Environmentally Friendly Design for Electrical Insulation System

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Abstract As the environment issues become more and more important, electrical equipments must be designed and manufactured to satisfy more strict requirements. It is required that we should consider not only the utility performance but also the environmental performance and corresponding environmental legislations during product design and manufacturing processes. Environmental performance of electrical equipment will be the chief target for the manufacturers to pursue in the near future. In this paper, environmental friendly design for electrical products, especially for an insulation system is presented, including material selection, product design and product recycle. A model of environmentally friendly design for electrical equipments is put forward.

Key words: environmentally friendly electrical equipment insulation LCA

1. INTRODUCTION

Two governing factors have been normally considered in a conventional design of electrical systems, these are low cost and reliable performance. Since the environmental issue becomes increasingly important, the associated design guidelines and legislations have been proposed and implemented in more and more countries. Therefore, it is imperative to fully consider environmental friendliness in design of an electrical system and in its manufacture in order to comply with the codes and regulations. At the same time people's demand on the environmental friendly products is growing and producing such a product or system becomes more competitive.

As opposed to the conventional design concept, environmentally friendly designs exact not only high performance and low cost but also green and environmentally friendliness.

Material selection is a key step in the design of an electrical insulation system. It also forms a basis to appraise its environmental friendliness. This is because in a complete cycle of material preparation, usage and disposal, each stage may engender damage to environment. Selecting an insulation material that will cause minimum damage is critical in achieving an environmentally friendly design.

Apart from using environmentally friendly insulation materials, a design of environmental friendly system needs to extend to its whole life cycle. It is necessary to introduce a Life Cycle Assessment (LCA) scheme and procedure to evaluate the effect of each stage of a manufacture process upon environment and to take all necessary measures to contain risks with respect to environment.

2. DESIGN CONCEPT

The essence of an environmental friendly design (Ecodesign) is its environmental dimension that differentiates it from the conventional design. Its concept is to produce a green and environmental friendly system. The concept is being developed apace and its employment has been encouraged by the introduction of relevant regulations and legislation. Enforcement of regulations makes manufacturers put emphasis on the environmental issues. Market demand and social elements feed Ecodesign's further development. This is illustrated by Figure 1.

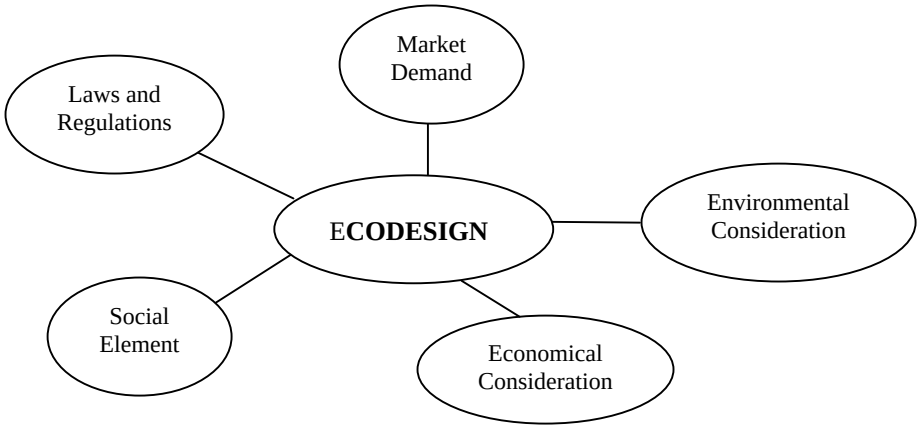

Fig. 1 Influence factors of environmentally friendly design

(a) Law and Regulations

Globalisation of the world economy has forced companies in each country to participate in the process of relevant code development, standardisation and implementation. Many countries have drafted codes and some have started to implement them. For instance, the Montreal and Tokyo agreement, European standard on environment, a standard specifically for electrical equipment known as WEEE (Waste from Electrical and Electronic Equipment), and most importantly ISO 14000.

(b) Market Demand

Since environmentally friendly products are favoured and thus competitive, they are not only beneficial to customers but also to manufacturers themselves.

(c) Environmental Consideration

Such products can significantly reduce the damage to environment.

(d) Economical Consideration

Such design involves consideration of many factors. But this does not equate to more capital investment. For example, an ecodesign that uses less raw materials and consumes less energy can reduce its overall cost. From the life cycle point of view, such a design is economical.

