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Research Paper

SELECTION OF CUTTING FLUID FOR GREEN MANUFACTURING USING ANALYTICAL HIERARCHY PROCESS (AHP): A CASE STUDY

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With the growing concerns of environmental contamination around the globe, various steps are being taken now-a-days to prevent it. Along with other sources, manufacturing processes also play a vital role in contaminating the environment. So green or eco friendly cutting, is the need of the hour. Cutting fluid is one of the greatest contributors of environmental pollution. Apart from contaminating the land and water sources, it poses a direct threat to the operator's health. Prolonged use of cutting fluid results in a number of lethal diseases ranging from skin disease to respiratory diseases. Here in this paper, with the help of Analytical Hierarchy Process (AHP), a decision support system is developed in the unstructured environment to select the optimum cutting fluid which will result in least environmental impacts. Three cutting fluids are considered for the purpose and the one with most favourable qualities is considered as the optimum cutting fluid which will favour green manufacturing. The proposed model considers the most important objective factors such as: Environmental impact (E), Cost (C) and Qualities (Q). The aim is to reduce E and C while increasing Q.

Keywords: Analytical Hierarchy Process (AHP), Green Manufacturing (GM), Multi Criteria Decision Making (MCDM)

INTRODUCTION

Manufacturing processes are an integral part of any industry. But the growing concerns, now-a-days are to reduce the environmental impacts caused by various manufacturing operations. It is estimated that the greatest contributor of pollution is the cutting fluid, used during any machining operations. Cutting fluids are generally used as a coolant or lubricant to ensure a smooth machining operation. Apart from serving as a lubricant, these fluids also serve to ensure good surface finish and improved tool life. Friction during machining process results in the generation of heat which

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in turn reduces tool life. So the section of suitable cutting fluids is very important towards increasing tool life (Çakir *et al.*, 2007).

However along with the above mentioned advantages, cutting fluids also offers some disadvantages. The use of cutting fluids contaminates the environment. The disposal of coolants in water bodies contaminates the water sources to a large extent. M Sokovic and Mijanovic (2001) characterised the ecological factors of cutting fluids and showed its impact on nature, and wild life. Minimum Quantity Lubrication (MQL) is a strategy which supports green manufacturing. It is the technique of spraying minute amounts of high-quality lubricant directly to the cutting tool/ work piece interface instead of using traditional flood coolants. Ali *et al.* (2011) showed significant reduction in tool wear, dimensional accuracy and surface roughness by using MQL technique over dry machining by reducing the temperature in the cutting zone.

The selection of the right cutting fluid is an important criterion towards achieving Green manufacturing and to increase the qualities. Various models have been proposed by various researchers in order to minimise the environmental impacts by cutting fluid.

In this paper Analytical Hierarchy Process (AHP) is used for developing a decision hierarchy, taking into view the various cost and environmental factors associated with the cutting fluid selection.

Analytical Hierarchy Process

Developed by Thomas L Satty, AHP is the process of pair wise comparison of criterion, to obtain priority values for each criteria (Saaty, 2008). Each criterion is assigned a value, based on an expert's intuition to signify its relative importance over the other. Decision making has evolved as a mathematical science and has huge importance in the field of multi criteria decision making (Figuera *et al.*, 2005). The values are numbers ranging from 1 to 9.

Table 1: Basic Scale Given by Satty for Pair Wise Comparison in AHP

Values	Description
1	Equal importance
3	Moderate importance
5	Essential difference in importance
7	Major difference in importance
9	Extreme difference in importance
2, 4, 6, 8	Intermediate values between
Reciprocal	If requirement *i* has one of the above numbers assigned to it whencompared with requirement *j*, then *j* has the reciprocal value whencompared with *i*.

Source: Saaty (1980)

