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Virtual Optimization of Motorcycle Sprocket Material by Using FEA and Taguchi Coupled TOPSIS-GA-SA

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Abstract

Sprockets are most commonly employed as a part of vehicle segment and in machineries either to transmit rotating movement between two shafts wherever adapts are contrary or to convey undeviating movement to a pathway and so on. They exist in different measurements, teeth number and are made of various materials. In this study, the current sprocket of chromoly steel is distinguished with the sprocket of AlSiC Metal Matrix Composite. CAD modelling of sprocket has been made through Reverse Engineering approach and analyzed using Finite Element Analysis. In light of the outcomes, sprocket material has been optimized which can perform well under different torque condition keeping same constraints. This study focuses on optimizing sprocket material with respect to torque using Taguchi based TOPSIS method to minimize the maximum stress, maximum strain and maximum deformation obtained. Analysis has been conducted using the L_9 orthogonal array in ANSYS 17.2 version. The developed predictive model is used to formulate the objective function for genetic algorithm and simulated annealing which was used to search for an optimal setting. The confirmation experiments are performed to validate the developed model. It will not only help in designing the CAD model and analyzing it faster but also help in developing more precise sprocket.

Keywords: *ANSYS, CAD, Chromoly Steel, Genetic Algorithm, Metal Matrix Composite, Simulated Annealing, Sprocket, TOPSIS*

3.1.Introduction

A chain sprocket or sprocket-wheel is a profiled wheel with teeth that work with a chain, track or other pricked or indented material. Sprockets are employed as a part of bikes, cruisers, autos, followed vehicles, and other apparatus either to transmit turning movement between two shafts where gears are unacceptable or to bestow direct movement to a track, tape and so on. Inside worldwide principles sprockets are reasonably essential mechanical gadgets. Be that as it may, their adaptability prompts numerous differentiating styles (Ambole and Kale, 2016). Sprockets can be provided in different materials and styles, contingent on the application and seriousness of administration prerequisites. They keep running at fast and a few types of chain are so developed as to be quiet while coinciding with sprocket even at rapid task (Nikam and Tanpure, 2016). The sprocket's teeth work inside a roller chain, in this way exchanging rotational vitality between parallel shafts over separations. Sprockets have a few purposes of high-grinding contact with a roller chain, which is imperative to proficient pivot, yet in addition wears the sprocket and roller chain rapidly. This is battled with greased up bushings around the stick that the sprocket handles, and additionally between the plates that hold the chain together (Ghodake et. al., 2014).

Fig. 1: Chain sprocket assembly of a motorcycle

Different researchers have tried to replace and optimize the sprocket material with other alternative materials. Almost all materials show good mechanical properties as compared to traditional mild steel sprocket. In this study, Taguchi's method is used for experimental design, and multi response optimization techniques has been employed i.e. TOPSIS method (Technique for order of preference by similarity to ideal solution), Genetic Algorithm and Simulated Annealing are used to find optimum results

3.2.CAD Modelling Through Reverse Engineering Process

Reverse Engineering is a process of duplicating a current segment, subassembly, or item, without the guide of drawings, documentation, or computer model. For some product development processes reverse engineering is utilized to create surface models by 3D-examining strategy, and thus this system grants to fabricate distinctive parts for automobiles, machineries, moulds, dies, press tools in a short development period (faro, n.d.). Here, FaroArm scanner is utilized for producing 3D model of the sprocket which is preeminent portable coordinate measuring machine (PCMM). The Input for design of sprocket is taken from rear wheel conventional sprocket model of Hero Xtreme having 43 teeth. The specimen was cleaned, coated with developer liquid and then scanned by using FaroArm Fusion scanner. The scanned model was generated in Geomagic studio software which is used for transforming 3D scanned data into highly accurate native CAD models. After generating, the model was imported in CATIA V5 R21 for more accurate development.

