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Selecting a Best Parameter for Manufacturing a Motorcycle Axle Using Multi Criteria Decision Technique [VIKOR Method] & AHP

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Abstract

This study explores the ranking method for selecting the priority parameter for manufacturing of an axle for a motorcycle from various criteria. Before production of any product, predominant selection of the parameters are considered so that after that, there are minimum chances of failure of the system due to unplanned schedule, by this system ranking can be done of most appropriate combination of those conflicting criteria according to requirements.

Keywords: Multiple criteria decision making (MCDM), Ranking, Vikor, Analytical Hierarchy Process [AHP], Hardenability[H.D], Availability[A.V], Chemical Composition[C.C], Mechanical Properties[M.P].

Introduction

The choice of materials for a particular product is a challenging task, as the selected material directly determines the visible quality and the cost of the product. Material selection is a continuous process, aiming to choose the best material for a given application to satisfy a predetermined set of requirements. The materials selection decision is made during the initial decision stage of a product life cycle, i.e., when first the component is designed or when it is redesigned.

An incorrectly chosen material can lead only to a premature failure of a component, but also to an unnecessary cost. At present numerous engineering materials exist than ever before like alloy steels, stainless steels, ceramics, plastics and composites etc. in addition, many materials have successively obtained improved properties like stainless steel does not corrode, rust or stain with water as ordinary steel does. The main purpose of material selection is not to recognize the predominant selection criteria and then to obtain the most appropriate combination of those conflicting criteria according to the requirements.

Some of the important properties of the materials are strength, durability, flexibility, weight, resistance to heat and corrosion, ability of cast, welded or hardened, machinability, electrical conductivity etc. Selection of best parameter for an industrial application from two or more alternatives on basis of several conflicting criteria can be treated as a multi-criteria decision-making (MCDM) problem using VIKOR method.

An Axle

An axle is a straight shaft that is fixed in a location and is used to mount rotating wheels or gears. The wheel or gear can be attached to the axle with a built in bearing or bushing. A bearing or bushing fits inside the centre of the wheels and allows it to rotate without affecting the axle itself. In a vehicle, the axle absorbs braking and acceleration forces, as well as the actual weight of the vehicle. The axle forms a central part of the structural strength of the vehicle. It must be able to absorb the weight and transfer the forces away from the wheels in order to reduce pressure on the joints of the vehicle. The design of the axle has been modified over time to accommodate these multiple requirements and to ensure an appropriate level of structural support.

Different Attributes/Criteria to select Material for an Axle

Attribute / Criteria are defined as a factor that influences the selection of a material for given application. These attributes include; physical properties, electrical properties, magnetic properties, mechanical properties, chemical properties, manufacturing properties (machinability, formability, weldability, castability, heat treatments etc.), material

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cost, product shape, material impact on environment, performance characteristics, availability, market trends, aesthetics, recycling, target groups, etc.

By interviewing the R&D, Production, Quality, Maintenance, Sales staff and Management authority of motorcycle manufacturing companies and axle manufacturing companies' we selected some criteria those are mainly taking in considerations at the time of selection of the material of the axle.

Main criteria for an axle:

1. Cost of raw material
2. Harden ability of raw material
3. Availability of raw material
4. Chemical composition of material
5. Mechanical Properties (Yield strength) of material

1. Cost of raw material: When producing mechanical components the material cost is generally of limited significance. The material cost for a particular component may be 20 times the cost if made from one material compared to another on a weight to weight basis. However the lifetime costs may be very similar if all of the other factors are also taken into considerations.

2. Harden ability of raw material: Hardness of the raw materials for an axle is important to do cold forging processes, but it is not so high that its processing becomes difficult. Harden ability of raw material is measured by Rockwell hardness test on B-scale and for the best cold forging processes for axle its value should lies between 70 to 90 HRB.

3. Availability of raw material: The availability of raw material is also very important for the issue of a best material for an axle in motorcycle. The material selected should be easily available in the market.

4. Chemical composition of material: One of the most important parameters affecting the properties of steel is its chemical composition. All alloy steels has its own compositions of different materials. But the percentage of carbon (C) affect the hardness of a material most, and for an axle the hardness is most important factor. So percentage of C for chemical composition criteria is also very important aspect.

5. Mechanical Properties (Yield strength) of material: Yield strength is one of the types of tensile strength. The yield strength or yield point of a material is defined in engineering and material science as the stress at which the material begins to deform plastically. Prior to yield point the material will deform elastically and will return to its original shape when the applied stress is removed. Once the yield point is passed, some fraction of the deformation will be permanent or non-reversible. For this component the yield point should be high, so that it can absorb shocks due to road surface vibrations.

