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Assessment of Steering Knuckle by DFMAE Method

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ABSTRACT

Steering knuckle is the main part of the steering and suspension system various link of suspension and steering are linked to it and depend on the steering knuckle. Therefore, it requires high precision, quality and durability. The strength component is always in demanding for race car application. Earlier if the knuckle fails the design team used to modify the design part by trial and error method. Now we are using DFMAE method followed by experimental analysis. The two step process has been used for the same. First part involves modeling and analysis of steering knuckle by CATIA V5 R21 and ANSYS 16.0. The second step is experimental stress analysis by using strain gauge. Strain gauge is component which senses the stress acting on component and the give the result in form of stress vs time. In automotive suspension, the knuckle is the main part through the suspension wishbone link are connected and the suspension spring are on the wishbone. The hub and braking systems are mounted on the steering knuckle to complete the wheel assembly. The wheel and tyre assembly attach to the hub or spindle of the knuckle where the tire/wheel rotates while being held in a stable plane of motion by the knuckle/suspension assembly. Failure region were identified from the static and dynamic analysis and results compared to experimental analysis by using strain gauge. And this analysis carried out under all operating conditions.

Keywords: *DFMAE Method, Stress Analysis, Strain Gauge*

1. INTRODUCTION

Steering knuckle is the main part of the steering and suspension system various link of suspension and steering are linked to it and depend on the steering knuckle. Therefore, it requires high precision, quality, and durability. The main objective of this work is to explore performance opportunities, in the design and life testing of a steering knuckle. In automotive suspension, the knuckle is the main part through the suspension wishbone link are connected and the suspension spring are on the wishbone. The hub and braking systems are mounted on the steering knuckle to complete the wheel assembly. The wheel and tire assembly attach to the hub or spindle of the knuckle where the tire/wheel rotates while being held in a stable plane of motion by the knuckle/suspension assembly. The steering knuckle in dynamic condition possess various dynamic stress acted by vehicle on it such as the tyre forces, steering force and weight of the car body. In the case of automobile vehicle, due to rotation of the wheel torsional stresses act on knuckle and due to braking the braking stress is act on the knuckle. For the better performance and achieve maximum speed the vehicle should be light as much as possible and this done by proper optimization of part use in the car. Steering knuckle is manufactured by various method according to money and quantity and time .Generally in automobile industry manufactured by the casting and forging method. We have been built this part by VMC.

As vehicle suspension and steering system mainly depend on steering knuckle so it should be of high strength. So during designing of knuckle all the forces which were experienced by the race car driver are need to be considered while designing the new car. Now this knuckle is tested by using the ANSYS only. But this design is not always up to the mark for the actual dynamic condition. So the designer should not depend on only software results. So the practical analysis has to be done before the actual use of knuckle in dynamic condition. Therefore we are going to use DFMAE method for the experimental analysis. DFMAE is a systematic group of activities used to determine how to recognize and evaluate potential systems, products or process failures. This method allows designer to report uncertainties associated with potential failure modes inherited form a parts design. This information can be used to mitigate risk and find alternatives to counteract defects. Design teams are able narrow down concepts in developing most resilient part design. The main component we used in DFMAE method is strain gauge. . We use strain gauge to measure stress and strain on steering knuckle. Invented by Edward E. Simmons and Arthur C. Ruge in 1938, the strain gauge device is based on the Wheatstone bridge circuit. The strain gauge device consist a chip it consist of a flexible copper metal strip. When there is difference in the resistance is occurred due to stress acting on knuckle recoded by the receiver and graph is drawn.

2. LITERATURE REVIEW

M. Fonte, V. Infante, L. Reis, M. Freitas have studied and give A failure mode analysis of a diesel motor (110 kW) crankshaft from an automobile vehicle is presented. After 120,000 km in service, an abnormal vibration was detected which was increasing with the time. Then the crankshaft was subjected to a simple vibration analysis and a preliminary indication of possible existence of a crack was concluded. A crack was found at the crankpin web-fillet and after a complete opening of the crack, the failure analysis showed that fatigue was the dominant failure mechanism.

Huai-Wei Lo, James J.H. Liou, Chun-Nen Huang, Yen-Ching Chuang, give the knowledge about increasing the reliability of machine tools and reducing possible risks during the manufacturing process is crucial for the future of industry. The failure mode and effects analysis (FMEA) method is reliant upon the experience of experts to determine the primary failure modes and detect the most critical factors for preventing risk.