Fig. 2: Sprocket specimen scanned using FaroArm scanner

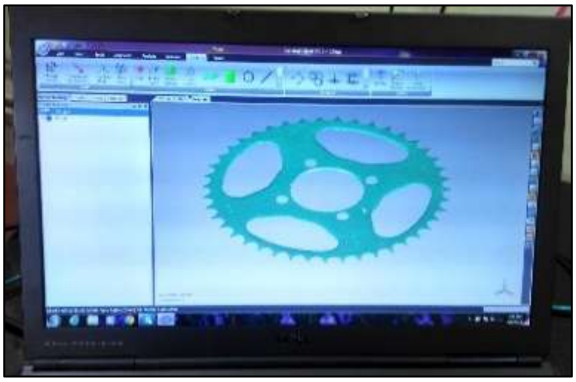

Fig. 3: Scanned specimen generated in Geomagic Studio

Fig. 2: 3-D CAD model of the Sprocket

3.3.Materials for Motorcycle Sprocket

The material choice for the manufacturing of sprocket relies on the strength and operating conditions like wear, noise, load etc. It includes the cost and in addition the material execution. The sprockets might be fabricated from metallic or non-metallic materials. Carbon steel is generally utilized for the manufacturing of sprocket because of its great wearing properties, magnificent machinability and simplicity of creating muddled shapes by machining. Alloy steels are additionally used in a few spots for substantial working condition or aluminium alloy is used for high speed operation like motorcycle racing.

2.1 Chromoly Steel (AISI 4140)

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AISI 4140 alloy steel is high tensile alloy steel. Alloying components incorporate chromium and Molybdenum. Thus, it is called as chromoly steel. It has a superb strength to weight proportion and is impressively more grounded and harder than standard mild steel, yet are not effortlessly welded which requires heat treatment both before after welding to avoid cold cracking. It has high fatigue strength, abrasion and impact resistance, toughness, and torsional strength. While these evaluations of steel do contain chromium, it isn't in sufficiently incredible amounts to give the corrosion obstruction found in stainless steel. One of the characteristics of this steel is the ability to be case hardened by carburization of the surface. This makes this steel a phenomenal material for utilizations, for example, gears, cylinder pins, and crankshafts, and so forth (azom, n.d.). The mechanical properties of Chromoly steel are stated in Table 1.

2.2 Metal Matrix Composite (AlSiC)

AlSiC is a metal framework composite comprising of aluminium grid with silicon carbide particles. AlSiC composites can be created generally modestly the committed tooling anyway causes vast in advance costs, making AlSiC more appropriate for develop outlines. Impervious to erosion, salt water, lightweight and so forth makes AlSiC valuable in numerous fields like development of flying machine, marine development, car parts and so forth. (ofalloncasting, n.d.).

Table 1: Mechanical Properties of AISI 4140 and AlSiC (Approx.)

Properties	AISI 4140	AlSiC 20%	AlSiC 30%
Young's Modulus, E	210 GPa	100 GPa	120 GPa
Poisson's Ratio, ν	0.28	0.30	0.30
Density, ρ	7870 kg/m^3	2700 kg/m^3	2800 kg/m^3
Yield Stress, σ_{yield}	400 MPa	305 Mpa	210 GPa
Ultimate Tensile Stress, σ_{uts}	650 MPa	360 Mpa	220 GPa

3. Finite Element Analysis of Sprocket

Finite element analysis (FEA) is an onscreen method for envisaging how a product reacts to real-world forces, shows whether a product will breakdown, wear out or work the way it is premeditated. It is termed as analysis, but in the product improvement process, it is used to envisage what's going to happen when the product is used. Here, Static Analysis is done by using ANSYS 17.2 and boundary conditions are fitted to get desired solution (Ambole and Kale, 2016)

3.1 Meshing

For meshing, CATPART file of the CAD model of sprocket is imported to ANSYS 17.2. Since all the dimensions of the sprocket are measurable, the best element for meshing is the tetrahedral element. Meshing tool in ANSYS workbench was used to create a very fine mesh with element size 2 mm after convergence. Fig. 5 shows the meshed model of sprocket in ANSYS (Ambole and Kale, 2016).