Methodology

Analytical hierarchy process (AHP) comes under multi criteria decision making that was originally proposed by Thomas L. Saaty. It is a technique developed to deal with complex and complicated decisions. First of all the decision problem is decomposed into a hierarchy of more easily comprehended sub-problems, and each can be analysed independently. The elements of hierarchy can relate to any aspect of the decision problem like tangible or intangible, roughly or carefully measured and estimated etc. Once the hierarchy is build the decision makers systematically evaluates its various elements by comparing them with one another two at a time. It is the essence of AHP that the human judo vent and not just the underlying information can be used in performing the evaluations.

The Al It' converts these evaluations into numerical values that can be processed and used for the entire range of problem. A numerical weight is derived for each element of hierarchy allowing diverse and often incommensurable elements to be compared to one another a consistent manner. This capability distinguishes the A]-IP from other decision making techniques. Analytical hierarchy process (AHP) is most useful where teams are working on complex problems, especially those with high stakes, involving human perception and judgment. It has a unique advantage when important elements of the decision are difficult to quantify and compare. AHP can be applied to the decisions related to choice, Ranking, Prioritization, Resource allocation, Benchmarking, and Quality management decisions. Other areas include Forecasting; service evaluation etc. AHP is a method requires pair-wise comparison. Suppose we do not have any weighting instrument, can we, somehow, try to estimate the relative weights of several different objects by hands? One way is to use the lightest one as a primary standard, assume it is weighted unit (1). On the basis of that, we can guess one other object's weight by lifting the lightest one and another one at the same time and compare them. Another way is to compare the objects in pairs: lift two objects.

Record the estimated difference between them; then lift another pair until we are done with all the possible pairs (i.e., if we have three objects A, B and C, then we need to judge three times: A and B, B

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and C, A and C.). Clearly, the second way named pair wise comparison utilizes more available information. Thomas L. Saaty develops a system called Al-IP that transforms the pair wise comparison scores into weights of different attributes and priorities of all alternatives on each attribute to obtain the overall ranking of alternatives. The procedure of AHP can be summarized as:
1) Formulate the problem;
2) Determine the relative weights of the comparison attributes;
3) Compare the alternatives on each attribute;
4) Aggregate weights to produce final evaluation.

Compromise Ranking Method (VIKOR/VLsekriterijumskon KOmromisno Rangiranje)

The VIKOR is a method for multi criteria optimization of complex systems. "It determines the compromise raking-list, the compromise solution, and the weight stability intervals for preference stability of the compromise solution obtained with the initial weights" (Opricovic, S. and G.-H. Tzeng). Ranking and selecting from a set of alternatives in the presence of conflicting criteria is goal of this method. VIKOR addresses the multi-criteria ranking index based on the particular measures of "closeness" to the "ideal" solution. VIKOR is a useful method in Service Selection problem based on MCDM because it can be work on situation where the preferences of user is not clarified at the beginning of selection process. The compromise solution could be the basis of negotiations, involving the 'decision makers' preference by attribute weights.

The MCDM problem is stated as follows: Determine the best (compromise) solution in multi-criteria sense from the set of J feasible alternatives A1, A2, …AJ, evaluated according to the set of n criterion functions. The input data are the elements fij of the performance (decision) matrix, where fij is the value of the i-th criterion function for the alternative.

Calculations

The VIKOR procedure has the following steps:

Step 1: The first step is to determine the objective, and to identify the pertinent evaluation attributes. Also determine the best,
i.e., (mi j)max. and the worst, i.e., (mi j)min. values of all attributes.

Step 2: Calculate the values of Ei and Fi:

Ei = wj [(mi j)max -(mi j)] / [(mi j)max -(mi j)min]
j=1
Fi = Max.m of {wj [(mi j)max -(mi j)] / [(mi j)max -(mij)min] | j = 1, 2, ….., M}

Step 3: Calculate the values of Pi:

Pi = v ((Ei -Ei-min) / (Ei-max -Ei-min)) + (1 -v) ((Fi -Fi-min) / (Fi-max -Fi-min))
Where, Ei-max is the maximum value of Ei, and Ei-min. the minimum value of Ei; Fi-max. is the maximum value of Fi, and Fi-min. is
the minimum value of Fi. V is introduced as weight of strategy of 'the majority of attributes'. Usually, the value of V is taken as 0.5. However, V can take any value from 0-1.

Step 4: Arrange the alternatives in the ascending order, according to the values of Pi. Similarly, arrange the alternatives according to the values of Ei and Fi separately. Thus, ranking lists can be obtained. The compromise ranking list for a given V is obtained by ranking with Pi measures. The best alternatives, ranked by Pi, are the one with the minimum value of Pi.

