

## **INVESTIGATION OF MECHANICAL FAILURE OF STABILIZER ROD OF USED VEHICLE: A CASE STUDY OF NISSAN XTERRA VEHICLE**

**J.G. Kolo\***

**A.A. Musilim\***

**I.A. Alli\***

**A.O Oddiah\*\***

**<sup>1</sup>O.V. Kolawole\***

---

### ***ABSTRACT***

Stabilizer rods are part of an automobile suspension system which limits body roll angle. It is usually a U-shaped metal rod connecting opposite wheel together through lever arm and it is clamped to the vehicle chassis with rubber bushes. Its function is to reduce body roll while cornering and when travelling on uneven road which enhances safety and comfort during driving. The aim of this project is to investigate the mechanical failure of stabilizer rod of used vehicles (Toyota, Ford, and Nissan Xterra). Fracture usually occurs as a result of material composition in the rod and the loading condition of the vehicle. However, the goal of this project is to identify the causes of the fracture and proffer solution by using micro-structural technique, mechanical impact testing, and heat treatment processes. The chemical analyses of sample of the stabilizer rods are classified by using optical emission spectrometer, the AISI for Nissan Xterra and Ford are 4140 and 1020 respectively. The impact test recorded as received sample and tempered for ford, Toyota and Xterra model are 37.96J, 24.40J, 33.90J and 82.71J, 28.47J, 24.40J respectively, derived using Charpy impact test. For Ford, it is basically tempered martensite by showing carbide precipitate, Toyota is tempered martensite and Nissan Xterra reveals martensite respectively, an indication that it has been tempered for longer hours. From the chemical analysis, the presence of nickel, manganese and sulphur are the main causes of failure in Nissan Xterra model, coupled with prolong thermal stress.

**Keywords:** Stabilizer rod, Fracture, Impact testing, Optical Emission Spectrometer, Body roll

---

\* *Mechanical Engineering Department, Yaba College of Technology, Lagos*

\*\* *Industrial and Maintenance Engineering Department, Yaba College of Technology, Lagos*

## 1.0 INTRODUCTION

A stabilizer rod is a steel bar that connects suspension components on opposite wheels, a measure to combat body roll mostly employed on independent front suspension systems often known by many names such as anti-roll bar, sway bar, anti-sway bar and stabilizer bar. It is usually U-shaped and oriented parallel to the ground; with the bottom of the “U” attached to the frame with bushings and ends of the “U” attached to the lower control arms of opposite wheels. When a vehicle enters a turn the inertia causes the body to lean towards the outer wheels, a phenomenon called body roll. Body roll is defined as the angle through which the vehicle’s body rotates about its longitudinal axis; this motion is not only uncomfortable for passengers, but detrimental to vehicle traction and handling due to the non-linear response of pneumatic automotive tires. An outer wheel’s control arm rises and the inner wheel control arm drops, relative to the leaning body. The stabilizer rod is a spring steel torsion bar, a component that springs back when twisted. The bushing that attach the bar pivot upwards with them along the ride, but in a turn the control arm on one side lifts its end of the bar and the opposite control arm pulls the end down [1]. By resisting this torsion, or twisting, the stabilizing rod limits the control arms movement and keeps the body from leaning as far as it otherwise would have lean. Other benefits of anti-roll bar include improvement of traction by limiting the camber angle change, body roll, improve directional control and stability.

Design changes of anti-roll bars are quite common at various steps of vehicle production and a design analysis must be performed for each change. A detailed finite element analysis (FEA) was used in the design of anti-roll bars for effective performance [2]. Further finite element analysis was performed by ANSYS, and the work also includes pre-processing analysis, post processing, and analyzing the FEA results by using APDL (ANSYS Parametric Design Language).

Ride comfort requires insulating the vehicle and its occupants from vibrations and shocks caused by the road surface. An anti-roll bar improves the handling of a vehicle by increasing stability during cornering. Handling requires providing safety in maneuvers and in ease of steering. For good road holding, the tires must be kept in contact with the road surface in order to ensure directional control and stability with adequate traction and braking capabilities [3]. Several papers propose methods to reduce the chassis roll motion of road vehicles. Three different active systems are applied: anti-roll bars, auxiliary steering angle and differential braking forces [4]. The benefits of the integration of anti-roll bars and the lateral control are presented in [5]. A special construction of semi-active anti-roll bars, which guarantees both ride and roll performances, is shown in [6].

