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Identification of Influential Parameters for Remanufacturing of locomotive wheels Using Fuzzy TOPSIS Optimization

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Abstract

The locomotive wheels have a larger diameter than common wheels, usually above 1,000mm. There are two types of locomotive wheels: the overall wheel and split wheel. For this purpose, the 6 selected methods are assigned ranks using Fuzzy TOPSIS method by taking opinion from decision makers and averaged for further analysis. On the basis of reviews 6 main problems in locomotive wheel due to product in life (Adhesive wear, Creepage, rolling contact fatigue, residual stresses, Chemical wear and Erosive wear) are taken into considerations and 20 decision maker's opinion is taken on measures taken measures taken to prevent problems in locomotive wheel due to product in life are Proper Lubrication, Material Change, Special Coating, Design change, proper maintenance and Contact surface. The result shows that Chemical wear ranking one among all the problems and followed by residual stresses, Erosive wear, rolling contact fatigue, Creepage and Adhesive wear which is greatly reduced by various measures taken by engineers. Fuzzy Topsis Method can be applied in certain other aspects also to make suitable decisions.

Keywords: locomotive wheels, Remanufacturing, Fuzzy TOPSIS.

1. Introduction

Main reason of the short wheel life is the severe rolling contact fatigue (RCF). Wear-Abrasive wear: wear caused by rough and hard surfaces sliding on each other or wear caused by hard particle strapped between two surfaces like hard oxide debris. Adhesive wear: wear caused by shearing of junctions formed between two contacting surfaces. Chemical wear (Corrosive wear): wear caused by formation of any oxide or other components on surfaces due to chemical reaction of the surfaces with the environment. Erosive wear: Wear due to relative motion of contact surfaces while a fluid containing solid particles is between the surfaces. Rolling contact fatigue (RCF): caused by cyclic stress variations leading to fatigue of the materials. Generally resulting in the formation of surface, sub-surface and deep-surface cracks, material pitting and spalling [1]. The level and distribution of residual stresses in treads are among the important factors that have an effect on the reliability of locomotive wheels. Residual stresses are formed during the manufacturing of treads as a result of their rolling and thermal treatment and may change in the process of operation due to increased abrasive wear upon starting, force action during the motion of railway rolling stock, and mechanical treatment by cutting during the turning of a tread in the process of its repair. An excessively high level of residual stresses in wheel treads reduces their strength under shock, as well as alternating and cyclic loads, and this has an effect on their wear. Under the action of loads, the residual stresses are summed with the stresses from eternal forces and may exceed the ultimate elasticity strength and even the ultimate yield strength in local zones, thus leading to the non-uniform elasto plastic strain, instability, and fracture of a tread [2]. Calculations contain a number of uncertainties including heat losses from the wheel by convection and radiation (here neglected). The heat conduction estimates assume perfect mating surfaces at the rail-wheel contact, the absence of insulating films, and they neglect the reduction of the contact patch size accompanying local heating. A reduction in contact patch size is expected to amplify the thermal fluctuations and reduce heat flow to the rail. These details deserve more attention, and it would be desirable to compare the analysis with measurements on a model system [3]. In connection with improving the adhesion of locomotives, a study was made of the conditions of contact existing between locomotive driving wheels and the rail. Observations were made of such measurable quantities as contact area and shape, relative movement or "creep" in rolling, and limiting coefficient of friction, with different values of vertical load, wheel diameter, tractive force, etc. Whenever possible measurements were made upon actual wheels and rails, but when this was impossible the problem was simulated by a model in a material giving greater deflection under load. Consideration was also given to the effect of wear upon tyres and rails. In general, reasonable agreement was obtained between actual and calculated values, except that the areas of contact could apparently be increased by roughness of the contacting surfaces, and in the case of creep there appeared to be some additional factor which has so far been neglected in calculation [4]. Adhesion creepage characteristics of a locomotive wheel simulation under different contaminants, such as water, sand, diesel fuel, lubricating oil, sand after oil and oil after sand, are also reported. It was observed that the liquid contaminants decreased adhesion levels and increased creepage and application reduces the high creepage due to liquid contaminants, simultaneously increasing the attainable adhesion levels. Contrary to earlier findings, it was observed that the degree of sanding does influence the adhesion creepage characteristics, low sanding rates resulting in higher adhesion levels and lower creepage as compared to medium/high sanding rates. The wear and adhesion studies indicate that the beneficial effects of sanding in improving adhesion are more than offset by the increased wear rates. This increase is one to two orders of magnitude, compared to no sanding condition, depending on levels of traction. It is concluded that application of sand should be avoided as far as possible and high adhesion should be achieved by other means in order to minimize wear and the resulting track and equipment costs [5]. The contact stresses between a railroad wheel and rail have become increasingly important in the last decade or two. In the U.S., economic conditions of railroads have dictated usage of heavier freight cars and longer trains, along with more powerful locomotives. The rate of degradation of tracks has consequently increased on most railroads. Wear, plastic flow, and ultimate fatigue of the rails are the main types of rail degradation. These, in turn, lead to several rail defects like flaking, spalling, shelling, cracking, and fracture [1]. The root of all these defects is directly or indirectly related to the increase in the magnitude of contact stresses between wheel and rail [6]. The root causes of damage on the wheels of heavy haul locomotives and its mitigation [7]. In this paper we used Multi Criteria Decision Making Fuzzy Topsis tool for selecting the method of disposal to be adopted for biomedical wastes. Fuzzy numbers are functions whose domain is a specified set they depict the physical world more realistically than any single valued numbers 2. This technique is used for selecting the order of preference for any operation 3, 4. For this purpose, the 6 selected methods are assigned ranks using Fuzzy TOPSIS method by taking opinion from decision makers and averaged for further analysis. On the basis of reviews 6 main problems in locomotive wheel due to product in life (Adhesive wear, Creepage, rolling contact fatigue, residual stresses, Chemical wear and Erosive wear) are taken into considerations and 20 decision maker's opinion is taken on measures taken to prevent problems in locomotive wheel due to product in life are Proper Lubrication, Material Change, Special Coating, Design change, proper maintenance and Contact surface.

