Prioritizing material selection requirements for incinerator using Analytic Hierarchy Process

M.T. Mastura[1,2*], Z. Mahanum[1,2] and M. Nur Hazwani[1,2]

[1)] Faculty of Mechanical and Manufacturing Engineering Technology, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[2)] Centre for Advanced Research on Energy, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

[*]Corresponding e-mail: mastura.taha@utem.edu.my

Keywords: material selection; analytic hierarchy process; incinerator

ABSTRACT – A decision making tools using AHP was conducted to design and develop a sustainable eco-friendly low cost incinerator. This articles provides a structured and effective prioritizing process of material selection requirements using decision making tools. As a result, environmentally safe as one of the alternatives obtained the highest value which is 13.4% amongst the other alternatives. Young's modulus as one of the mechanical properties criteria gained the lowest by 3.7%. This indicates that environmental elements are more important requirements for the materials of design incinerator.

1. INTRODUCTION

Engineering design is an activity that requires consideration of materials, geometric limitation, manufacturing process, function analysis and failure analysis. Each of these elements are related to each other and should be analysed concurrently [1]. Consequently, design process activity would consume less time and perform effectively as all departments communicate directly instead of throwing the ideas over the wall. Conceptual design is one of the earlier stage in design process that critically requires ideas and opinions from other departments to solve any design problems. This include material selection process where decision making tool is employed to prioritize the material requirements and select the most suitable materials for particular design [2].

There are several decision making tools are employed to evaluate the priority value of materials candidates for vary product design such as Analytic Hierarchy Process (AHP), TOPSIS and QFD. Moreover, there is a study from Noryani, Sapuan and Mastura [3] that showed the application of decision making tools in prioritized material requirements for natural fiber composites design. Tramarico et al. [4] stated that Analytic Hierarchy Process (AHP) is commonly applied in making decision as this tool is found in published articles from year 1990 to 2014. Generally, AHP is one of the common tools in decision making and can be applied in various background of study such as supply chain, education, business management and engineering. Therefore, in this study, application of AHP in framework of selecting the most suitable materials for engineering product design is discussed. Design of incinerator is taken as a case study where the thermal application is considered concurrently with other material constraints.

2. RESEARCH METHODOLOGY

Incinerator is commonly used to treat waste by combustion process. Due to harmful gases production during combustion, development of the incinerator must consider a few aspects for the specification of the design. Material selection process is one of the crucial processes that have to carefully done due to high temperature during operation of incinerator. Decision making process in material selection would consider the material that come from ceramic group. However, other parameter such as weight and dimension of incinerator could influence the decision of the right material. Furthermore, safety and maintenance of operation also need to be considered.

Analytic Hierarchy Process via Expert Choice v11.5 software is implemented to prioritize material requirements for material selection of incinerator. Selection of material requirements is based on the literature review as per AHP's hierarchy framework as shown Figure 2.1. Level 1 consists of goal that will be achieved. Level 2 is the criteria for the material requirements. Alternatives for this prioritizing process consist of all the material selection requirements for the solid waste incinerator as listed in Table 2.1.

In AHP, pairwise comparison matrix is developed to judge the preference of each alternative with respect to each criterion in Level 2. Nine-point scale is used to construct these matrices. The calculations to obtain priority vectors are by calculate the eigenvector of comparison matrix. The eigenvalue of the comparison matrix would be used to calculate the consistency index and consistency ratio of the judgments in pairwise comparison. Consistency ratio will be generating from the Expert Choice software and it should be less than 10% to validate the judgement in the pairwise comparison matrix is acceptable.