Fig. 3: Meshed model of sprocket

3.2 Boundary Conditions

Subsequently meshing is accomplished, boundary conditions were applied. These boundary conditions are the reference points for calculating the results of analysis.
Forces acting on sprocket:

- Torque at the rear sprocket
- Gravitational force which is neglected in this case

Calculation for Torque at rear sprocket (Hero Xtreme) (heromotocorp, n.d.):

Maximum Power: 11.64 kW (15.6 BHP) @8500rpm
Maximum torque by Engine (T_e): 13.5 Nm @ 6500 rpm
Primary Gear Reduction (i_x): 3.35
Final Gear Reduction (i_o): 3.0714
Torque at rear sprocket = (i_x) x (i_o) x (Te) = 3.35 x 3.0714 x 13.5 = 138.9 Nm
Sprocket has been restraint at the circumference and maximum torque of 138.9 Nm is applied at centre. In this study, variable torque of 118.9 Nm (lower), 128.9 Nm (medium) and 138.9 Nm (high) has been applied for optimization.

3.3 Solution

After meshing and boundary condition applied to the model, analysis process was done in ANSYS 17.2 version. It computed the deflection with respect to the boundary conditions applied, then on the basis of deflection it calculated the stress. Results were

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observed and consequently changes were planned according to high stress regions acquired. If the stresses were afar the permissible limits then variations such as change in material, change in thickness of component or addition of ribs etc. are made according to suitability. The calculation of stress be contingent upon the failure theory apposite for the analysis.

4. Multi-Objective Optimization Procedures

4.1 TOPSIS Method

TOPSIS Method (Technique for order of preference by similarity to ideal solution) is used for estimating the substitutions before the multiple attribute decision making; based on the fact that the chosen substitute should have the shortest distance from the positive ideal solution and the farthest distance from negative ideal solution. Positive ideal solution defines the best performance values established by any substitute for each attribute whereas negative ideal solution can be demarcated as worst performance values [Pradhan, 2018; Mahapatra and Patnaik, 2007). Following are the steps involved in TOPSIS:

Step 1: Formation of decision Matrix:

$$D = \begin{matrix} A_1 \\ A_2 \\ . \\ A_i \\ . \\ A_m \end{matrix} \begin{bmatrix} x_{11} & x_{12} & . & x_{1j} & x_{1n} \\ x_{21} & x_{22} & . & x_{2j} & x_{2n} \\ . & . & . & . & . \\ x_{i1} & x_{i2} & . & x_{1j} & . \\ . & . & . & . & . \\ x_{m1} & x_{m2} & . & x_{mj} & x_{mn} \end{bmatrix} \quad \text{(i)}$$

Here, A_i (i=1,2, ..., m) represents the possible alternatives; x_j (j=1,2, ..., n) represents the attributes relating to alternative performance, j=1,2, ..., n and x_{ij} is the performance of A_i with respect to attribute x_j

Step 2: Normalization of matrix:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad \text{(ii)}$$

Here, r_{ij} represents the normalized performance of A_i with respect to attribute x_j.

Step 3: Weighted Decision matrix:

$$V = \lfloor v_{ij} \rfloor V = w_j r_{ij} \quad \text{(iii)}$$

$$D = \begin{bmatrix} y_{11} & y_{12} & . & y_{1j} & y_{1n} \\ y_{21} & y_{22} & . & y_{2j} & y_{2n} \\ . & . & . & . & . \\ y_{i1} & y_{i2} & . & y_{1j} & . \\ . & . & . & . & . \\ y_{m1} & y_{m2} & . & y_{mj} & y_{mn} \end{bmatrix} \quad \text{(iv)}$$

Here, $\sum_{j=1}^{n} w_j = 1$

Step 4: Determine the positive ideal and negative ideal solutions:

a) The positive ideal solution:

$$A^+ = \{(\max_i y_{ij} | j \in J), (\min_i y_{ij} | j \in J | i = 1,2,\ldots,m = y1+, y2+, \ldots\ldots\ldots yj+, \ldots\ldots\ldots yn+ \quad \text{(v)}$$

$$A^+ = \{(\min_i y_{ij} | j \in J), (\max_i y_{ij} | j \in J | i = 1,2,\ldots,m = y1-, y2-, \ldots\ldots\ldots yj-, \ldots\ldots\ldots yn- \quad \text{(vi)}$$