Formation of the hierarchy is the first step of AHP. According to Satty, a hierarchy is the result of people's perspectives and clear understanding of the problem. A hierarchy consists of the goal at the top most position, criteria and sub criteria at the intermediate position and finally ending with the alternatives. Mathematica Aeterna (2012) in their work carried out AHP for with an aim to select a student eligible for All Round Excellence Award for the year 2004-05 by taking seven criteria and five alternative colleges in AP, India. Wu and Wu (1991) used AHP for storage for strategic planning model by the complex strategic problems into a three level AHP model. Despodov Zoran *et al.* (2011) used AHP for the selection of an optimal transportation system in a main haul corridor. AHP is used in various decision making problems like selecting cranes for construction purpose, supply chain management, etc. (Angels and Lee, 1996; Lee and Kwak, 1999; Wedley *et al.*, 2001; Doraid Dalalah *et al.*, 2010; and Shahroodi *et al.*, 2012). Complex problems can be decomposed into constituent parts and arranged in hierarchy. The pair wise comparison of the criterion is convenient in evaluating each criteria separately (Macharis *et al.*, 2004). The flexibility and the ability to check inconsistencies make AHP better than other MCDM techniques (Ramanathan, 2001). AHP minimises the biasing in decision making by evaluating both subjective and objective sides of alternatives (Ishizaka Alessio and Lusti Markus, 2003). One more major advantage of AHP is its ability to combine with other techniques like fuzzy Logic, QFD, etc.

Although AHP has been in use for a long time, since its inception, but the problem chosen here, i.e., the selection of cutting fluid to favour green manufacturing using AHP is a new approach. The reason for considering AHP for this purpose is its ability to define the various problems in a hierarchy and compare the criteria with respect to each other. The ranking of the alternatives then can easily be done on the basis of their priority values.

Selection of the Criteria

For this problem, three major criteria, Environmental factors (E), Cost (C) and Quality (Q) are selected. The Environmental factors are further sub divided into following sub criteria:

Ecological Impact: The cutting fluids degrade the ecological system by contaminating land, water bodies and wild life.

Health and Safety Hazard: Long term exposure to the cutting fluid environment gives rise to some lethal diseases.

Insecurities: Refers to the accidents and other hazards caused by machining.

Checking the Consistency Ratio

Consistency ratio is a parameter to check the consistency of the pair wise comparison (Jeff Kunzto, 2010). A higher value of CR signifies inconsistency in the pair wise comparison. A lower CR value is desirable as it means that the pair wise comparison is consistent.

$$CR = CI/RI \quad ...(1)$$

$$CI = (\text{Lamda max}-n)/(n-1) \quad ...(2)$$

where,

CI = Consistency index

n = no. of criteria

RI = is the random number index

The acceptable value of CR is < 10% or 0.10. If the value of CR becomes more than 0.10, then the evaluation process should be

Table 2: Random Number Index

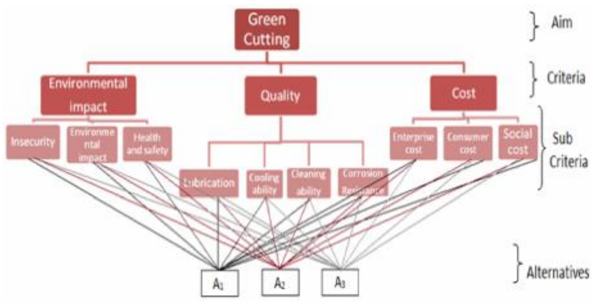
n	RI
1	0
2	0
3	0.58
4	0.9
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

re-evaluated and checked for in consistencies.

The Decision Making (DM) Framework

The hierarchy starts with the goal, i.e., 'Green Cutting' at the top, followed by main criteria and sub-criteria in the successive levels. The hierarchy ends with the alternatives (in this case cutting fluids) to choose from. The aim of this paper is to select the optimum cutting fluid which will favor green cutting by maximising the Quality (Q) and minimising Cost (C) and Environmental Impacts (E) (Figure 1).

Figure 1: The Decision Support System



Case Study

Based on the above model, a case study is selected to discuss the working and significance of the model. Tan *et al.* (2002) created a decision making model based on fuzzy analysis to select a cutting fluid for Green Manufacturing. The three cutting fluids selected for this purpose were i) Traditional cutting fluid ii) Syntilo 9930c, and iii) Syntilo R Plus cutting oil. In the present work, we have used AHP to select the best cutting fluid out of these three above mentioned options. Pair wise comparisons have been made between the criteria, sub criteria to determine their individual weights. The alternatives are also compared with respect to the sub criteria and finally the priority values are obtained. The tables showing the results of the pair wise comparison are shown below:

The overall priority values of the alternatives are thus evaluated and the alternatives are ranked according to their priority values.

RESULTS AND DISCUSSION

From Table 6, the overall priorities of the alternatives have been found and they are ranked according to their priority values.

The cutting fluid A2 has the highest priority value which means that A2 is the best option out of the three cutting fluids which satisfies the conditions for green manufacturing.

