MATERIAL SELECTION FOR SOLAR FLAT PLATE COLLECTORS USING AHP

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ABSTRACT
Material selection is a rapidly growing multi-criteria decision-making (MCDM) problem owing to the large number of factors affecting decision making. The right choice of available material is critical to the success and competitiveness of the manufacturing organization. The AHP is a tool designed to solve MCDM problems. The present work is focused on selection of best polymer to manufacture solar flat plate collector, because polymers have its own advantages over conventional metals. Finally best material has been identified by considering different criteria using AHP.

KEYWORDS
AHP, material selection, solar flat plate collectors, Multi-criteria decision making

NOMENCLATURE

AHP Analytical hierarchical process
g_i - Goal set (i=1,2,.......m criteria)
HDPE - High density polyethylene
MCDM -Multi criteria decision making
n - Size of matrix
PA66 - Polyamide66
PC - Polycarbonate
PET -Polyethyleneterephtalate
PP - Polypropylene
PPE+PS – Polyphenyleneether and polysulfide blend
PPO - Polyphenylene oxide
PPS - Polyphenyl Sulfide
PSU - Polysulfone
PTFE - Polytetrafluroethylene
PV - Priority vector
λ_{max} - Principal Eigen value

1. INTRODUCTION
Today selection of materials is an important part of industrial designs because the competition in the market is heavy. If the product is to be used outdoors, it may be necessary to consider the effect of ultraviolet light rays and other environmental factors. If a proper material selection is not done, the product life tends to be highly unpredictable. Therefore the material selection process is quite important for the long term success of engineering applications. In the selection of materials, a systematic approach is required to select the best materials for a particular application. If a proper technique is followed, first it is required to carefully define the application requirements in terms of mechanical, thermal, environmental, electrical, and chemical properties. Then the choices are narrowed down by the method of elimination.. In the solar engineering industry, which is an emerging energy alternative, there is a greater need to focus attention on proper selection of material. Numerous authors have presented different ranking methods to rank alternatives, during the last two decades . Bottani and Rizzi[2] had used fuzzy logic to deal with vagueness of human thought and AHP to make a selection the most suitable purchased item. In the past Abdul-Hamid, Y.T. *et al.* (1999)[1] used AHP for choosing a manufacturing plant layout. Calantone, R.J. *et al.* (1999)[3] used the AHP for new product screening. From literature, a little work has been done regarding the material selection for solar system components using AHP. To address the lack of research in this work, the present work has been done with the objective to evaluate the best material using AHP process.

2. AHP METHODOLOGY
Step 1: Define criteria for material selection

The first step in any material selection procedure is to establish the criteria to be used for assessing the material. To comply with the criteria for material selection and their importance required data were collected based on the consideration of literature. Important criteria were selected. After defining the criteria for selecting the supplier, the different experts were asked to identify the importance of each criterion by using Saaty s scale

Step 2: Structure the hierarchical model

This phase involves building the AHP hierarchy model. The developed AHP model, based on the identified criteria, contains five levels: the goal, the criteria, and alternatives. Figure 6 shows an illustrative 3-level hierarchy for the material selection problem. The goal of our problem in selecting the material for the solar flat plate collectors is identified in the first level. The second level criteria are

Density	A
Thermal conductivity	B
Cost	C
Safety level temperature	D
Tensile strength	E
Coefficent of thermal expansion	F
Notch impact strength	G

The lowest level of the hierarchy contains of the alternatives, namely the different materials to be evaluated in order to select the best material as shown in Figure 1

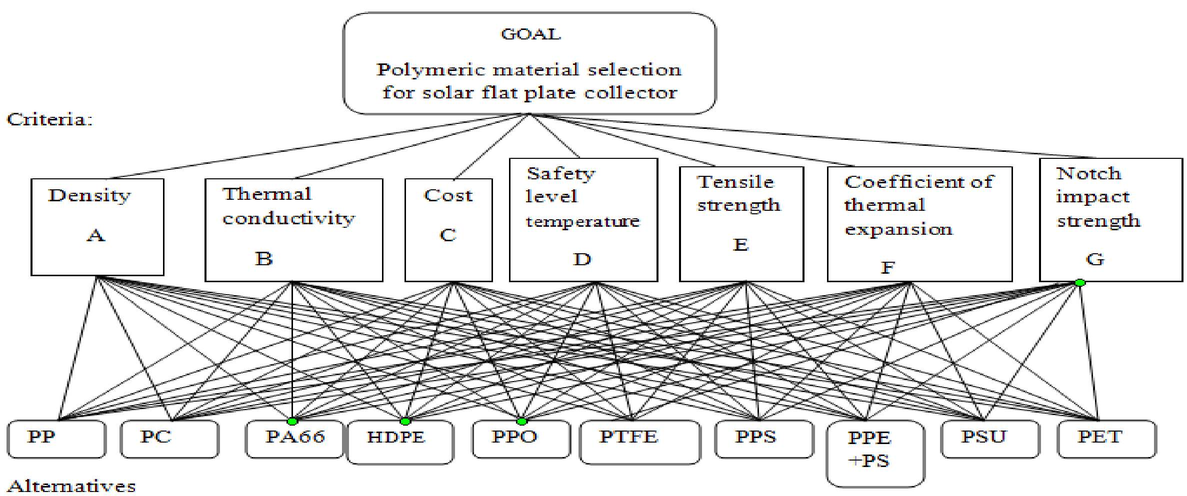

Figure1: Hierarchical structure of the problem

Step 3: Formation of pairwise comparison matrix

Obtain the pair wise comparisons of the relative importance of the criteria in achieving the goal. The criteria are density, thermal conductivity, cost, safety level temperature, tensile strength, coefficient of thermal expansion, notch impact strength will be compared with each other in order to determine the relative importance of each factor to accomplish an overall.According to expert judgment density is not very strongly Preferred than thermal conductivity factor with respect to the best polymer. This means from saaty scale as shown in Table 1, 1/7 is the factor. Likewise expert judgment in linguistic variables is given in below Table

