phases, had carried out in OpenLCA to assess their environmental impacts as result of extraction, production, and distribution of materials. This study agreement with induction motors and permanent magnet motors aims to look into the environmental performance of the two. Electric motors are required as they are playing vital role in the economy statically as well as environmentally by consuming as much as 40-45% of the industrial electric energy in the world. This is where OpenLCA has to come in to be able to make up a statement about how much energy demand and CO 2 were living in the extraction and production of the mention materials, which are e.g. iron, copper, structure materials, etc., e.g. aluminum isolating materials, and permanent magnets and how much they did not live so that in the end the result, which must be taken from the virtual shelf, is as accurate as possible. And it was of course also taken into account that surfaces have influence on each of the material impacts because everywhere raw materials had to be driven to. The induction motors trade-off comparison is more expensive with a higher emission footprint in production, whereas the permanent Magnet are cheaper with lower production emission but is costlier that they have limited and expensive to mine of earth. This suggestion implies a significantly less material variety move, less broad motor types, and bringing the design for environment considerations much earlier in the cycle so that the affected ecosystem is the least impacted. This research from the above point aims to investigate and the impact on the motor environment – through design – and with the work, presents the first steps towards motor friendly, sustainable production.

Keywords: Life Cycle Assessment (LCA), Electric Motor, CO2, OpenLCA, Environmental Impact, Cradle to Gate, Emission.

I. INTRODUCTION

Today, the most commonly cited example is that of global warming and climate change. The correlation between human being and environment was significant in the lifecycles of materials. The demand for cost effective operation eventually led to a shift in focus to engineering technology for the electric motors. Movable electric motors are the new largest consumer of energy in the world. Between 40 and 45 percent of the energy they eat up is within the industry itself. This surpasses growth since 2010, and is nearly double from international consumption of energy. The comprehensive lifecycle assessment exposes critical procedures that assist in lessening the burden machines give to ecosystem, therefore an instrument for the assessment that impact of particular products on the environment from cradle to grave – beginning with working out the materials, followed by designing manufacturing, transporting, marketing, using, and recycling [1].

Today there are four energy classes to describe the energy efficiency of motors: standard efficiency (IE1); high efficiency (IE2); premium efficiency (IE3); and super premium efficiency (IE4). It was the demand for higher energy efficiency which drove the researchers towards alternative technologies for electrical machines. There is probability to achieve the IE3 and IE4 efficiency class is use of earth PM in the rotating electrical machines, where we achieve to the end that causes higher environmental impact than the IE2 efficiency class [2].

Besides the energy cost, the high efficient rotating electrical machines require a great amount of natural resources, like iron, copper, permanent magnet material, as well as other metallic minerals, in addition to that for the ore extraction, refining, fabrication as well as transportation [3]. Eco-design emphasises the role of the lifecycle of products from raw materials up to the end of life [4]. Increasing a efficiency of the electrical machine design (EMD) (where electric motor is the primary constituent) is simultaneously by lowering the harmful emissions issued during the stages of manufacture, application, & disposal [5].

Lifecycle evaluation reveals some of the important steps which assist to restrict the negative impact of machines on nature and environment. In this way it's a tool to calculate the measurements of the environmental impact of certain products from womb to tomb — not just the resources needed to make them, but the manufacturing process, logistics, delivery of these machines when they're being sold, and when they're actually used, and what happens at the end.

The project report presents a lifecycle assessment study of electric motors using OpenLCA tool [6].

II. LITERATURE REVIEW

In the last few years, strong regulations have really pushed manufacturing businesses to take concrete steps in making production greener and cleaner. Sure, we've really reduced total emissions by using the best available techniques, but industry makers still need pointers on how to cut down on all the nastiness that comes along with running factories. Guidance is still sorely needed for cutting down negative environmental impacts. Environmental impact assessment shortly becomes a compulsory phase. An impact assessment tool is used for the environmental evaluation. The evaluation method used is the lifecycle assessment method. The quick and easy assessment of energetic and environmental performances contributes to determine the weak points of various products technologies and services or production processes or the best suited treatment in a specific context. [7].