Step 5: For given attribute weights, propose a compromise solution, alternative Ak, which is the best ranked by the measure P, if the following two conditions are satisfied (Tzeng et al., 2005):

Condition 1: 'Acceptable advantage' P(Ak)-P(Al)=(1/(N-1)). Al is the second-best alternative in the ranking by P.

Condition 2: 'Acceptable stability in decision-making' alternative Ak must also be the best ranked by E and/or F. This compromise solution is stable within a decision-making processes which could be; 'voting by majority rule' (when V>0.5 is needed) or 'by consensus' (when V˜0.5) or 'with veto' (when V>0.5). If one of the conditions is not satisfied, then a set of compromise solution is proposed, which consists of: Alternatives Ak and Al if only condition 2 is not satisfied. Alternatives Ak , Al , ……, Ap if condition 1 is not satisfied; Ap is determined by the relation P(Ap)-P(Al)˜(1/(N-1)). VIKOR is a helpful tool in MADM, particularly in a situation where the decision maker is not able, or does not know how to express preference at the beginning of system design. The obtained compromise solution could be accepted by the decision makers because it provides a maximum 'group utility' (represented by Ei-min.) of the 'majority', and a minimum of individual regret (represented by Fi-min.) of the 'opponent' (Opricovic

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and Tzeng, 2002, 2003, 2004, 2007). The compromise solution could be the basis of negotiations, involving the 'decision makers' preference by attribute weights and B, B and C, A and C.).

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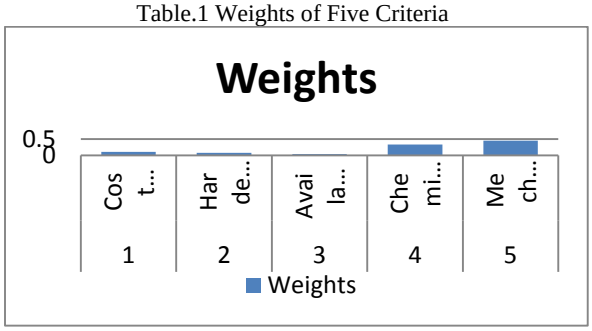
1) Formulate the problem.
2) Determine the relative weights of the comparison attributes.
3) Compare the alternatives on each attribute.
4) Aggregate weights to produce final evaluation.

In the present research various axle manufacturing Industries and R&D's in and around Rohtak (Haryana) were taken that what are the parameters and criteria they are following for manufacturing of axles.

S. No.	Attributes	Weights
1	Cost of raw material	0.1061
2	Harden ability of raw material	0.0757
3	Availability of raw material	0.0393
4	Chemical composition of material	0.3277
5	Mechanical Properties (Yield strength) of material	0.4512

Table.1 Weights of Five Criteria



Graph.1 Weights of Five Criteria

Comparative Analysis

In a highly competitive environment, the relative performance of firm in sale, market share and it depends primarily on its strategic decision and financial aspects. The best attribute selection for an axle motorcycle is very important because an axle is an central shaft for an rotating wheel or gear by taking in concentration criteria like cost, availability of raw material etc.

The selection of best criteria is a typical MCDM problem to deal with uncertain judgment of decision maker, a Fuzzy modification of AHP method is applied as an evaluation tool, where uncertain and imprecise judgment of decision maker are translated into the VIKOR method.

Linguistic Scale	Triangular Fuzzy Scale	Triangular Fuzzy Reciprocal Scale
Just Equal	(1,1,1)	(1,1,1)
Equally important	(1/2,1,3/2)	(2/3,1,2)
Weakly more important	(1,3/2,2)	(1/2,2/3,1)
Strongly more important	(3/2,2,5/2)	(2/5,1/2,2/3)
Very strongly more important	(2,5/2,3)	(1/3,2/5,1/2)
Absolutely more important	(5/2,3,7/2)	(2/7,1/3,2/5)

Analyze Using VIKOR Method

Criteria	Cost	H.D	A.V	C.C	M.P
Cost	(1,1,1)	(2/3,1,2)	(2/3,1,2)	(2/5,1/2,2/3)	(1/3,2/5,1/2)
H.D	(½,1,3/2)	(1,1,1)	(2/3,1,2)	(2/5,1/2,2/3)	(1/3,2/5,1/2)
A.V	(½,1,3/2)	(½,1,3/2)	(1,1,1)	(2/5,1/2,2/3)	(1/3,2/5,1/2)
C.C	(3/2,2,5/2)	(3/2,2,5/2)	(3/2,2,5/2)	(1,1,1)	(½,2/3,1)
M.P	(2,5/2,3)	(2,5/2,3)	(2,5/2,3)	(1,3/2,2)	(1,1,1)