Here,

$J = \{j = 1,2, \ldots \ldots .., n | j\}$: Associated with the beneficial attributes

$J' = \{j = 1,2, \ldots \ldots .., n | j\}$: Associated with non-beneficial attributes

Step 5: Determine the distance measures. The separation of each alternative from the ideal solution is given by n- dimensional Euclidean distance from the following equations:

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (y_{ij} - y_j^+)^2 \; i = 1,2, \ldots \ldots \ldots, m} \quad \text{(vii)}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (y_{ij} - y_j^-)^2 \; i = 1,2, \ldots \ldots \ldots, m} \quad \text{(viii)}$$

Step 6: Calculate the Overall performance coefficient closest to the ideal solution:

$$C_i^+ = \frac{S_i^-}{S_i^+ + S_i^-}, i = 1,2, \ldots \ldots \ldots, m; 0 \le C_i^+ \le 1 \quad \text{(ix)}$$

4.2 Genetic Algorithm

Genetic Algorithm is based on the natural advancement process which is utilized to advance answers for complex enhancement issues. A potential answer for an issue might be spoken to by an arrangement of parameters known as qualities. These qualities are consolidated together to frame a string which is alluded to as a chromosome. The arrangement of parameters spoken to by a specific chromosome is called as genotype. This genotype contains the data required to develop a living being known as the phenotype. A wellness work is practically equivalent to the target work in a streamlining issue. The wellness work restores a solitary numerical wellness which is relative to the utility or the capacity of the person which that chromosome speaks to. Two parents are chosen and their chromosomes are recombined, ordinarily utilizing the instruments of hybrid and change. Crossover is more important for rapidly exploring a search space. Mutation provides only a small amount of random search (Mahapatra and Patnaik, 2007; Parida et. al., 2018).

Algorithm of GA approach

1. Random population of chromosomes are generated.
2. The fitness of each chromosome in the population are evaluated
3. Stop and return the best result in current population if the end condition is satisfied,
4. A new population is created by repeating the following steps till the new population is ample. Two parent chromosomes of the population is selected according to their fitness. With a crossover probability, cross over the parents to produce a new offspring. With a mutation probability, transmute new offspring at each position in the chromosome.
5. Usage of new generated population is done for a supplementary run of the algorithm.
6. Go to step 2.

4.1 Simulated Annealing

Simulated Annealing is a probabilistic technique which mirrors the way toward tempering (moderate cooling of liquid metal) with a specific end goal to accomplish least unguent esteem in a minimization issue. The cooling phenomenon is conceded out by governing a temperature like parameter presented with the concept of the Boltzmann probability distribution. Giving to this dispersal a framework in warm balance at temperature T has its vitality probabilistically scattered as per Equation (x) (Mundada and Narala, 2018).

$$P(E) = exp(-\Delta E/kT) \qquad (x)$$

5. Results and Discussion

5.1 Best experimental run

In this study, the sprocket made of chromoly steel and AlSiC MMC is used. The analytical studies were carried out using ANSYS 17.2 software. The analysis was conducted under static loading conditions. The Analysis was carried out using materials and torque as input parameters. These input parameters are shown in Table 2. After applying the parameters like stress, deformation and strain of the sprocket, there was obtained for different run of analysis. The experimental results for the maximum stress, strain and deformation are listed in Table 3. Typically, small values of all the responses are required for optimization in the sprocket. Here, this analysis focuses on optimizing sprocket material with respect to torque using Taguchi based TOPSIS method (Technique for order of preference by similarity to ideal solution) to minimize the maximum stress, maximum strain and maximum deformation achieved. Analysis has been conducted using the L_9 orthogonal array based on Taguchi approach by Minitab Software 18 version. Then, esteemed approach of genetic algorithm (GA) and simulated annealing (SA) was applied using Matlab R2017a Software to obtained results.