Arjun Ram and Piyush Sharma studied about life cycle assessment, terminologies used in life. In this paper they clearly explain about frame work lifecycle assessment. The work mainly focuses about phases of LCA such as setting a goal, inventory design, performing LCA using tools and interpretation of results with combination of LCI and LCIA [8].

S. Orlova et.al performed comparative the evaluation of variety motors from the perspective of damage due to them during their operational period. There are three motors that have been studied: Synchronous reluctance motor, permanent magnet be of use to synchronous reluctance motor, and induction motor. Lifecycle assessment has been done on four fronts: manufacturing, distribution, utilization, and disposal. The findings indicate that the production costs associated with the permanent magnetic motors are more than that of synchronous motors; however, owing to their low efficiency, these motors have the highest environmental impact. The overall conclusion is that there is reduction of impact, if a design stage impact assessment on the environment is well designed, conducted and managed [9].

Pratiwi et.al demonstrated application OpenLCA tool in analyzing change impact assessment of enhanced geothermal system plants in the Upper Rhine Valley. The results obtained by OpenLCA aids to set new guidelines for construction phase, this stage most responsible for GHG emitted per kWh [10].

In order to compare the different models, Lifecycle assessment is applied, using the software OpenLCA, and the database ecoinvent 3.6. The Functional Unit defined is 1 p*km (per kilometer). In an attempt to evaluate and quantify the impacts of the production of the raw materials, production of the scooter, transportation, use and dismantling of the different scooters, ReCiPe 2016 Midpoint (H) is selected and all the impact categories available in this method are considered in this study [11].

Thomas Poppe in their research study compares the environmental impacts of producing permanent magnet motors (PM) and induction motors (IM). It includes the production of materials, transportation, and assembly, and compares these motors to internal combustion engines (ICE).The study shows that the type of mover and the materials used is dependent for the CO2 pollution. Furthermore, the emission caused by electric energy production is compared to the European average and the neighbour countries of the Netherlands, Germany and Belgium. These countries have different emission values the production of the electric energy [12].

III. MATHEMATICAL FRAMEWORK

During the production stage CO_2 emission of different material is calculated as below.

$$P_{copper} = E_c A_c \quad -1$$

$$P_{steel} = E_S A_S \quad -2$$

$$P_{aluminium} = E_a A_a \quad -3$$

$$P_{insulating\ mateial} = E_i A_i \quad -4$$

$$P_{permanent\ magnets} = E_{pm} A_{pm} \quad -5$$

Where, 'E' in the above equations stands for kg CO_2 emitted per kg of material. The letter 'A' stands for amount of material in kg.

Total CO_2 emission for production is calculated by using equation 6.

$$P_M = P_{copper} + P_{steel} + P_{aluminium} + P_{insulating\ mateial} + P_{permanent\ magnets} \quad --6$$

CO_2 emission during transportation of different material is calculated by using following equations

$$TD = Dboat + Dtrain + Dtruck \quad --7$$

$$Tcopper = EkmTDc \quad --8$$

$$Tsteel = EkmTDs \quad --9$$

$$Taluminium = EkmTDa \quad --10$$

$$T_{insulating\ mate} = E_{km} T_{Di} \quad --11$$

$$T_{permanent\ magnets} = E_{km} T_{D\ pm} \quad --12$$

Where, 'T_D' in the equation 7 to 12 stands for total distance travelled and E_{km} stands for CO_2 emitted per travelled km for kg of material.