(e) Social Consideration

Electrical products of ecodesign can gain easy acceptance from the general public. It can influence society. Assessment of this influence is a complicated project and it can provide more employment opportunities.

In the field of electrical products and associated manufacture, there have been some successful precedents employing the ecodesign concept.

3. SELECTION OF MATERIALS

Due to the characteristics of the electrical products and their working environment, there are many factors to be considered when selecting materials. Among these an insulation system design is at the forefront. For an assembly of electrical products, an insulation system takes up a big proportion. This is another feature that electrical products differ from other products. Design of environmentally friendly electrical products relies fundamentally on the ecodesign of the insulation system. In selecting insulation materials, their cost and environmental friendliness should be considered in conjunction with the functional properties.

3.1 Procedure in Selecting Materials

The following steps should be taken in selecting insulation materials for electrical products.

1) identify installation environment for the insulation components, especially the immediate surroundings. The first step is to determine the product environment (external and intrinsic, such as voltage) and design requirements including temperature, humidity, supply voltage, compositions of insulation components at the interfaces, and radiation etc.

2) examine properties and specifications of the candidate materials. Eliminate those that do not meet with the requirements.

3) Examine the compatibility of all the components for an insulation system to ensure that the filling gas and liquid will not give rise to a chemical reaction when in contact with other components, such as washers, insulating films, etc.

4) Consider the manufacturing process, cost, product life and re-cycle. Choose the best one after a comparative study.

5) According to the standards (GB of China, ISO, ASTM), prepare samples for tests and follow these procedures to conduct measurements.

The above outlines covers the general procedure to guarantee that the material selected will meet with the requirements. Considering the environmentally friendliness of materials is key to an ecodesign.

3.2 Environmentally Friendly Insulation Materials

Insulation materials are in general made of a few chemical compositions. Their use and disposal can result in disservice to the human being and the environment (Ref 3).

How to evaluate environmental friendliness of an insulation material is a complex subject. Currently a widely used approach is LCA system. LCA is based on the life cycle assessment of a material,

including its manufacture, utilization and disposal, each of which requires a thorough study. One of the LCA features is to quantify the environmental impact. It is expected that in the 21st century, the LCA appraisal system will be employed as a routine procedure in conjunction with the ISO 14000 standard.

In the electrical and electronic industry, a database has been setup and a software has been developed, such as EIME (environmental Information and Management Explorer) which can be used to assess environmental impact likely to be caused by an electrical product (Ref 4).

A majority of materials and their environmental influence have been populated in the package.

Through a comparison of these materials an appropriate material can be chosen.

On the other hand, there are a few rules to follow in the quest for selecting a material. A material will be considered environmentally friendly if it can easily be re-cycled, re-used and can reduce the use of other raw materials when producing components, i.e. meeting the 3R (recycle, reuse, and reduce) criterion. Accordingly the following rules can be used in material selection.

1) Easily recycled using the technology commercially available with minimum cost.

2) Can be reused. After reprocessing the properties meet with all requirements.

3) Homogeneous materials of single composition. Although composite materials have their unique advantages, the more chemical components a material contains, the more complicated a manufacture process will be. As a consequence, the process will consume more energy. Further more, composite materials, such as GRP are not easily recycled and glass fibre may be damaged.

4) Materials in the absence of a fire retardant

5) Avoid using harmful materials proscribed by law

At present, large electrical companies are exploring alternative insulation materials. A typical example is thermal PP materials. Some thermal PP materials have balanced electrical and mechanical properties. Their thermal performance is satisfactory.

The use yields the following advantages:

1) Good mouldability and geo-stability
2) Locking features avoiding the use of metallic materials for joints
3) Long product life with an excellent electrical performance.
4) Easy and economical to manufacture with low cost, simple equipment and large quantity.

4. ECODESIGN OF ELECTRICAL PRODUCTS

Although electrical products bring about an increasing pressure on environment, the paramount design requirement is functionality. Ecodesign or any improvement is hinged upon this condition. Product components, manufacture processes, packaging, transportation, recycle have to be taken into account in an ecodesign. Two objectives have to be achieved:

1) reduction in the use of materials
2) ease of recycling

4.1 Reduction in the Use of Materials

For an electrical product, many aspects can be considered in order to reduce the use of raw materials. As illustrated in Figure 2, a change in the packing arrangement of switchgear can markedly reduce the use of packaging materials.