Table.3

Table.4 Fuzzy comparison matrices for five criteria
Using and placing the equations

COST	3.07	3.9	6.17
HARDENABILITY	2.9	3.9	5.67
AVIALABILTY	2.73	3.9	5.17
CHEMICAL	6	7.67	9.5
MECHANICAL PROPERTIES	8	10	12

By using these equations we can find out the value of E1, E2, E3, E4 and E5

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E1	(3.07-3.07)/(8-3.047)	(3.9-3.9)/(10-3.9)	(6.17-5.17)/(12-5.17)
E2	(2.9-2.73)/(8-2.73)	(3.9-3.9)/(10-3.9)	(5.67-5.17)/(12-5.17)
E3	(2.73-2.73)/(8-2.73)	(3.9-3.9)/(10-3.9)	(5.17-5.17)/(12-5.17)
E4	(6-2.73)/(8-2.73)	(7.67-3.9)/(10-3.9)	(9.5-5.17)/(12-5.17)
E5	(8-2.73)/(8-2.73)	(10-3.9)/(10-3.9)	(12-5.17)/(12-5.17)

Table.5

E1	0	0	0.14641	0.146
E2	0.03225	0	0.07320	0.105
E3	0	0	0	0
E4	0.62049	0.61803	0.63396	1.867
E5	1	1	1	3

Table.6

Ei (min) =0 **Ei (max) = 3**

F (1)=1 F(2)=1 F(3)=1

PI= v{EI-Ei(min)} / {EI (max)}-{EI (min)} + (I-v){FI-FI(min)} / {FI(max)-FI(min)}

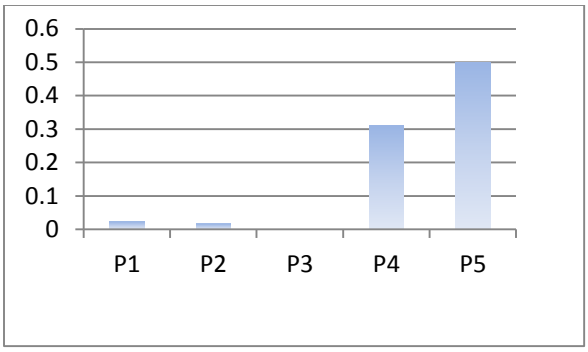
Cost	0.5*{(0.146-0)/(30-0)}+(1-0.5)*{(1-1)/(1-1)}	0.0243
Hardenability	0.5*{(0.1052-0)/(3-0)}+(1-0.5)*{(1-1)/(1-1)}	0.0175
Availability	0.5*{(0-0)/(0-0)}+(1-0.5)*{(1-1)/(1-1)}	0
Chemical Composition	0.5{(1.867-0)/(3-0)}+(1-0.5)*{(1-1)/(1-1)}	0.3111
Mechanical Properties	0.5{(3-0)/(3-0)}+(1-0.5)*{(1-1)/(1-1)}	0.5

Table.7

3. Placing the tables

Cost	P1	0.0243
Hardenability	P2	0.0175
Availability	P3	0
Chemical Composition	P4	0.3111
Mechanical Properties	P5	0.5

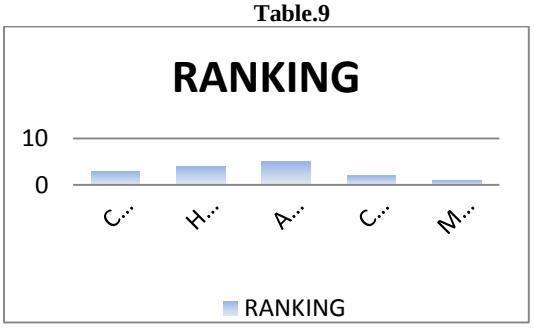
Table.8



Graph.2

Cost	3
Hardenability	4
Availability	5
Chemical Composition	2
Mechanical Properties	1

Table.9



Graph.3

Conclusions

In this present study, feasibility of MCDM approach VIKOR method has been highlighted to solve impact for opting best parameter for manufacturing of an motorcycle axles. The main purpose of material selection process is to recognize the predominant selection criteria and then to obtain the most appropriate combination of those conflicting criteria according to requirements. It is essential that the designer should have a thorough knowledge about the properties of considered materials and their behaviour under working conditions. Some of the important properties of materials are strength, durability, flexibility, weight, ability to cast, machinability, electrical conductivity etc. By following this framework, firms can identify areas of opportunity for improvement in selecting their most prior parameter. The study demonstrates the effectiveness of the said MCDM technique in RANKING the best Attribute/Criteria for manufacturing an axle in the specific region.

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