International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622
International Conference On Emerging Trends in Mechanical and Electrical Engineering
(ICETMEE- 13th-14th March 2014)

RESEARCH ARTICLE OPEN ACCESS

"Taguchi parametric optimization technique used for reduction in failure of rear axle shaft in automobile vehicles by using different materials"

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ABSTRACT:
This report describe the **reduction in the failure of 'rear axle shaft' used in an automobile** by the application of the '**Taguchi Parametric Optimization Technique'** by using different material, different load condition, torque, stress etc. on the shaft.
The work hasbeen carried out in order to establish, whether the failure was the cause (generally due to material composition, subjected to torsional stress and bending stress due to self-weight or weights of components or possible misalignment between journal bearings.) or a consequence of the accident,after failure, which resulted in the vehicle suddenly pulling right or left. Significant impact damage is caused to the vehicle.
Keywords: Taguchi technique, rear axle,

I. Introduction

Diffrent vehicles have different type of axle shaft-differential assembly incorporated into the driveline. Rear wheel Drive is a common form of engine-transmission layout used in automobiles. Understand that rear wheel drive means the power from the engine and the transmission goes to the rear wheels. In automobiles, axle shafts are used to connect wheel and differential at their ends for the purpose of Transmitting power and rotational motion. In operation, axle shafts are generally subjected to torsional Stress and bending stress due to self-weight or weights of components or possible misalignment between Journal bearings. Thus, these rotating components are susceptible to fatigue by the nature of their operation and the fatigue failures are generally of the torsional, rotating-bending, and reversed (two-way) bending type.In rear wheel drive vehicles, the rear wheels are the driving wheels, whereas in the vehicles with front wheels drive the front wheels are the driving wheels. Almost all the rear axles in the modern vehicle are live axles, which mean that these axles move with the wheels, or revolve with the wheels and are known as live axles. Dead Axles are those axles which remain stationary and do not move with the wheels.

Rear axles / Live Axles are further classified into three types:

1. Semi Float Axles
2. Full Float axles
3. Three quarter floating axles.

The Semi float axle is used in light trucks and passenger vehicle / buses. In the vehicles equipped with Semi Float axle the shaft as well as the differential housing supports the weight of the vehicle .The wheel hub is directly connected to the axle shaft or is an extension of the same, the inner end of the axle shaft is splined and it is supported by the final drive unit. The outer end is supported by a single bearing inside the axle casing / axle tube. The vehicle load is transmitted to each of the axle shafts through the casing and the bearing, this causes a bending load and a tendency to shear at a point. Besides the side forces also cause end thrust and bending moment in the axle shafts, which have to take driving torque also. The semi float axle is the simplest and the cheapest of all types, However, since axle shafts have to support all loads, they have to be of larger diameter for the same torque transmitted to the other types of axle supporting. The axle shafts take the stress caused by turning, skidding or wobbling of the wheels. The axle shafts are flanged or tapered on the ends. If in case the axle shaft breaks on the vehicle using this type of arrangement, the wheel of the vehicle will get separated from the vehicle.

Full Float Axle is considered as a robust one and is used for heavy vehicles / trucks meant to carry heavy loads. The axle shaft has flanges at the outer ends, which are connected to the flanged sleeve by means of bolts. There are two taper roller bearings supporting the axle casting in the hub, which take up any side load. Thus in case of Full

Float axles , the axle shafts carry only the driving torque. The weight of the vehicle and the end thrust are not carried by them. The weight of the vehicle is completely supported by the wheels and the axle casing. As the axle shafts carry only the driving torque, their failure or removal does not effect the wheels. Thus the axle shafts can be taken out or replaced without jacking up the vehicle. For the same reason vehicle can be towed even with a broken half shaft. We can say that the axle shaft takes the whole weight of the vehicle and absorbs all types of stresses or end thrust caused by turning, skidding, and pulling. Full Float axle is considered as the most heavy and costly axle.

