Extended summary

COOKER HOOD ECO-EFFICIENCY ANALYSIS

Curriculum: Energetica

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Abstract.

One of the current priorities of the European Union and the European Commission is to develop sustainable production models and the efficient use of environmental resources

The Integrated Product Policy (IPP) [1] aims at promoting a European market for ecologically compatible products through an innovative process that takes into account the environmental impact of every step in the life cycle of products and services. The new approach assesses production, distribution, lifespan and disposal-related environmental pollution of products and services [2]. Increasing attention has been devoted to the LCA of household appliances [3] [4], which are related to considerable amounts of energy consumption both in the manufacturing phase and throughout their lives.

In the last period (three- five years ago), in accordance with the emissions reduction targets defined by Kyoto Protocol, energy classes were defined by European Commission to qualify also the hoods as already done for the other appliances.

The study was carried out using a cradle-to-grave approach, impacts were assessed with the Eco-indicator 99 methodology [5],[6],[7]. An LCA was conducted according to ISO 14040 standards [8],[9].

The LCA has given as result:

- a parametric model of the environmental impact of a standard hood adaptable to other models
- evaluate and define the most effective improvement projects

The analysis shows that the use phase is predominant in determining the environmental impact of product life cycle. To reduce this impact two energy saving projects have been developed: the inverter driven three-phase induction motor and the lamp with light emission diode.

Finally, the improvements obtained by replacing the single-phase electrical motor with an inverter-driven three-phase induction and the halogen lamps with Light Emitting Diode (LED) [10] lamps were assessed.

The energy saving projects developed permits to obtain the A energy class to the PhD co-financing AIRFORCE S.p.A company for the most part of products.

In addition, the reduction of the life cycle environmental impact is 37%, the maximum energy efficiency of the fan is increased from 22% to 30% and the active power consumption, considering work condition of 600m3/h and static pressure equal to zero, has been reduced from 160W to 100W. The reduction of energy increases with decreasing maximum output of the fan.

The innovation in the sector of household hoods was significant, since did not already exist similar solutions industrialized.

The plans for the new motor and energy efficient lighting system allowed in advanced the Company to take in place marketing activities in the European market and match against hoods and fans major manufacturers.

Keywords. LCA of cooker hood, energy efficiency, tree-phase motor, inverter, lamp LED

1 Problem statement and objectives

The LCA analysis methods are well known, supported by scientific documentation [11], [12],[13],[14],[15] and performed with dedicated analysis software.

In the last three years this analysis applied to the hood, has assumed major importance.

In this last period, in accordance with the emissions reduction targets defined by Kyoto Protocol, the European Economic Community is defining the energy classes to qualify also the hoods as has already been for other appliances.

The energy classes will allow to enhance A classes products and higher, that are "energy saving" product, and banning from the market exclusion of energy inefficient product.

In this industrial and scientific context these research activities were developed.

The environmental impact reduction of life cycle and energy reduction consumption target was achieved with inverter control on three-phase motor project and a dedicated LED lamp design.

Construction technology and three-phase motor behavior are known since a long time in technical literature [16], [17],[18],[19] as well as piloting algorithms in own specific sector.

The most innovative part of the project is the development of a dedicated three-phase motor control application for fans installed in hoods.

The fan has a specific characteristic curves optimized to maximize efficiency.

Other developed project to reduce energy consumption is a custom housing for rectangular LED modules.

2 Research planning and activities

The research project target is to reduce environmental impact and the electrical energy consumption of cooker hoods to achieve future A class energy. Its required to:

1. Apply LCA (Life Cycle Assessment) to a standard hood [9]
2. Evaluate the most effective and sustainable improvements in terms of economic and industrial resources
3. Develop projects defined as three-phase motor and LED lighting system with custom housing

2.1 Life cicle analysis

LCA requires a selection of one type hood as a reference and the boundaries definition for the study [20], which includes the life cycle phases from cradle to grave.

The study include life cycle processes analysis such as the production of raw materials, manufacturing product, packaging, distribution, use, end of life.

Next step is LCIA (life cycle inventor analysis) and the definition of a parametric model for calculating the environmental impact. This was performed with the software Gabi Professional.

Finally, the environmental impact was calculated using the method Eco-indicator 99 EE (Egalitarian Approach) [6],[7], obtaining that the use phase is predominant for all power-grid mixes of different European countries

		From cradle to grave	Cradle to market	End of life	USE (in Italy)
EI99, EE (Egalitarian approach)	EI99, EE (Egalitarian approach)	61,8	5,4	0,0	56,3
ECOSYSTEM QUALITY [PDF*m2*a]	Acidifica-tion/nutrification	1,6	0,1	0,0	1,5
	Ecotoxicity	1,5	0,4	0,0	1,1
	Land conversion	0,0	0,0	0,0	0,0
	Land-use	0,0	0,0	0,0	0,0
HUMAN HEALTH [DALY]	Carcinogenic effects	0,4	0,0	0,0	0,4
	Climate Change	4,7	0,3	0,0	4,3
	Ozone layer depletion	0,0	0,0	0,0	0,0
	Radiation	0,0	0,0	0,0	0,0
	Respiratory (inorgan-ic)	9,9	0,8	0,0	9,1
	Respiratory (organic)	0,0	0,0	0,0	0,0
RESOURCES [MJ surplus energy]	Fossil fuels	42,6	2,8	0,0	39,8
	Minerals	0,9	0,9	0,0	0,0