Chien-Yi Huang, Kuo-ChingYing give the Printed circuit boards (PCBs) are composite structures consisting of FR-4, solder mask, and Cu materials. When heated during reflow, these materials exhibit different levels of expansion because of their dissimilar thermal expansion coefficients. Currently, the shadow moiré method is the primary means for measuring PCB war page. However, applying this method to soldered PCBs can yield inaccurate war page data because of differences in component height.

K. Zhou, Z.Y. Wu it give information about Structural performance assessment is essential for maintaining the safety and functionality of in-service civil infrastructures. The field measurements that provide engineers with adequate useful information are required for effectively monitoring and evaluating structural performance. Moreover, strain/stress information generally shows powerful capacity for detecting the local structural property variations. Thus strain gauges are commonly used for monitoring and testing structural performance. Placing strain gauges is the key step towards a cost-effective monitoring or testing program.

According to research paper available on Steering knuckle and Strain gauge and DFMAE method. We conclude that the DFMAE method is used for the Analysis of failure mode and effect on The steering knuckle .So we decided to do the steering knuckle analysis by this DFMAE method.IN this method we calculated force analysis calculation according to race track condition and the theoretical analysis by using ANSYS software by using strain gauge we are going to compare that both reading.

Amit Jomdea, Virendra Bhojwanib, Shreyans Kediab, Nitish Jangaleb, Kshitij Kolasb, Pravin Khedkarb, Suhas Deshmukh give info about The compressor is the most important and expensive component in Refrigeration system. Moreover, linear compressor is an immerging technology in cryogenics and refrigeration field. Hence, it is necessary to improve the reliability of the linear compressor. Failure modes effects and criticality analysis (FMECA) is a step-by-step approach for identifying all possible causes of failures and its effects in designing, manufacturing and assembly process of a product. In this paper, an attempt has been made to perform FMECA of linear compressor. Major failure modes such as valve failure, continuity in coil former, breakage of flexure bearing and leakage are identified. The effect of these identified failure modes is studied. Depending on impact of failure modes on the system components are classified into different levels. In this work, 7 failure modes of linear compressor are prioritized by probability of occurrence, detect ability and severity of the failure, accordingly Risk Priority Number (RPN) is calculated. The results of this analysis can be used to improve the design and optimize the performance of the linear compressor.

Rakesh Kolhapure, Vasudev Shinde, Vijay Kamble This paper presents the geometrical optimization of strain gauge 'Double Ended Shear Beam' (DESB) force transducer. Multi objective optimization of elastic member of transducer is carried out by maximum stress sustaining capacity of strain gauge by minimizing volume. Optimal design utilizes the Finite Element Method (FEM) software. Combined Taguchi and Grey Relational Analysis (GRA) is used for optimization. Taguchi method has been applied to construct an orthogonal array based on selected parameters. Next, multi-objective optimization is performed. As Taguchi method is unable to perform multi-objective optimization combined approach of Taguchi and Grey Relational Analysis (GRA) is carried out. This combined approach gives optimum parametric combination based on highest Grey Relation Coefficient (GRC). Analysis of Variance (ANOVA) is statistical technique is used to investigate contribution of each process parameters on the performance characteristic.

3. CRITICAL REVIEW OF LITERATURE

According to research paper available on Steering knuckle and Strain gauge and DFMAE method, we conclude that the DFMAE method is used for the Analysis of failure mode and effect on The steering knuckle .So we decided to do the steering knuckle analysis by this DFMAE method.IN this method we calculated force analysis calculation according to race track condition and the theoretical analysis by using ANSYS software by using strain gauge we are going to compare that both reading.

4. OBJECTIVES

- Evaluation of forces on steering knuckle. To find solution to avoid failure of steering knuckle.
- To evaluate the forces acting on steering knuckle during its various operating conditions.
- To eliminate trial and error method during the design stage and used to design modify by using experimental analysis by using strain gauge.

5. METHODOLOGY

As we are participants of racing events we are familiar with the all racing conditions. By taking this condition into consideration we calculated the forces that would be acted on racing car in dynamic conditions.

1. By this stress analysis we developed 3D cad model of knuckle by using CATIA V5.
2. After the creation of 3D CAD model we have done the stress analysis by using ANSYS.
3. According to the results, generated by ANSYS, the modification in 3D CAD model has been done.

Now, based on the design specification the actual part manufacturing is done by using machining methods VMC. Now at this stage, we are doing the stress analysis of steering knuckle in dynamic condition of car by using strain gauge.