Table 1: Input parameters

Factors	Symbol	Level 1	Level 2	Level 3
Material	A	AISI 4140	AlSiC 20%	AlSiC 30%
Torque (N m)	B	118.9	128.9	138.9

Table 2: Orthogonal array L9 of the experimental runs and results

Run No.	A	B	Max. Stress (MPa)	Max. Strain	Max. Deformation (mm)
1	AISI 4140	118.9	25.14	0.000132	0.001301
2	AISI 4140	128.9	27.254	0.000143	0.00141
3	AISI 4140	138.9	29.368	0.000154	0.00152
4	MMC 20%	118.9	25.187	0.000281	0.002766
5	MMC 20%	128.9	27.305	0.000305	0.002999
6	MMC 20%	138.9	29.424	0.000328	0.003231
7	MMC 30%	118.9	25.187	0.000232	0.002282
8	MMC 30%	128.9	27.305	0.000251	0.002474
9	MMC 30%	138.9	29.424	0.000271	0.002666

5.5 Optimization using TOPSIS method

In TOPSIS, the output responses have been standardized into a solo dimensionless scale in between 0 to 1. These standardized data have been tabularized in Table 4. Here, each response parameters have been hypothetical to equally imperative so they have been allotted equal priority weight. Table 5 presents the weighted normalized decision matrix. Positive ideal solution and negative ideal solution are articulated in order to evaluate parting distance which is furnished in Table 6. Finally, overall performance index (OPI) has been computed by TOPSIS has been shown in. SN (Signal to Noise) ratio plot for calculating optimal setting has been shown in Figure 6.

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Table 3: Normalized Output Responses

Sl. No.	Max. Stress	Max. Strain	Max. Deformation
1	0.3065	0.1814	0.0002
2	0.3322	0.1967	0.0003
3	0.3580	0.2119	0.0003
4	0.3071	0.3854	0.0011
5	0.3329	0.4179	0.0013
6	0.3587	0.4503	0.0015
7	0.3071	0.3180	0.0007
8	0.3329	0.3447	0.0009
9	0.3587	0.3715	0.0010

Table 4: Weighted Output Responses

Sl. No.	Max. Stress	Max. Strain	Max. Deformation
1	0.09194	0.05442	0.00009
2	0.09967	0.05900	0.00011
3	0.10741	0.06358	0.00013
4	0.09212	0.11563	0.00043
5	0.09986	0.12536	0.00050
6	0.10761	0.13508	0.00058
7	0.09212	0.09540	0.00029
8	0.09986	0.10342	0.00034
9	0.10761	0.11144	0.00040

Table 5: Positive Ideal and negative ideal solution

Type of Ideal Solution	Max. Stress	Max. Strain	Max. Deformation
Positive Ideal Solution	0.09194	0.05442	0.00024
Negative Ideal Solution	0.10761	0.13508	0.00147

Table 6: Calculated distance measure and Overall performance coefficient

Sl. No.	S+	S-	C+
1	0.0004	0.0822	0.9946
2	0.0092	0.0765	0.8922
3	0.0182	0.0715	0.7969
4	0.0576	0.0249	0.3015
5	0.0488	0.0125	0.2034
6	0.0079	0.0009	0.1007
7	0.0447	0.0426	0.4880
8	0.0510	0.0326	0.3899
9	0.0587	0.0237	0.2872

Based on this study, one can select a mixture of the levels that provide the smaller average response. In Fig. 6, the combination of A_2 B_1 shows the smallest value of the SN ratio plot for the factors A and B respectively. Therefore, A_2B_1 i.e. AlSiC 20% and torque of 118.9 Nm is the optimal parameter combination.