This is a compromise between the more robust full float axle and the simplest semi float type of to withstand any shearing or bending actions due to the weight of the vehicle, which are taken up by the axle casing through the hub and the bearing, provided the bearing lies in the plane of the road wheel. However, it has to take the end loads and the driving torque. Earlier, Three quarter floating axles were much popular for cases and lighter commercial vehicles, but with the passage of time and with more improvements in the design, development, materials and fabrication techniques, preference is given to the Semi Float Axles, as these are simpler in design and cheaper to useaxle. In Semi Floating axle the bearing is located between the axle casing and the hub instead of being between the axle casing and the shaft as in case of semi float axle. The axle shafts do not have.

"Failure analysis of rear axle of a tractor with loaded trolley"[1]

This paper describes the failure analysis of the rear axle at the root of the spline of a tractor with a loaded trolley used for haulage operation. The analysis has been made using the principles of mechanics. The reason behind the failure has been found to be the weight transfer from front to rear, reduction of which is considered to be a remedial measure for the occurrence failure.

"Analysis and Failure Improvement of Shaft of Gear Motor"[2]

Results indicate that the axle shaft fractured in reversed bending fatigue as a result of improper welding. The present study clearly indicates that improper welding of hardened materials involves low ductility in the HAZ, stress concentration points, and inclusions in the structure that served as nuclei for the fatigue cracks. We therefore conclude that the failure was the cause of the accident.

"Static and dynamic analysis of front axle housing of tractor using finite element methods"[3]

Finite element analysis results showed that the maximum stress of 238.84MPa is applied on the upper housing. According to Von- Misses theory, the value of maximum applied stress and allowable stress, the safety factor of 1.05 was obtained which is less than the required value. The first four natural frequencies of housing were found as 678.54, 720.29, 908.78 and 1877 Hz,

"Failure Analysis of Induction Hardened Automotive Axles"

Rollover accidents in light trucks and cars involving an axle failure frequently raise the question of whether the axle broke causing the rollover or did the axle break as a result of the rollover. Axles in these vehicles are induction hardened medium carbon steel. Bearings ride directly on the axles. This article provides a fractography/ fracture mechanic approach to making the determination of when the axle failed. Full scale tests on axle assemblies and suspensions provided data for fracture toughness in the induction hardened outer case on the axle. These tests also demonstrated that roller bearing indentions on the axle journal, cross pin indentation on the end of the axle, and axle bending can be accounted for by spring energy release following axle failure. Pre-existing cracks in the inductionhardened axle are small and are often difficult to see without a microscope. The pre-existing crack morphology was intergranular fracture in the axles studied. An estimate of the force required to cause the axle fracture can be made using the measured crack size, fracture toughness determined from these tests, and linear elastic fracture mechanics. The axle can be reliably said to have failed prior to rollover if the estimated force for failure is equal to or less than forces imposed on the axle during events leading to the rollover.

"Fatigue failure of a rear axle shaft of an automobile"

The investigation was carried out in order to establish whether the failure was the cause or a consequence of the accident. An evaluation of the failed axle shaft was undertaken to assess its integrity that included a visual examination, photo documentation, chemical analysis, micro-hardness measurement, tensile testing, and metallographic examination. The failure zones were examined with the help of a scanning electron microscope equipped with EDX facility. Results indicate that the axle shaft fractured in reversed bending fatigue as a result of improper welding.

The obtained factor of safety is very low and obviously this value decreases under dynamic loading conditions of field operation. The present study clearly indicates that the front axle housing of MT250D Mitsubishi tractor is not strong enough to be mounted on a tractor. There is a need to optimize the existing design of the front axle housing, if we want to use a mechanical shovel.

II. Research methodology

This introduces Taguchi's Method in which multiple variables can be changed simultaneously without losing control of the experiment. The complete methodology, design and analysis procedure is discussed.