The present work aims at investigating the mechanical failure of stabilized rod of used vehicle, using Nissan Xterra jeeps as a case study. The goal is to determine the internal structure that leads to fracture of the region. Parametric optimization was used to reduce the stress concentration at the corner bends of anti-roll bar of an intercity passenger bus [7]. Fatigue life assessment of an anti-roll bar component of a passenger vehicle, is investigated by ANSYS 11 software. A stress analysis was also carried out by the finite element technique for the determination of highly stressed regions on the bar [8].

Several structural analyses of an anti-roll bar made of SAE 9262 were carried out by means of finite element (FE) technique to determine stress distributions by [9]. The result of FE analyses indicated that equivalent stress in the inner surface of the corner bend was the maximum; wherein the shear stress dominates. Fracture analysis of a failed anti-roll bar of an automobile was conducted by [10]. The analyzed type of the anti-roll bar is especially important as many cases are reported about the fracture after 100,000 km of travel. It was concluded that the fracture took place after a fatigue procedure under a combined bending and torsional stresses that

have a highly reversible nature; the crack of the fracture is initiated at the highly stressed region of the bar; the fracture took place in a ductile manner; and the production process could have affected the initiation region of the failure. [11] focuses on design and modeling of anti-roll system for a subcompact passenger car using a software base modeling. The system consists of hydraulic assisted torsion bars on car suspensions, a hydraulic power unit, and controls.

## 2.0 MATERIALS AND METHODS

### 2.1 Physical Appearance

Stabilizer rods procured for this investigation are Toyota, Ford and Nissan Xterra models. The physical properties of each of the stabilizer rod are shown in Table 3.1. Also Fig 3.1 shows pictures of the stabilizer rods.

**Table 2.1** Physical properties of stabilizer rods from the three different vehicles

Property	Toyota	Ford	Nissan Xterra
Colour	Black Coat Paint	Black coat paint	Black coat paint
Length	134cm	160cm	128cm
Diameter	17.50mm	19.50mm	27.00mm
Bend	3	4	3
Angles	45-90°	Less than 45°	Above 90°



**Fig 2.1:** Stabilizer rods (a) Nissan Xterra (b) Ford (c) Toyota

## 2.2 Chemical Analysis of Samples

The purpose of chemical analysis is to ascertain the composition of a substance. Quantitative analysis of the samples for this study was carried out using an optical emission spectroscopy. A Thermo Scientific Model No: ARL Quanto Desk Optical Emission Spectrometer shown in Fig. 2.2 was used to analyze samples cut from Nissan Xterra, Toyota and Ford.



**Fig. 2.2:** Optical Emission spectrometer

The surfaces of the samples were prepared by grinding using silicon carbide paper of grit size P36 and P150. Each of the samples was securely placed in the excitation chamber and afterward the covering lid was closed. Argon gas was passed through the purifier to obtain high purity argon at a pressure of 2.7 Kbar to 3.0 Kbar and a relatively humid environment. A spark source is commonly operated in an argon or nitrogen gas environment because the exclusion of oxygen improves reproducibility. After the spectrometer was switched on the excitation chamber was flushed with argon gas for about 3 minutes and the sample was vapourized and excited by an alternating current spark and the constituent atoms emitted radiation in the optical region of the electromagnetic spectrum. Every excited element emits a characteristic line spectrum that can be used to identify that element. Iron low carbon steel software in the attached computer was used

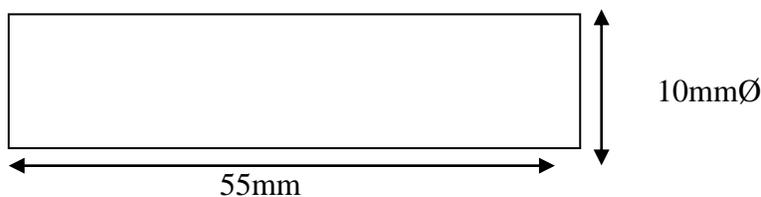
to quantitatively analyze the spark results. Each of the samples sparked three times and an average spark result was generated. The sparked samples are shown in Fig 2.3:



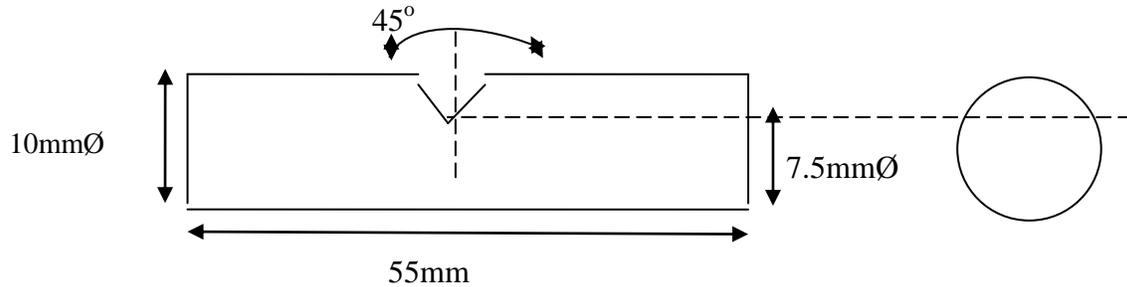
**Fig 2.3:** Sparked samples of Nissan Xterra, Toyota and Ford

**2.3 Mechanical Test:** The rods were turned on a lathe to the dimensions shown in Fig. 2.4 for impact test according to the BSI standard and specification. Six test-pieces were prepared from each sample for the impact test. Care was taken to ensure a concentric turning as this might affect the impact test result if not properly done.

**2.4 Impact Test:** Three test pieces from each sample were V- notched in accordance to Charpy impact test specimen as shown in Fig. 2.5. Accurate notching is best done using the notching machine to obtain an accurate root diameter of 5.8mm.



**Fig. 2.4** Impact test piece



**Fig. 2.5** V-notched Charpy impact test

## 2.5 Metallographic

Sample selection/cutting, grinding, polishing and etching were the steps taking during metallographic sample preparation:

**2.5.1 Sample Selection/Cutting:** Samples were cut from a position which gives true representation of the parent material. Cutting was done with a lubricated hacksaw to a size convenient for grinding and polishing. The sample was drawn over a long angle lathe file to render a plane surface and to remove any distorted material from the sawing operation.

**2.5.2 Grinding:** This was achieved using a rotating disc grinding machine Fig. 2.6.



**Fig 2.6:** Grinding/Polishing Machine

The specimen rods were ground on a series of silicon carbide papers. With increasing smoothness of 150, 220, 320, 400, 600, 800 and 1200 grit successively. The specimen rods were rubbed on the grit sizes on forward stroke and withdrawn during the backward stroke at right angles to the scratches left by the previous operation. Constant flow of water was allowed on the carbide paper to wash away the ground particles and as coolant to avoid heating up the sample. This operation was done at a grinding speed of 250 rpm.

**2.5.3 Polishing:** This completely removes fine scratches and makes the surface smooth and mirror-like. This was done using the rotating disc polishing machine Fig. 2.6. Initial polishing was done using a nappies cloth with polishing lubricant and  $3\mu$  diamond paste. It was followed by intermediate polishing with  $1\mu$  diamond paste. This operation was done at a polishing speed of 250 rpm with a light pressure applied on the specimen. Final polishing was accomplished on a rotating disc covered with high napped final polishing cloth and operated at a speed of 150-200 rpm using  $0.05\mu$  alumina slurry polishing medium to produce a scratch-free surface on the specimen. After the scratch free surface has been prepared, the specimen rods were washed thoroughly in a stream of water and then dried by blowing the excess water from the surface with a specimen dryer. The specimen rods were then kept in a desiccator where dust and dirt from the atmosphere will not be collected on the surfaces.

**2.5.4 Etching:** Vilella reagent was used as the etching reagent to reveal the microstructure. This was prepared by measuring 1g picric acid + 5ml Hydrochloric acid + 100ml Ethanol. Vilella's reagent was used because it best suits the chemical composition and the physical condition of the stabilizer rods. Etching was accomplished by swabbing a selected area with Vilella and an etching time of 5-10s. The reaction was stopped after observing a dull surface by dipping the etched surface into a beaker of water and then drying the surface with cotton wool.

The specimens after etching were observed using a metallurgical microscope as shown in Fig. 3.7