Table 7: The response table for Overall performance coefficient (OPI)

Level	A	B
1	1.003	5.564
2	14.728	7.668
3	8.416	10.915
Delta	13.725	5.351
Rank	1	2

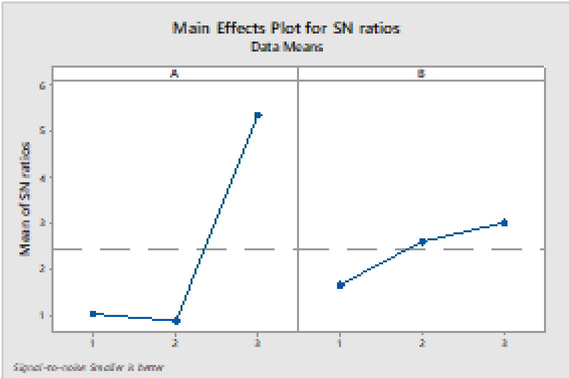

Fig. 4: SN ratio plot with factors and their levels

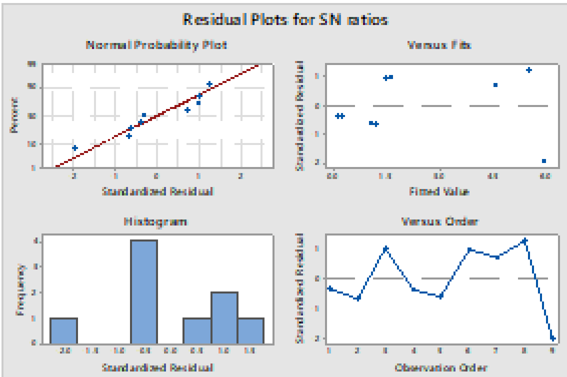

Fig. 5: Residual Plots for overall performance index (OPI)

5.6 Most influential factor

Table 12 gives the results of the analysis of variance (ANOVA) for the maximum stress, maximum strain and maximum deformation using the calculated values from the Overall performance coefficient of Table 7. According to Table 9, factor A, the material with 82.73% of contribution, is the most significant controlled parameters for the sprocket followed by factor B, the torque with 12.74 % of contribution if the minimization of maximum stress, maximum strain and maximum deformation simultaneously considered.

Table 8: ANOVA result for Overall performance coefficient (OPI)

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% Contribution
A	2	283.17	141.587	36.56	0.003	82.73
B	2	43.61	21.804	5.63	0.069	12.74
Error	4	15.49	3.873			4.53
Total	8	342.27				

S = 1.968   R-Sq = 95.5%   R-Sq(adj) = 90.9%

5.7 Confirmation test

After finding the best level of parameters, in order to verify the enhancement of output quality characteristics, a confirmation test is done. The Overall performance coefficient (OPI) estimated is expressed from the output of confirmation experiment. The Overall performance coefficient (OPI) can be estimated using the formulae given in Eq. xi.

$$\mu_{predicted} = a_{2m} + b_{1m} - 3\mu_{mean} \quad (xi)$$

where a_{2m} and b_{1m} are the individual mean values of the Overall performance coefficient (OPI) with optimum level values of each parameters and μ_{mean} is the overall mean of Overall performance coefficient (OPI). The predicted mean ($\mu_{predicted}$) at optimal setting is found to be 0.301636. From the confirmation experiment performed with the same experimental setup, maximum stress increases from 25.14 to 25.187 MPa, Maximum strain increases from 0.000132 to 0.000281 and maximum deformation increases from 0.001301 to 0.002766. Thus, the analytical optimal level performance is 0.3015.

Table 9: Initial and optimal level performance

	Initial	Predicted	Analytical
Level Setting	A_1B_1	A_2B_1	A_2B_1
Stress	25.14	*	25.187
Strain	0.000132	*	0.000281
Deformation	0.001301	*	0.002766
overall performance index (OPI)	0.9946	0.301636	0.3015

*5.8*Optimization using Genetic Algorithm and Simulated Annealing

The selection of optimum parameters has always been a difficult job in designing. In actual fact, the designing parameters are generally selected on the basis of human judgment, experience and referring the available catalogues and handbooks which leads to non-optimal parameters. The optimal parameters can be achieved efficiently by using a suitable optimization method. Consequently, the designing parameters are distinct in the standard optimal format and solved using genetic algorithm and simulated annealing. The minimization problem formulated in the standard mathematical format is as below:

Maximize

$$3.674 - 2.0015a - 0.00890b + 0.43960a^2 - 0.000004b^2 - 0.000078ab \quad (xii)$$

Subjected to constraints:

$1 \leq a \leq 3$

$118.9 \leq b \leq 138.9$

A genetic algorithm and simulated annealing was castoff to solve the above objective function. For GA, a population size of 200 and initial population range covering the entire range of values for “a” and “b” has been used to avoid getting local minimum. The cross over rate used was 0.8 and mutation function was *uniform*. The scaling function and selection function were rank and *uniform* respectively. The optimum parameters obtained by the GA are shown in Figure 8. The optimal solution was obtained after 68 generations. For SA, maximum iterations and time limit has been set to infinite. Boltzmann annealing has been chosen as annealing function. The Initial temperature of the body has been set to 100. The optimal solution was obtained after 1516 generations. The optimum parameters obtained by the SA are shown in Figure 9.

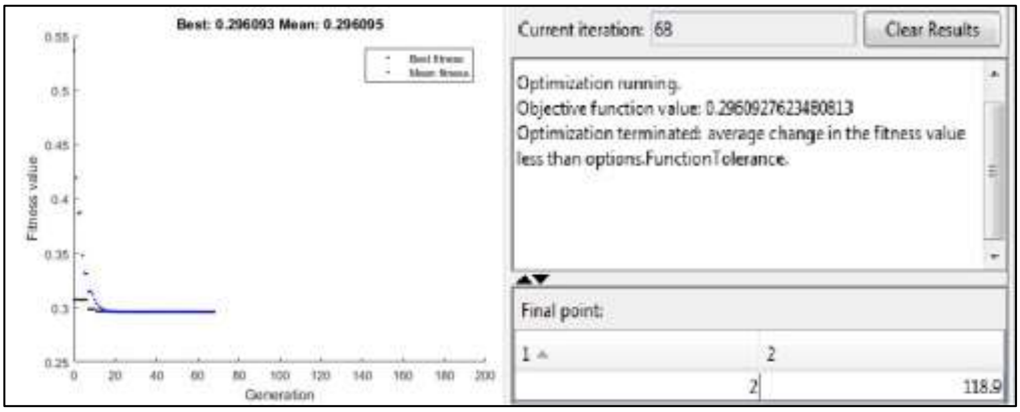

Fig. 7: variations of the best fitness value with generations and the optimum parameters using GA

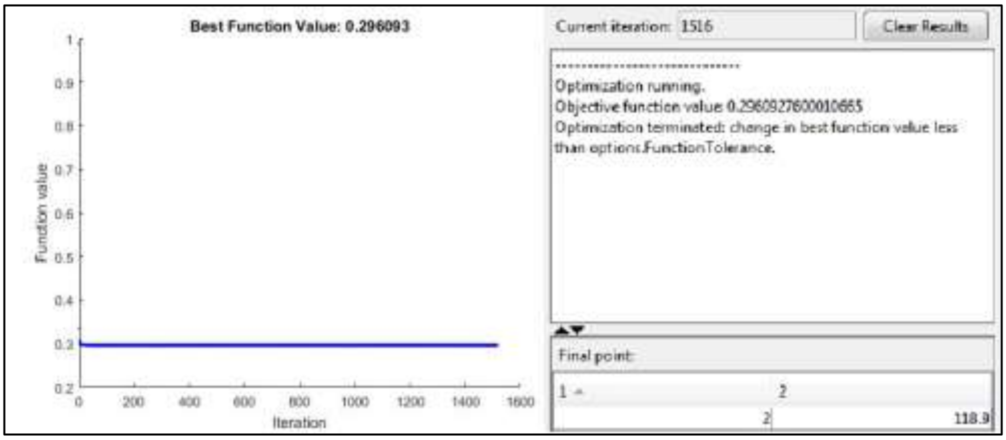

Fig. 8: variations of best fitness value with generations and the optimum parameters using SA

Table 10: Optimal parameters using three optimization methods

Algorithm	A	B
TOPSIS	AlSiC 20%	118.9 MPa
Genetic Algorithm	AlSiC 20%	118.9 MPa
Simulated Annealing	AlSiC 20%	118.9 MPa

Table 11 shows the comparison of optimized parameters obtained from different optimization techniques. Based on confirmatory test and above optimal parameters, Von-Mises stress, total deformation and Von-Mises strain has been plotted in the ANSYS 17.2.