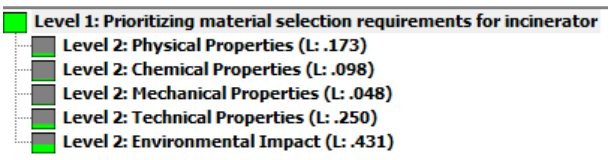

Figure 2.1 Hierarchical framework of prioritizing material selection requirements for incinerator

Table 2.1 Details of alternatives [5]

Alternatives	Description/criteria
Burning rate	Measurement of the linear combustion rate of a material
Environmentally safe	The component are safe to use, generating fewer emissions both during preparation and when in use
Carbon foot print	The amount of carbon dioxide released into the atmosphere as a result of the preparation and during incineration
Corrosion resistance	The material can withstand damage caused by oxidization or other chemical reactions
Elongation to break	The component keeps its shape during impact
Young's modulus	Measurement of the ability of a material to withstand changes in length when under lengthwise tension or compression
Thermal conductivity	Measurement of the heat transfer ability of the material
Coefficient of thermal expansion	Measurement of the fractional change in size per degree change in temperature at a constant pressure.
Specific Heat	The amount of heat per unit mass required increasing the temperature by one degree Celsius.
Density	Measure of mass per unit volume
Cost	Global price per kg
Processing energy consumption	Amount of consumed in a process system or by an organization or society.

3. RESULTS AND DISCUSSION

There are 13 alternatives with respect to the five criteria which are physical properties, chemical properties, mechanical properties, technical properties and environmental impact. There are five comparison matrices for the 13 alternatives but only one of the comparison matrices with respect to environmental impact is shown as in Figure 3.1. As in Figure 3.1, the importance of "environmentally safe" in terms of environment perspective is evaluated on pair-wise basis. To assist in the pair-wise judgement, operation analysis and problem definition that mostly found from literature studies as in Table 2.1 were used as reference. The consistency ratio for comparison matrix with respect to goal is less than 10% which is 9%. This would indicate that judgment on the criteria with respect to goal was considered consistent. Next, the consistency ratio for the comparison matrix of the alternatives with respect to environmental impact is also less than 10% which is 4%. This result is also considered consistent on the judgement towards the 15 alternatives with respect to environmental impact. Finally, the global priority value were calculated and presented in Figure 3.2.

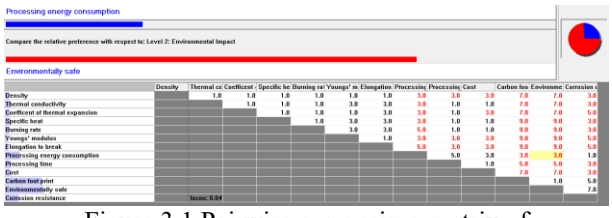

Figure 3.1 Pairwise comparison matrix of "Environmentally safe" with respect to environmental impact

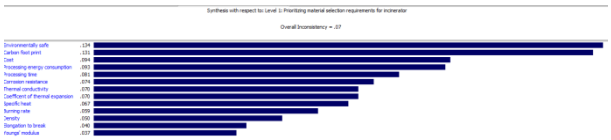

Figure 3.2 Global priority values for material selection requirements of incinerator

As shown in Figure 3.2, environmentally safe is considered as the most important material selection requirement in design development of incinerator followed by carbon foot print and material cost. However, density, elongation to break and Young's Modulus has less important. The present finding revealed that mechanical properties have less impact on the overall material selection process. An incinerator is considered sustainable and eco-friendly when it can reduce the carbon foot print, high combustion efficiency and at the same time economically reduce the volume, weight and health hazard of any solid waste charged to it. Able to handle a wide variety of waste such as recycle waste, organic waste and hazardous waste. The overall installation cost plays a significant role in constructing a good incineration system [6]. A minimal external surface temperature is vital to ensure the safety and comfort to operators

4. SUMMARY

In conclusion, product design development includes the important process that requires effective and systematic early decision making. Therefore, prior to selection material process each of requirements should be prioritized as to ease the process of decision making on the most suitable material. Through AHP, all the requirements are prioritized and it shows that the requirements with regard to environmental impact obtain the higher global priority values. Environmentally safe obtained 13.4% priority value as the most important requirement among the others. While, Young's modulus is considered as the less important requirement as it gained 3.7% for priority value. Hence, design of incinerator should follow the safety and health regulation including the type of materials that is going to employ.

ACKNOWLEDGEMENT

The authors would like to thank Universiti Teknikal Malaysia Melaka for providing the facilities to the authors to carry out this research project.

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