Table 1 –Environmental impact from cradle to grave IT

2.2 Assessment of improvement projects

To reduce the electricity consumption in use phase and obtaining the best class in future energy classes, have been developed projects with dedicated control system for three-phase motor and a LED lighting.

Both of these solutions could afford to reach their objectives, be economically sustainable and feasible from the PhD co-financing company and his supply chain.

The development of LED lamp allows to obtain an energy lighting systems consumption reduction of 80%, in comparison of halogen lamps and having a custom design of the lamp.

2.3 Development of energy saving projects

Three phase motor

The development of three-phase motor and inverter control was performed according to the experimental method, supported by laboratory tests.

To measure the flow-pressure curves of the samples a Venturi tube was designed and realized in accordance with UNI 5167 [21],[22],[23].

The study was performed planning a series of tests to define a better solution in terms of stator height, number of turns per winding section of copper wire.

The firm-ware control motor has been customized for the application by a targets point of performance (speed and active power consumption) in two working conditions.

The two conditions of work have been reproduced by closing the outlet section of the fan. The industrialization of the control board required three releases for reducing the faults given by electromagnetic interference and many versions of firm-ware to have a motor control compliance to target.

The developed V/F (voltage frequency) control type reproduces the powering voltage for each three phases at a certain frequency give by PWM (Power Width Modulation) with feedback on the current phase.

The feedback signal is used to modify the voltage and frequency of the signal power given to the motor.

The optimal values of voltage and frequency have been investigated by experimental tests performed on the test laboratory just developed.

Lamp LED

Has been defined the aesthetics of the housing lamp according with marketing information, which required a rectangular shape, glass matt or satin, lighting of at least 190 lux on the hob and electric power input 4 W.

The prototypes were realized in order to maximize heat dissipation sub plate.

The final prototype was test to verify the temperature junction of the LED in accordance with manufacturer's specifications.

Finally, tests were carried out of light and life to ensure all market requirements.

3 Analysis and discussion of main results

The projects allow reducing the overall environmental impact by 37% (power grid mix IT).

		From cradle to grave (IT)			
		LED + THREE PHASE	OLD	DIFFERENCE	
EI99, EE (Egalitarian approach)	EI99, EE	39,2	61,8	-22,6	-37%
ECOSYSTEM QUALITY [PDF*m2*a]	Acidification/nutrification	1,0	1,6	-0,6	-38%
	Ecotoxicity	1,1	1,5	-0,4	-27%
	Land conversion	0,0	0,0	0	0%
	Land-use	0,0	0,0	0	0%
HUMAN HEALTH [DALY]	Carcinogenic effects	0,3	0,4	-0,1	-25%
	Climate Change	3,0	4,7	-1,7	-36%
	Ozone layer depletion	0,0	0,0	0	0%
	Radiation	0,0	0,0	0	0%
	Respiratory (inorganic)	6,3	9,9	-3,6	-36%
	Respiratory (organic)	0,0	0,0	0	0%
RESOURCES [MJ surplus energy]	Fossil fuels	26,7	42,6	-15,9	-37%
	Minerals	0,9	0,9	0	0%

Table 2. Impact from cradle to grave IT - overall improvements

The maximum energy efficiency of the fan is increased from 22% to 30% and the active power consumption, considering work condition of 600m^3/h and static pressure equal to zero, has been reduced from 160W to 100W.
Both projects have been fully developed and placed on the market; lamp led since last year and three motor since September 2011 with any call rate registered.

4 Conclusions

The energy saving projects developed permit to obtain the A energy class to the PhD co-financing company for the most products. In addition, the reduction of the life cycle environmental impact is 37%.

The innovation in the sector of household hoods was significant, since did not already exist similar solutions industrialized.

Also parameterized inverter controls were not available to reproduce individual flow-pressure curves for fan efficiency optimization.

The plans for the new motor and energy efficient lighting system allowed in advanced the Company to take in place marketing activities in the European market and match against hoods and fans major manufacturers.

The three-phase project has been structured as a motors development platform allowing futures energy-saving solutions.

Evolution of the project regards the contribution of new partners such as Pisa University and new control system suppliers.

The future control firm-ware version will be a type "field oriented control" that could achieve significant increases in overall fan efficiency system and a cost reduction of the electronic board.

Starting from the same hard-ware will be possible to extend the project to drive permanent magnet motors powered at 220 VAC already available on the market, by replacing IGBT - MOSFET components and updating firm-ware.

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