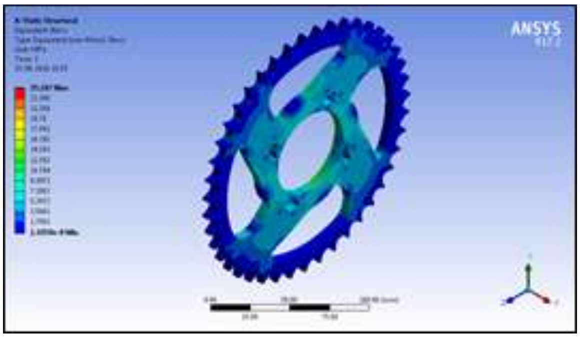

Fig. 9: Von-Mises Stress plot for optimal parameters

Fig. 10 Shows the Von-Mises stress plot, Fig. 11 shows the total deformation and Fig. 12 shows the Von-Mises strain plot.

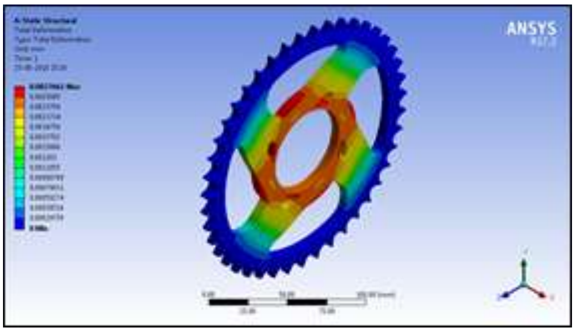

Fig. 10: Total Deformation plot for optimal parameters

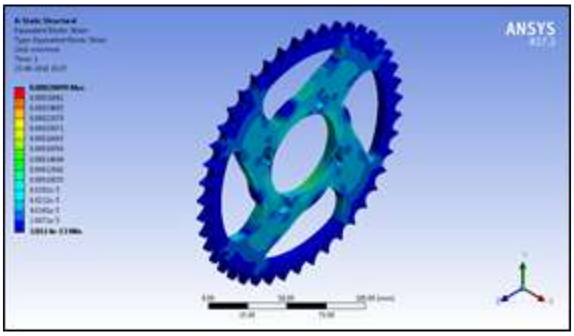

Fig. 11: Von-Mises Strain plot for optimal parameters

7. Conclusions

From results of finite element analysis, it is perceived that stresses are the maximum between pockets and hub. It is also observed that all the three materials have stress values less than their respective permissible yield stress values. Hence, the design is safe. It is found that Chromoly Steel has the least maximum stress, maximum strain and max. deformation among the materials used here for analysis and it also shows the stress, strain and deformation of AlSiC metal matrix composite is very similar to that of Chromoly steel due to its good strength to weight ratio. According to the optimization, AlSiC-20% is the material which can perform well under variable torque condition. Hence, AlSiC-20% Metal Matrix Composite can be chosen as the best alternative material for sprocket for its similar behaviour like that of steel and is expected to perform better with satisfying amount of weight reduction. According to survey after approx. 20,000 km of motorcycle drive chain sprocket assembly needs to be replaced. But, by using AlSiC MMC, chain sprocket can run longer than the conventional steel sprocket. Also both Chromoly steel and AlSiC MMC require less lubrication than conventional mild steel. Hence, by applying All-Purpose Grease in fewer amounts, the wear in the sprocket teeth can be controlled. More weight reduction can be done by re-designing the sprocket. Researchers are also searching for more alternative materials to replace the conventional mild steel. Cost of material is another factor which restricts the use of alternate materials in place of existing materials for sprocket manufacturing for motorcycles. So, these can be used for further development of chain sprocket and more efficiency can be achieved during power transmission.

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