**Fig 3.7:** Metallurgical Microscope

### 3.0 RESULTS AND DISCUSSION

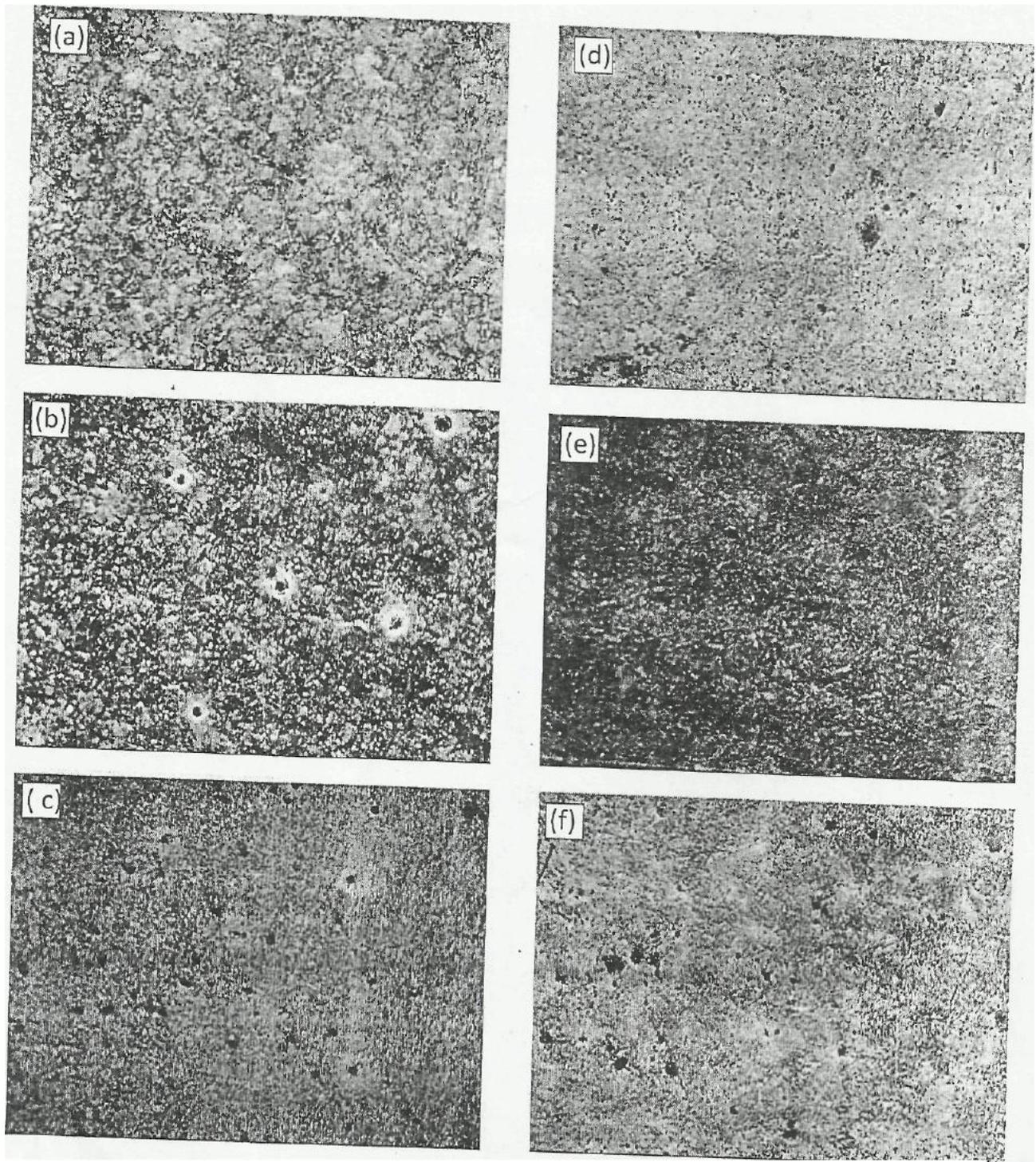
#### 3.1 RESULTS

##### 3.1.1 Chemical Compositions

**Table 3.1:** Chemical Composition of the different Stabilizing Rods (wt %)

Type	Fe	C	Si	Mn	P	S	Cr	Ni	Mo	Cu	V	Co	Nb	W	Sn
<b>Ford</b>	98.37	0.244	0.198	0.578	0.199	0.072	0.028	0.058	0.035	0.062	0.000	0.006	0.004	0.032	0.003
<b>Toyot</b>	97.88	0.636	0.179	0.596	0.23	0.068	0.065	0.042	0.030	0.137	0.030	0.005	0.000	0.000	0.007
<b>Xterra</b>	97.18	0.332	0.269	0.753	0.268	0.068	0.657	0.032	0.077	0.110	0.018	0.002	0.017	0.116	0.004