Table 3: Pair-Wise Comparison of the Alternatives

	Quality	**Environmental Impact**	**Cost**	**3rd Root of Product**	**Priority Vector**
Quality	1	2	2	1.586667686	0.499826713
Environmental Impact	0.5	1	1	0.793883931	0.250086643
Cost	0.5	1	1	0.793883931	0.250086643
Sum	2	4	4	3.174435548	1
Sum x PV	0.9996534	1.000346574	1.000347		
Lamda max	3.0003466				
CI	0.0001733				
CR	0.0002988				

Table 4: Pair-Wise Comparison of the Sub Criteria

	Toxicity Harm	Security	Environmental Pollution	3rd Root of Product	Priority Vector
Toxicity harm	1	0.5	0.2	0.464515275	0.12217011
Security	2	1	0.333333333	0.873698542	0.229787592
Environmental pollution	5	3	1	2.46398687	0.648042298
Sum	8	4.5	1.533333333	3.802200687	1
Sum x PV	0.977360878	1.0340442	0.993664857		
Lamda max	3.0050699				
CI	0.00253495				
CR	0.004370604				
	Enterprise Cost	**Consumer Cost**	**Social Cost**	**3rd Root of Product**	**Priority Vector**
Enterprise Cost	1	5	2	2.152781735	0.581332077
Consumer cost	0.2	1	0.333333333	0.405846318	0.109593778
Social cost	0.5	3	1	1.144559539	0.309074145
Sum	1.7	9	3.333333333	3.703187592	1
Sum x PV	0.988264531	0.986344001	1.03024715		
Lamda max	3.004855682				
CI	0.002427841				
CR	0.004185933				

Table 5: Pair-Wise Comparison of the Alternatives with Respect to Sub Criteria

Insecurity	A1	B1	C1	3rd Root of Product	Priority Vector
A1	1	0.25	0.166667	0.347048088	0.089118974
A2	4	1	0.5	1.25962998	0.32346218
A3	6	2	1	2.287532932	0.587418846
Sum	11	3.25	1.666667	3.894211	1
Sum x PV	0.9803087	1.0512521	0.979031		
Lamda max	3.0105922				
CI	0.0052961				
CR	0.0091312				
Environmental Polution	**A1**	**B1**	**C1**	**3rd Root of Product**	**Priority Vector**
A1	1	0.1428571	0.25	0.329682865	0.07874157
A2	7	1	3.003003	2.75704413	0.658493379
A3	4	0.333	1	1.100170275	0.262765051
Sum	12	1.4758571	4.253003	4.18689727	1

Table 5 (Cont.)

Environmental Polution	**A1**	**B1**	**C1**	**3rd Root of Product**	**Priority Vector**
Sum x PV	0.9448988	0.9718422	1.117541		
Lamda max	3.0342815				
CI	0.0171408				
CR	0.0295531				
Toxicity	**A1**	**B1**	**C1**	**3rd Root of Product**	**Priority Vector**
A1	1	0.25	0.166667	0.347048088	0.089118974
A2	4	1	0.5	1.25962998	0.32346218
A3	6	2	1	2.287532932	0.587418846
Sum	11	3.25	1.666667	3.894211	1
Sum x PV	0.9803087	1.0512521	0.979031		
Lamda max	3.0105922				
CI	0.0052961				
CR	0.0091312				
Lubricating Ability	**A1**	**B1**	**C1**	**3rd Root of Product**	**Priority Vector**
A1	1	0.142	0.333	0.361981144	0.092347414
A2	7.0422535	1	2	2.412853589	0.615559102
A3	3.003003	0.5	1	1.144940932	0.292093484
Sum	11.045257	1.642	3.333	3.919775665	1
Sum x PV	1.0200009	1.010748	0.973548		
Lamda max	3.0042965				
CI	0.0021483				
CR	0.0037039				
Cooling Ability	**A1**	**B1**	**C1**	**3rd Root of Product**	**Priority Vector**
A1	1	0.3333333	0.166667	0.381939219	0.100140547
A2	3	1	0.5	1.144559539	0.300091775
A3	6	2	1	2.287532932	0.599767678
Sum	10	3.3333333	1.666667	3.81403169	1
Sum x PV	1.0014055	1.0003059	0.999613		
Lamda max	3.0013242				
CI	0.0006621				
CR	0.0011415				

Table 5 (Cont.)