In early 1950's, Dr. Genichi Taguchi, "The Father of Quality Engineering," introduced the concept of off-line quality control techniques known as Taguchi parameter design. Offline quality control are those activities which were performed during the Product (or Process) Design and Development phase. Genichi Taguchi is a Japanese engineer, who has been active in the improvement of Japan's products and processes since the late 1940's. He has developed both a philosophy and methodology for the process of product quality improvement that depends heavily on statistical concepts and tools, especially statistically designed experiments. Many Japanese firms have achieved great success by applying his methods. It has been reported that thousand of engineers have performed tens of thousands of experiment based on his teaching. The Taguchi method is statistical tool, adopted experimentally to investigate influence of productivity by physical parameters such as Weight of worker, Weight of component and Age. The Taguchi process helps to select or to determine the assignment of right person on to the right machine by optimizing all the available factors. Many researchers developed many mathematical models to optimize these parameters to get the zero or minimum loss in target achievement by various processes. The variation in the worker weight, component weight and other factors affecting the productivity. Here the Taguchi design of experiments is used to optimize the considered parameters. Taguchi method is a powerful tool for the design of high quality systems. It provides simple, efficient and systematic approach to optimize designs for performance, quality and cost. Taguchi method is efficient method for designing process that operates consistently and optimally over a variety of condition. To determine the best design it requires the use of a strategically designed experiment Taguchi approach to design of experiments is easy to adopt and may be applied for users with limited knowledge of statistics, hence gained wide popularity in the engineering and scientific community. Taguchi method is especially suitable for industrial use, but can also be used for scientific research. Taguchi parameter design is based in the concept of fractional factorial design butthe Taguchi parameter design only conducts the balanced (orthogonal) experimental combinations, which makes the Taguchi design even more effective than fractional design. Taguchi has received some of Japan's most prestigious award for Quality achievements including the Deming Prize. In 1986; Taguchi received the most prestigious price "The Williard F. Rockwell medal" for excellence in technology from the International Technology Institute. Since 1983, after Taguchi's association with the top companies and institute in USA (AT & T), Bell Laboratories, Xerox, Lawrence Institute ofTechnology, Ford Motor Company etc., the concept provided major contribution and has involved the combination of engineering and statistical methods to achieve rapid improvements in cost and quality by optimizing product design and manufacturing process. Taguchi methods have been called a radical approach to quality experimental design and engineering. The term Taguchi method refers to parameter design, tolerance design, the quality loss function, design of experiments, using orthogonal arrays and methodology applied to evaluate measuring system.

Taguchi addresses design and engineering (off-line) as well as manufacturing online quality. This fundamentally differentiates Taguchi methods from the StatisticalProcess Control (SPC), which is purely an on line quality control method. Taguchi ideas can be distilled into three fundamental concepts:

a) Achieving high system quality levels economically requires quality to be designed into the product. Quality is designed but not manufactured into the product.

b) Quality losses must be defined as deviations from target not conformance to arbitrary specifications.

c) Quality is best achieved by minimizing the deviation from a target.

III. Taguchi design and analysis

Taguchi is the developer of the Taguchi method. He proposed that engineering optimization of a process or product should be carried out in a three-step approach, i.e. system design, parameter design and tolerance design. In system design, the engineer applies scientific and engineering knowledge to produce a basic functional prototype design; this design includes the product design stage and the process design stage. In the product design stage, the selection of materials, components, tentative product parameter values, etc. are involved. As to process design stage, the analysis of processing sequences, the selections of production equipment, tentative process parameter values, etc. are involved. Since system design is an initial functional design, it may be far from optimization in term of quality and cost. Following on from system design is parameter design. The objective of parameter design is to optimize the setting of the process parameter value for improving quality characteristics and to identify the product parameter values under the optimal process parameter values. In addition, it is expected that the optimal process parameter values obtained from parameter design are insensitive to variation in the environmental conditions and other noise factors. Finally, tolerance design is used to determine and analyze tolerances around the optimal settings recommended by the parameter design. Tolerance design is required if the reduced variation obtained by the parameter design does not meet the required performance, and involves tightening tolerances on the product parameters or process parameters for which variations result in a large negative influence on the required product performance. Typically, tightening tolerances mean purchasing better- grade materials, components, or machinery, which increases cost. However based on the above discussion, parameter design is the key step in the Taguchi method to achieve high quality without increasing cost. To obtain high productivity, the parameter design proposed by the Taguchi method is adopted in this thesis. Basically, experimental design method was developed by Fisher. However, classical experimental design methods are too complex and not easy to use. Furthermore, a large number of experiments have to be carried out when the number of the process parameters increases. To solve this problem, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with a small number of experiments only. The experimental results are then transformed into a signal-to-noise (S/N) ratio. Taguchi recommends the use of S/N ratio to measure the quality characteristics deviating from the desired values. Usually, there are three categories of quality characteristics in analysis of S/N ratio i.e. the lower-the- better, the higher-the better, and the nominal-thebest.