6. EXPERIMENTAL SETUP

FORCE ANALYSIS DURING DYNAMIC CONDITION-

6.1 Braking Torque

When the brakes are applied, the brake shoes press against the brake drums or the brake pads press against the disks. This generates frictional forces, the level of which can be controlled by the driver by the pressure applied to the brake pedal. The product of the frictional forces and the distance at which they act from the axis of rotation of the wheel is the braking torque *M*B.

$$\text{Braking torque} = T_B \times r_e$$

$$= 4905 \times 99.5 \times 10^3$$

$$= 488.036 \text{ N-m}$$

6.2 Weight Transfer Due To Turning:

During acceleration and braking, inertia of the vehicle chassis causes a load transfer in longitudinal direction on the vehicle; i.e. the load form the rear is transferred to the front while braking and the opposite effect takes place while accelerating.. Inertia causes load transfer in lateral direction; i.e. the load form the right side is transferred to the left side while taking a right turn and vice versa.

$$\text{Inertia force} = \text{mass} * \text{acceleration}$$

$$= 250 * 3.70$$

$$= 925.92 \text{ N}$$

6.3 Forces Due To Steering Gear Box:

This is the force exerted by the steering gearbox on the steering arm mounting of the knuckle through the tie rod while turning. Torque steer is a sensation that is commonly experienced in powerful front-wheel-drive cars. Car pulling to one side of the road as you accelerate. In turn, this means an unequal amount of stress is put upon the drive shafts by the engine torque and that's what causes the car to pull to one side.

6.4 Forces in Cornering:

Lateral force or side force is the cornering force produced by a vehicle tyre during cornering. It is equivalent to the centrifugal force generated due to cornering**.**

$$\text{CENTRIFUGAL FORCE} = MV^2/R$$

$$= 250*(5.55^2)/7.5159$$

$$= 1024 \text{ N}$$

DESIGN PARAMETERS FOR KNUCKLE:

Factors Consider During Design The Steering Knuckle:

- **Roll center =** Height of steering knuckle is consider on the basis how roll centre is required for better turn in high speed and car should not go out of the road.
- **Castor**=castor angle is the angular displacement of the steering axis from the vertical axis of a steered wheel in a car , motorcycle, bicycle or other vehicle, measured in the longitudinal direction.
- **Camber** = It is the angle of the wheel centre vertical axis to the tilt of the tire If the tire tilt outer side means the positive camber. If the tire tilt inner side mean negative camber.
- **King pin inclination =** It is the angle between the line drawn from centre of knuckle and the vertical Centre axis of knuckle. The standard king pin to inclination lies between 7 to 10 degree.

Scrub Radius = the scrub radius is the distance in front view between the king pin axis and the centre of the contact patch of the wheel, where both would theoretically touch the road.

DESIGN OF STEERING KNUCKLE

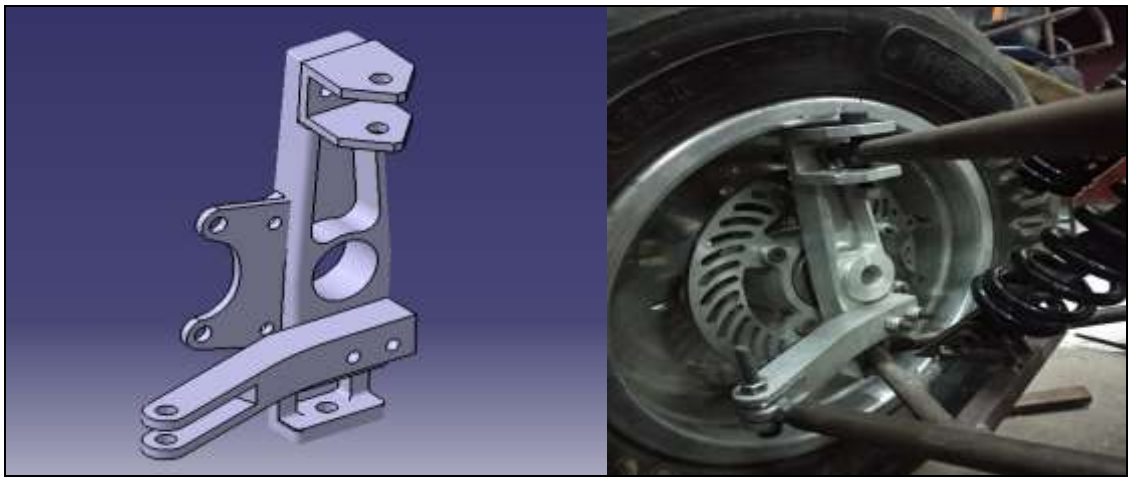

Figure 1: Design of steering knuckle by using CATIA.