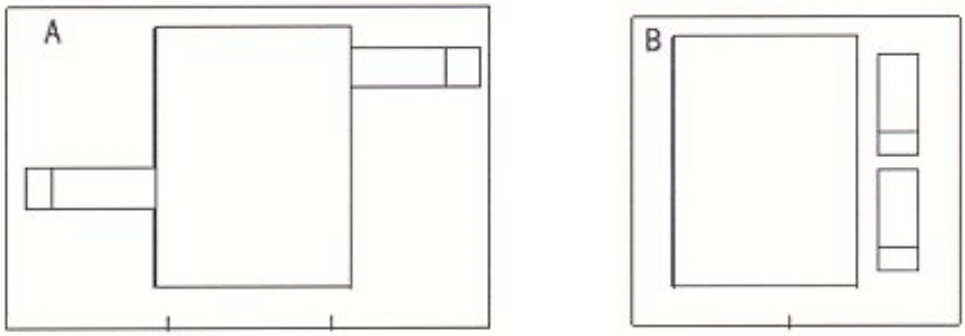

Fig.2 Original packaging (A) and improved environmentally friendly packaging (B)

Apparently, the improved design not only reduces the use of packaging materials, but also the gross volume, resulting in easier transportation.

Evaluating this design change and trade off in the perspective of the environmental impact, we can assume that:

Timber materials are used for packaging, filled with anti-damp and anti-vibration plastic and paper.

From Design A to Design B, a one third volume reduction is achieved. Table 4 quantitatively describes the design change. The resulted benefits are:

1) reduction in the use of raw materials
2) reduction in the use of energy
3) ease of transport and storage
4) economical.

Materials	Unit	Design A	Design B
Timber	Kg	15	10
Plastic	Kg	6	4
Paper	kg	3	2

Table 4. Comparison of Design A and B

When selecting an insulation material, low density materials are preferred if other properties are satisfactory. Low density will result in a reduction in the use of raw materials for the same volume. For insulation materials, insulation strength is a pivotal parameter. Employment of a high insulation strength material will lead to a thinner layer to be used and consequently reduce the usage.

It is important to explore and develop materials of high insulation strength because it is of significance to performance, economy and environmental friendliness.

The current trend is to employ materials of high insulation strength and thinner insulation layer. Figure 3 shows stator insulation thickness with respect to time.

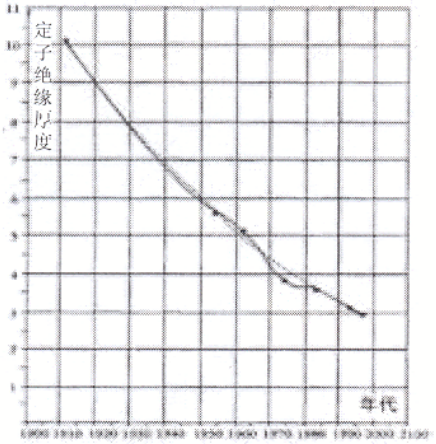

Fig.3 Stator Insulation Thickness as a Function of Time

4.2 Design for Recycle and Reuse

Designers need to review their design concept when the disposal and recycle of a product is considered.

Simple recycle and re-processing of materials should be considered early in the design stage.

A typical design principle for easy recycle and reuse consists of two elements:

1) Avoid the use of components made of mixed materials
2) Use single type of materials.

The key to achieve such a design is easy to assemble components and easy to separate and group according to materials used.

The principles are:

1) Avoid the use of metal reinforced plastic components.
2) Avoid the use of metal bolts and nuts and try to use locking features of the plastic materials.
3) Avoid the use of glue to prevent polLution when recycled.
4) Use the same type and grade of materials. When this is not possible, clearly mark and classify the materials, e.g. use of colour schemes.
5) Avoid the use of decorating materials, words, paints and protective coatings. By selecting proper materials and considering the deflection and colour, the same goal can be obtained. Resin is one such material.
6) Avoid the use of metal plates for marking and identification. Stamp onto products directly. It is convenient to recycle by doing so.

5. RECYCLE AND REUSE OF A PRODUCT

At present, manufacturers put an emphasis on the production of products and are only responsible for design and manufacture. As people gain more environmental awareness and relevant regulations are being introduced, manufacturers become concerned not only about production but also recycle and disposal. In the future they will be held responsible for all stages during the product life cycle, as is illustrated in Figure 4.