Table 1: AHP measurement scale

Intensity of importance	Definition	Explanation
1	Equally preferred	Two activities contribute equally to the objective
3	Moderately preferred	Experience and judgment slightly favor one activity over another
5	Strongly preferred	Experience and judgment strongly favor one activity over another
7	Very strongly preferred	An activity is favored very strongly over another; its dominance demonstrated in Practice.
9	Extremely preferred	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	For compromise between the values	Sometimes one needs to interpolate a compromise judgment numerically.
1/3,1/5,1/7,1/9	Reciprocals of the above quantities	If activity 'i' has one of the above quantity assigned to it when compared with activity `j' then j has reciprocal value when compared with 'i'

Table 2: Pairwise comparison of criteria

	A	B	C	D	E	F	G	$7\sqrt{z}$	Priority vector
A	1	1/7	1/8	1/5	1/3	1/5	1/4	0.248	0.025 Pv_1
B	7	1	1/3	4	5	3	5	2.549	0.258 Pv_2
C	8	3	1	4	6	3	5	3.65	0.370 Pv_3
D	5	1/4	1/4	1	4	1/3	5	1.032	0.101 Pv_4
E	3	1/5	1/6	1/4	1	1/5	1/5	0.548	0.036 Pv_5
F	5	1/3	1/3	3	5	1	4	1.075	0.162 Pv_6
G	4	1/5	1/5	1/3	5	1/4	1	0.679	0.066 Pv_7
Total	33 T_1	5.125 T_2	2.407 T_3	12.783 T_4	26.333 T_5	7.983 T_6	18.45 T_7	10.1825	

Step4: Calculation of Eigen vectors

Eigen vectors are computed for the above matrix to obtain good approximation of priorities using geometric mean method. This is done by multiplying the elements in each row and taking their *n*th root. Where n is number of criteria.

Eigen vector for density
=7√ (1*1/7*1/8*1/5*1/3*1/5*1/4)=0.248

For thermal conductivity
=7√ (7*1*1/3*4*5*3*5) =2.549

For cost
=7√ (8*3*1*4*6*3*5) =3.65

For safety level temperature
=7√ (5*1/4*1/4*1*4*1/3*5) =1.032
For tensile strength
=7√ (3*1/5*1/6*1/4*1*1/5*1/5) =0.372
For coefficient of thermal expansion
=7√(5*1/3*1/3*3*5*1*4)=1.650
For notched izod impact strength
=7√(4*1/5*1/5*1/3*5*1/4*1)=0.679

Step5: Calculation of priority vector

Priority vectors (pv) are obtained by normalizing the Eigen vector column by total sum of column elements
Priority vector for density =0.248/10.182=0.025
For thermal conductivity
=2.549/10.182=0.258
For cost
=3.65/10.182=0.358
For safety level temperature
=1.032/10.182=0.101
For tensile strength
=0.372/10.182=0.036
For coefficient of thermal expansion
=1.649/10.11=0.109
For tensile strength
=0.679/10.182=0.066

Step 6: Calculation of Principal Eigen value

Multiplying the column totals with the respective PV of each row and then adding the results to obtain Principal Eigen value

$\lambda_{max}=\sum_{i=1}^{n} T_i * Pv_i$

(33*0.025+5.125*0.258+2.407*0.358+12.783*0.101+26.333*0.036+7.983*0.162+18.45*0.066)
=7.736

Step 7: Calculation of consistency index

Then consistency index is calculated. We get

$$C.I = (\lambda_{max}-n)/(n-1)$$
$$=(7.736-7)/6 = 0.122$$

Step 8: Calculation of consistency ratio

The consistency ratio, CR is obtained by dividing CI with random Consistency number for the same size matrix. In this case R.I is 1.32 as the size of matrix is seven see Table 2.

C.R = (C.I/R.I)
= (0.122/1.32)
= 0.092

The value of CR should be less than 10% to be acceptable, in some cases up to 20% may be tolerated. Same calculations can be done for alternatives with respect to criteria, and final global priorty weightage is shown below.

Table 3: Total priority weight of alternatives with respect to criteria

	A 0.024	B 0.251	C 0.358	D 0.101	E 0.036	F 0.162	G 0.066	Priority	rank
PP	0.267	0.019	0.281	0.021	0.018	0.051	0.043	0.1262	2
PC	0.059	0.024	0.146	0.122	0.122	0.102	0.464	0.1188	3
PA66	0.087	0.089	0.078	0.27	0.222	0.175	0.054	0.0951	6
HDPE	0.217	0.375	0.223	0.031	0.014	0.022	0.06	0.190	1
PPO	0.143	0.029	0.098	0.048	0.082	0.127	0.137	0.0699	8

PTFE	0.009	0.055	0.059	0.061	0.02	0.017	0.081	0.050	10
PPS	0.033	0.121	0.011	0.314	0.249	0.207	0.023	0.1108	4
PPE+PS	0.119	0.046	0.03	0.107	0.063	0.061	0.058	0.0519	9
PSU	0.047	0.078	0.026	0.140	0.164	0.124	0.044	0.0731	7
PET	0.023	0.159	0.052	0.175	0.04	0.119	0.034	0.099	5

4. CONCLUSION

This paper has attempted to improve the precision in evaluating materials. From the results the proposed AHP method is practical enough for ranking the material with respect to multi-criteria decision model. This is a best evaluation methodology where vagueness and uncertainty are not involved. HDPE is found to be the best material for manufacturing solar flat plate collector.

5. REFERENCES

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