Procedure and steps of taguchi parameter design
Step-1: Selection of the quality characteristic
Step–2: Selection of noise factors and control factors
Step–3: Selection of Orthogonal Array
Step–4: Conducting the experiments
Step–5: Analyzing the results and determining the optimum cutting conditions
Step–6: Predicting Optimum Performance
Step-7: Establishing the design by using a confirmation experiment

Japanese companies such as Nippon Denso, NEC and Fugitsn have become world Economic computers by using the Taguchi which has potential for saving in experimental time and cost on product or process development and quality improvement. Since Taguchi's first visited to AT & T Bell Laboratories in 1980, the methodology advocated by Taguchi's has been applied within AT & T to a variety of problems ranging from IC fabrication to response time optimization of a UNIX system. Exploratory applications are extending in to the areas of physical design especially thermal design and circuit design. Taguchi's ideas are also being used in many other U.S. companies such as Ford and Xerox. There are also many courses on robust parameters design offered by organization like American Supplier Institute Rochester Institute of Technology and the Centre for Quality and Productivity Improvement at the University of Wisconsin in Madison. The American supplier institute also has an annual symposium where case studies on the application of the Taguchi methods are presented. The casting division of form motor has been done one of the pioneers in training employees in Taguchi's methods since 1983 Enright and Price have cited few case studies conducted in division of ford motor and illustrated the depth and impact on the product quality and productivity that has occurred since the decision to implement Taguchi's approach was made. Statistically designed experiments have been applied to improve industrial process for more than 50 years. However, most application optimizes the mean value of a response variable. Parameter design experiments, also called robust parameter design experiments are aimed at reducing variability caused by manufacturing variation. Moven Maker and Hubbard have presented a cased of application of loss function concept to the quality improvement program at the Rockell International Steel Foundry of Atchinson. Kanson, Lin and Kackar has shown how a 56 run orthogonal array design was used to improve a wave soldering process by studying 17 variables simultaneously, Prasad and Taguchi and Wu have provided many example of parameter design experiments. The success of many applications has demonstrated the power of Taguchi's overall approach. It is also worth mentioning that many of the specific statistical techniques he has proposed for implementing robust parameter design have generated a great deal of controversy.

Advantages:

(i) Consistency in experimental design and analysis.
(ii) Measurement of quality in terms of deviation from the target (loss functions).
(iii) Up-front improvement of quality by design and process development.
(iv) Reduction of time and cost of experiments.
(v) Design of robustness into product/process.
(vi) Problem solution by team approach and brain storming.
Limitations
(i) The technique can only be effective when applied early in the design of the product/process.
(ii) The technique needs knowledge and training.

Most severe limitations of the technique are the need for timing with respect to product/process development.

IV. Conclusion:

This study is conduct on a failure of rear axle shaft used in an automobile. . Sometimes we found that the rear wheel drive axle shaft had broken into two pieces close to the wheel hub. Theserotating components are susceptible to fatigue by the nature of their operation and the fatigue failures are generally of the torsional, rotating-bending , material composition selection etc. This could be minimize with the help of ***Taguchi Parametric Optimization Technique***, by selection of product as per requirement.

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