2. Analysis and Discussion

Table 1 shows the problems in locomotive wheel due to product in life are such as Adhesive wear, Creepage, rolling contact fatigue, residual stresses, Chemical wear and Erosive wear denoted with P1, P2…P6. The measures taken to prevent problems in locomotive wheel due to product in life are Proper Lubrication, Material Change, Special Coating, Design change, proper maintenance and Contact surface which is denoted by M1, M2…M6.

Table 1: Problems in locomotive wheel due to product in life and Measures Taken

Problems	Description	Measures taken	Description
P1	Adhesive wear	M1	Proper Lubrication
P2	Creepage	M2	Material Change
P3	rolling contact fatigue	M3	Special Coating
P4	residual stresses	M4	Design change
P5	Chemical wear	M5	proper maintenance
P6	Erosive wear	M6	Contact surface

Table 2 shows Linguistic variables which are assigned for problems in locomotive wheel due to product in life like Not Impact, Less Impact, Medium Low Impact, Medium Impact, Medium high Impact, High Impact and Very high Impact along with their notations and Triangular fuzzy numbers. Similarly, it shows the linguistic variables are assigned for measures taken to prevent problems in locomotive wheel due to product in life like Very efficient, Medium efficient, poorly efficient, fairly efficient, Good, Very Good and Excellent along with their notations and Triangular fuzzy numbers.

Table 2: Linguistic variables for problems and measures taken

Problems			Measures taken		
	Notation	Fuzzy No		Notation	Fuzzy No
Not Impact	NI	(0,0,0.1)	Very efficient	VE	(0,0,1)
Less Impact	LI	(0,0.1,0.3)	Mediuum efficient	ME	(0,1,3)
Medium Low Impact	MLI	(0.1,0.3,0.5)	Poorly efficient	PE	(1,3,5)
Medium Impact	MI	(0.3,0.5,0.7)	Fairly efficient	FE	(3,5,7)
Medium high Impact	MHI	(0.5,0.7,0.9)	Good	G	(5,7,9)
High Impact	HI	(0.7,0.9,1)	Very Good	VG	(7,9,10)
Very high Impact	VHI	(0.9,1,1)	Excellent	E	(9,10,10)

In Table 3 suggests on the main problems in locomotive wheel due to product in life and the aggregate fuzzy number is made based on 10 decision makers who are working with respect to locomotive wheels then the aggregated set of linguistic variables is calculated based on decision makers' opinions.

Table 3: Fuzzy decision matrix

Notations	Problems	Aggregate fuzzy number
P1	Adhesive wear	.318 0.463 .627
P2	Creepage	.245 0.5 .6
P3	rolling contact fatigue	.6 .772 .9
P4	residual stresses	.5 .66 .79
P5	Chemical wear	.53 .69 .81
P6	Erosive wear	.60 .79 .9

In Table 4 we taken the average of 10 decision maker's opinion regarding the problems in locomotive wheel due to product in life wrt to measures taken to prevent problems in locomotive wheel due to product in life is taken and we assign the fuzzy numbers to the linguistic variables suggested by decision maker in Table 4 on the basis of values given in Table 2.