7. RESULTS

In this analysis is carried out by using ANSYS software during this ANSYS the above all condition forces are acted in cad model and ANSYS software solve the analysis. By doing this theoretical analysis we get theoretical value of deformation and stress in model

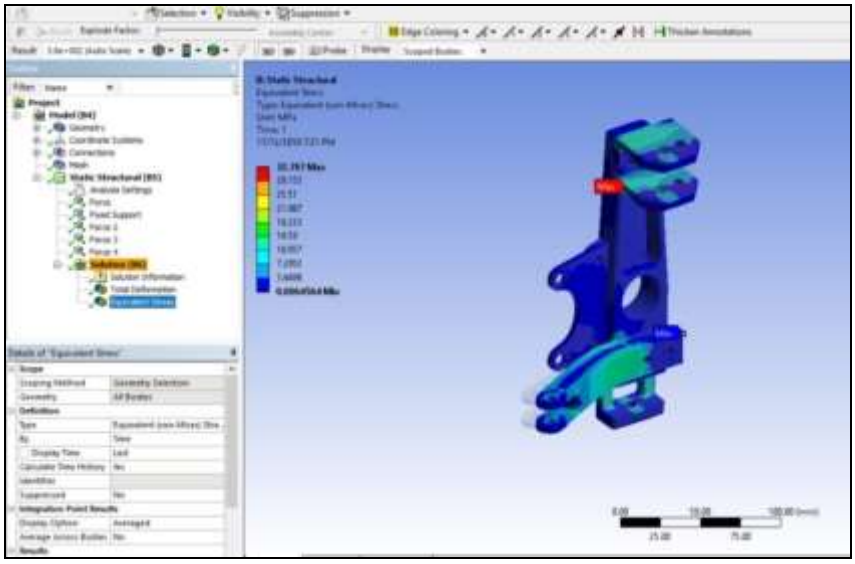

Figure:2 Deformation produced in Knuckle Joint calculated by ANSYS

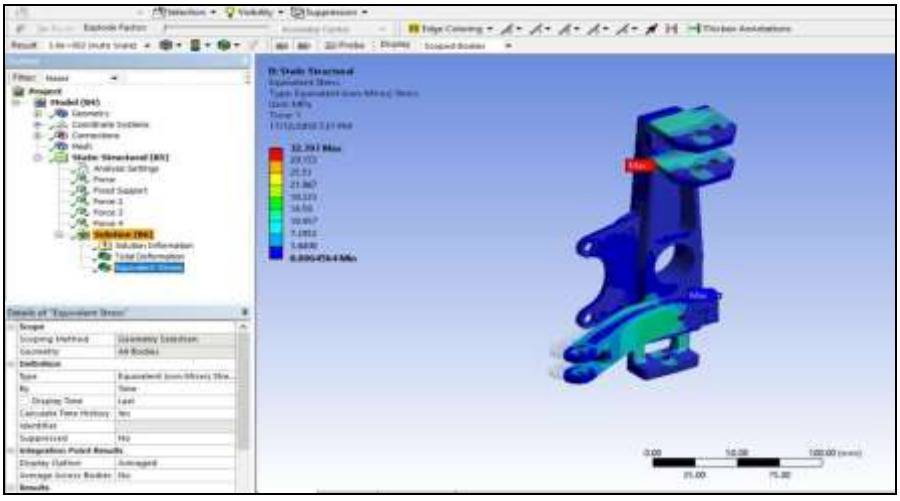

Figure:3 Stresses produced in Knuckle Joint calculated by ANSYS

8. CONCLUSION

In this project we studied the DFMAE method and we applied that method to find out the stress acting on the steering knuckle during the dynamic and static condition of car. Experimental analysis is done by the strain gauge.

Table No: 1 Forces of Steering Knuckle

SR. NO	FORCES IN DYNAMIC CONDITIOS	VALUE OF FORCES
1	Lateral force in cornering	1024N
2	Braking force on caliper mounting	4905N
3	Weight transfer due to braking/ turning	925N
4	Forces due to steering arm tie rod	According to steer torque

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