Cleaning Ability	**A1**	**B1**	**C1**	**3rd Root of Product**	**Priority Vector**
A1	1	0.2	0.333333	0.405846318	0.109593778
A2	5	1	2	2.152781735	0.581332077
A3	3	0.5	1	1.144559539	0.309074145
Sum	9	1.7	3.333333	3.703187592	1
Sum x PV	0.986344	0.9882645	1.030247		
Lamda max	3.0048557				
CI	0.0024278				
CR	0.0041859				
Corrosion Resistance	**A1**	**B1**	**C1**	**3rd Root of Product**	**Priority Vector**
A1	1	0.1428571	0.333333	0.36282815	0.09266669
A2	7	1	2	2.408023029	0.615011605
A3	3	0.5	1	1.144559539	0.292321706
Sum	11	1.6428571	3.333333	3.915410718	1
Sum x PV	1.0193336	1.0103762	0.974406		
Lamda max	3.0041155				
CI	0.0020577				
CR	0.0035478				
Enterprise Cost	**A1**	**B1**	**C1**	**3rd Root of Product**	**Priority Vector**
A1	1	5	3.000003	2.463987691	0.648042423
A2	0.2	1	0.5	0.464515275	0.122170093
A3	0.333333	2	1	0.873698251	0.229787484
Sum	1.533333	8	4.500003	3.802201216	1
Sum x PV	0.9936648	0.9773607	1.034044		
Lamda max	3.0050699				
CI	0.002535				
CR	0.0043706				
Consumer Cost	**A1**	**B1**	**C1**	**3rd Root of Product**	**Priority Vector**
A1	1	5	3	2.46398687	0.648042298
A2	0.2	1	0.5	0.464515275	0.12217011
A3	0.3333333	2	1	0.873698542	0.229787592
Sum	1.5333333	8	4.5	3.802200687	1

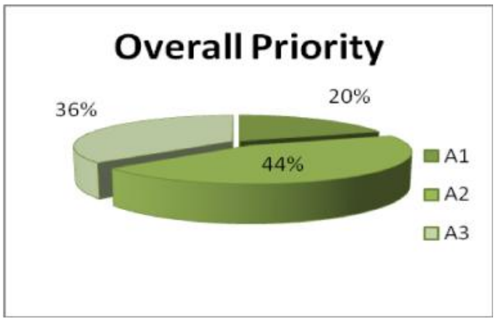
Table 5 (Cont.)

Consumer Cost	A1	B1	C1	3rd Root of Product	Priority Vector
Sum x PV	0.9936649	0.9773609	1.034044		
Lamda max	3.0050699				
CI	0.002535				
CR	0.0043706				
Social Cost	**A1**	**B1**	**C1**	**3rd Root of Product**	**Priority Vector**
A1	1	0.3333	0.5	0.55063165	0.169319304
A2	3.0003	1	1	1.441769522	0.443344315
A3	2	1	1	1.25962998	0.387336382
Sum	6.0003	2.3333	2.5	3.252031152	1
Sum x PV	1.0159666	1.0344553	0.968341		
Lamda max	3.0187629				
CI	0.0093814				
CR	0.0161749				

Table 6: Overall Priority

	Quality 0.4998				Environmental Impact 0.2500			Cost 0.2500			Overall Priority
	Lubricating Ability 0.3000	Cooling Ability 0.3000	Cleaning Ability 0.3000	Corrosion Resistance 0.0999	Toxicity Harm 0.1221	Security 0.2297	Environmental Pollution 0.6480	Enterprise Cost 0.5813	Consumer Cost 0.1095	Social Cost 0.3090	
A1	0.0923	0.1001	0.1095	0.0926	0.0891	0.0891	0.0787	0.6668	0.6480	0.1693	0.1970
A2	0.6155	0.3000	0.5813	0.6150	0.3234	0.3234	0.6584	0.1110	0.1221	0.4433	0.4436
A3	0.2920	0.5997	0.3090	0.2923	0.5874	0.5874	0.2627	0.2220	0.2297	0.3873	0.3625

Figure 2: Overall Priorities of the Alternatives



CONCLUSION

With an aim to select the optimum cutting fluid which will favour Green Manufacturing, a decision matrix was created and using analytical hierarchy process, the best alternative is selected. The aim of the decision matrix is to minimise E, C and to maximise Q. A case study is chosen for the purpose and the optimum cutting fluid is selected by the proposed model.

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