Total CO_2 emitted for the transportation is calculated by the equation 13.

$$T = T_{copper} + T_{steel} + T_{aluminium} + T_{insulating\ mateial} + T_{permanent\ magnets} \quad --13$$

IV. METHOD

Figure 1. Stages of Electric motor lifecycle

The materials are extracted and shipped to use and then emissions during the use through to recovery. The LCA of absolutely everything from processes such as extracting and shipping raw materials to Category Sustain marketing and until the process Cycle ends and up to rest, taking into account L. phases are covered can find, until it is recycled again as scrap. In general, there are four period in a motor lifetime. for example the raw material processing begins with the raw material and energy sources extract and goes further to them processing such as electric copper, sheet metal, galvanized sections, varnishes, enamels and various types of insulation. The transfer involves the finishing and delivery of the final products and includes energy consumption and waste emission to the environment. The cost of utilization is above all due to the customer interaction, the operation and maintenance energy use of the product. The efficiency and the output power of the equipment is increasingly becoming crucial and pollution is requested by the warming of the components, by the magnetic fields, noise, vibrations and emission of electric materials. Electric motors should be operated normally and we assume the average repair and maintenance radius that they have a life. Waste effective plastics-used-part disassembling and smashing type product The waste used plastics-used part of the product is of disassembling and smashing type, and is provided with regulation on a standard of waste processing of civilized composting or incineration based on product fuel consumption and per unit carbon dioxide emission requirements.

V. RESULTS

For Electric Motors done in OpenLCA the production stage is the most environmentally relevant one in cradle-to-gate LCA study. And that's because, it's the material extraction, is in case you don't know, how much energy it takes to manufacture? The most pertinent environmental impact categories assessed were global warming potential, acidification and eutrophication. In order to mitigate such effects sufficiently and without faults we need, otherwise, the efficiency of material plus recycling cannot actually be understand as an issue of a productive value chain. A lot has been done already to reduce such environmental burden on electric motor production. And thus, preventive common-sense wisdom about the region is not just smart; it's crucial.

Emission of CO_2 motor over life cycle stages are given in the table below and figure represents graph of the two electric motors.

Table 1. Environmental Impact Made by the motors in each Indicator stages

Indicator	Biogenic CO2 (kg CO2 eq)	CO2 from land transformation (kg CO2 eq)	CO2 uptake (kg CO2 eq)	Fossil CO2 (kg CO2 eq)
Induction Motor	1838.35	691.037	2189.64	3.90889
Permanent Magnet Motors	454.344	111.501	621.369	57342.8

The report tab in the OpenLCA, where we will find the calculated results in the template we chose in advance. It is created as an html file with interactive elements based on Java. The report includes introduction, Project variants, Impact categories, Impact assessment result, Variant comparison and relative results. This report is downloaded in pdf format and project report is shown in figure 5.1.

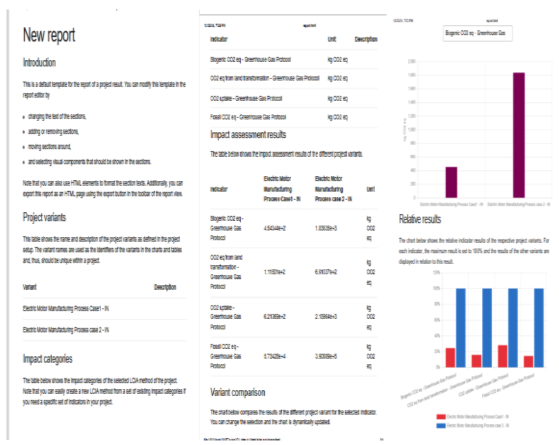

Figure 2. Project report downloaded in OpenLCA

VI. CONCLUSION

Environmental impact carried out by the motors in each Indicator stages as discussed in the result, it can be concluded in that the Induction Motor had a greater environmental impact in respect of biogenic CO2, CO2 uptake, and CO2 from land transformation compared to the Permanent magnet motor. The latter virtually has a significantly higher impact on fossil CO2 emissions. Hence, the selection between these motors regards the specific environmental impact priorities where one balances the trade between different types of CO2 emissions.

VII. ACKNOWLEDGMENT

The authors would like to thank GSSS Institute of Engineering & Technology for Women and Visvesvaraya Technological University (VTU) Belgaum, Karnataka for supporting and encouraging the study.

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