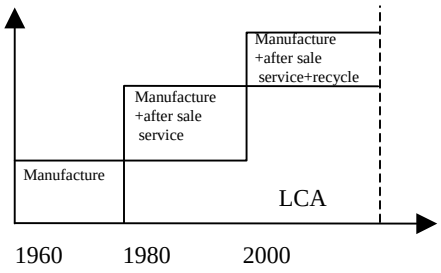

Fig. 4. Responsibility of manufacturer

WEEE, which concerns the recycle and reuse of electrical products, sets a future recycle and reuse target up to 50-75%. Plastic materials make up a large proportion.

Nowadays recycle and reuse is focused on plastic materials. There are three ways:

1) Mechanical Recycling
   This method is used for large structural components, such as external shields and insulation meshes. It involves classification, decommissioning, identification, and pulverising etc. Aged materials should be recycled and used for making products of lower grade and specifications.

2) Chemical Method
   For products of smaller volume and of more materials, separating components of different materials may not be easy. A chemical approach can be used through high temperature and incinerating methods. Emitted useful gases can be collected.

3) Direct conversion

For materials that cannot be reprocessed by the above mentioned methods can be burned directly. This method poses environmentally friendly aspects by saving fossil oil and gas resources.

6. SUMMARY

Ecodesign of insulation systems for electrical equipment should be based on their complete life cycle by introducing an LCA appraisal system and combined with 3R criterion. Each phase of the cycle should be assessed with respect to environmental impact. Appropriate measures can then be taken to minimise the environmental risks. A flow chart of an ecodesign process is shown in Figure 5.

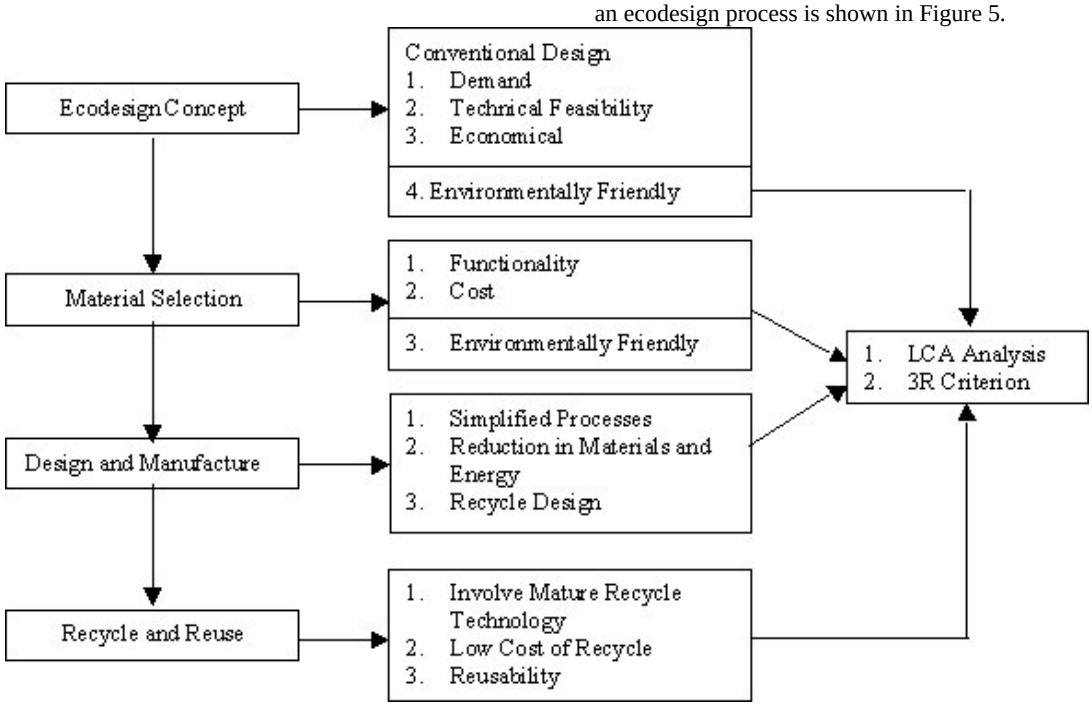

Fig 5. Environmentally friendly design process

7. ACKNOWLEDGEMENT

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