Table 4: Normalized fuzzy decision matrix

	M1	M2	M3	M4	M5	M6
P1	0,.1,.3	0,.1,.3	.1,.3,.5	.3 .5 .7	.5 .7 .9	.3 .5 .7
P2	0 .1 .3	.5 .7 .9	.1 .3 .5	.3 .5 .7	3 .5 .7	.3 .5 .7
P3	.1 .3 .5	0 .1 .3	.1 .3 .5	.5 .7 .9	.1 .3 .5	.1 .3 .5
P4	.1 .3 .5	5 .7 .9	5 .7 .9	5 .7 .9	.3 .5 .7	.5 .7 .9
P5	.1 .3 .5	5 .7 .9	0,.1,.3	5 .7 .9	.1 .3 .5	0,.1,.3
P6	.1 .3 .5	.1 .3 .5	3 .5 .7	5 .7 .9	.1,.3,.5	.3 .5 .7

In Table 5, for calculation of weighed normalized fuzzy decision matrix we multiply the values in Table 4 with the aggregated fuzzy no. of its respective column. e.g.: first column of Table 4 is for C1 so values in first column are multiplied by the aggregated fuzzy no for C1 as calculated in table 3 for better understanding consider the following example in above Table 4 first cell shows normalized fuzzy matrix on M1. P1 so for calculation of weighed normalized fuzzy decision matrix for M1. P1 we multiply cell one matrix with aggregated fuzzy number matrix for M1 given in Table 3. Normalized fuzzy decision matrix :(m1, m2, m3); aggregated fuzzy decision matrix for M1: (w1, w2, w3) therefore, weighed normalized fuzzy decision matrix(x, y, z) is equal to:

(x, y, z) = (m1*w1, m2*w2, m1*w2);

Table 5: Weighed normalized fuzzy decision matrix

0 .046 .188	0 .046 .188	.031 .138 .31	.095 .23 .438	.159 .324. 564	.095 .231 .438
0 .005 .18	.122 .35 .54	.024 .15 .3	.0735 .25 .42	.0735 .25 .42	.073 .25 .42
.06 .231 .45	0 .077 .27	.06 .231 .45	.3 .5404 .81	.06 .2316 .45	.06 .231 .45
.05 .198 .395	.25 .462 .711	.25 .462 .711	.25 .462 .711	.15 .33 .553	.25 .462 .711
.053 .207 .40	.265 .483 .72	0 .069 .243	265 .483 .729	.053 .207 .405	0 .069 .243
.06 .237 .45	.06 .23 .45	.18 .395 .63	.3 .553 .81	.06 .237 .45	.18 .395 .63

In Table 6, column no.2 shows Fuzzy positive ideal solutions (FPIS D*) and column no.3 shows Fuzzy negative ideal solutions (FNIS D-). D* can be calculated by following formula:

D*=∑ 1/2[max (|1st-1|; |3rd-1|) + (2nd-1)]

Here we consider weighed normalized decision matrix set from table no. 7 and the value greater between |1st-1| and |3rd-1| is selected and added with (2nd-1). Now D^- is given by:

D^- = ∑ ½ [max (|1st - 0|, |3rd - 0|) + |2nd - 0|] similarly, we find out D- by adding the greater value with 2nd term. We obtain the Relative Closest Coefficient of Strategies

(C*) using the formula,

$C^* = D^- / (D^* + D^-)$

Similarly, all C values are calculated and compared. The method with highest C value is ranked 1st and going so on ranks are assigned to the methods using Fuzzy Topsis.

Table 6: Relative closest coefficient of problems and measures taken

Problems	D*	D#	C VALUES	Rank
Adhesive wear	4.872	1.5734	0.24411	6
Creepage	5.172	1.7675	0.25468	5
rolling contact fatigue	4.936	2.2117	0.3094	4
residual stresses	4.19	3.0765	0.42338	2
Chemical wear	4.9	2.136	0.7035	1
Erosive wear	4.53	2.720	0.37517	3

The result shows that Chemical wear ranking one among all the problems and followed by residual stresses, Erosive wear, rolling contact fatigue, Creepage and Adhesive wear which is greatly reduced by various measures taken by engineers.

3. Conclusion

The survey on problems in locomotive wheel due to product in life was carried out. On the basis of reviews 6 main problems in locomotive wheel due to product in life and 6 main measures taken to prevent problems in locomotive wheel due to product in life. The result shows that Chemical wear ranking one among all the problems and followed by residual stresses, Erosive wear, rolling contact fatigue, Creepage and Adhesive wear which is greatly reduced by various measures taken by engineers. Fuzzy Topsis Method can be applied in certain other aspects also to make suitable decisions.

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