### 3.1.2 Microstructure

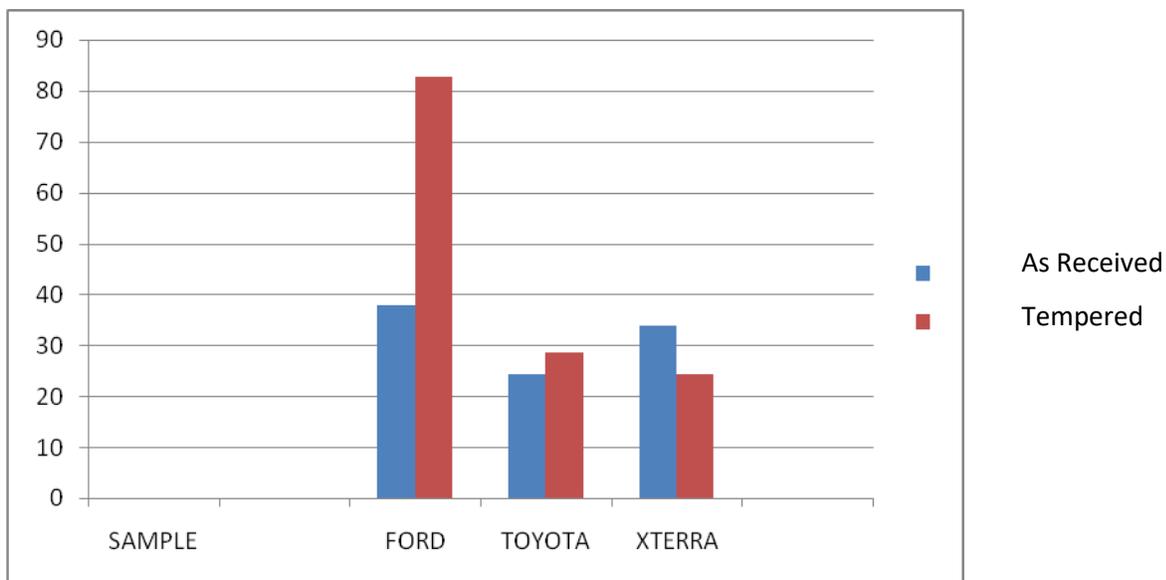


**Fig. 3.1:** Optical Micrographs of as-received samples (a) Ford (b) Toyota (c) Xterra and tempered samples (d) Ford (e) Toyota (f) Xterra, (x100)

### 3.1.3 Impact test results

**Table 3.2:** Impact Strength of different Stabilizer Rod

Sample	Impact Energy (J)	
	AS-Received	Tempered
<b>Ford</b>	37.96	82.71
<b>Toyota</b>	24.40	28.47
<b>Xterra</b>	33.90	24.40



**Fig. 3.2** Graph showing Impact Strength of different Stabilizer Rods

## 3.2 DISCUSSION

### 3.2.1 Effect of Chemical Compositions on the Impact Strength of Stabilizing Rod

The addition of alloying elements to iron generally affects the microstructure and the mechanical properties of the steel produced.

Table 3.1 shows the chemical composition (wt %) of stabilizing rods for Ford, Toyota and Xterra respectively. These materials are low alloy steel with carbon content varying between 0.2 and 0.7 wt %. Xterra was classified as AISI 4140 and Ford AISI 1020. Hardness and tensile strength increases with the increase in carbon content up to about 0.85% C. In low alloy steel a major element used to increase the toughness of steel is nickel. Chemical analysis above shows that Xterra has the lowest nickel content 0.032 wt% while the highest is Ford 0.058 wt%.

Other elements like vanadium, chromium and silicon in combination with other elements also helps to increase toughness. Manganese which is detrimental to toughness is highest in Xterra 0.753 wt%. Sulphur and phosphorus are other detrimental elements to toughness and should be maintained at minimum levels. The wt% of phosphorus is highest in Xterra 0.268 wt%, the impact test results shows that Ford has the highest impact energy of 37.96J, followed by Xterra 33.90J and Toyota 24.40J.

### **3.2.2 Microstructure and Impact Strength of Stabilizer Rod**

The microstructure as obtained in the stabilizer rods for Ford, Toyota and Xterra are shown in Fig. 3.1(a-c) respectively. Fig. 3.1a shows the microstructure of Ford which is basically tempered martensite. The dark parts are carbide precipitate. Fig. 3.1b shows the microstructure of Toyota also a tempered martensite microstructure comprising of dark sphere-like cementite constituents in a ferrite matrix. The spherical martensite is an indication that it has been tempered around 600°C for long hours and usually induces some softness into the brittle martensite formed during quenching. Fig. 3.1c reveals a tempered martensite microstructure in the Xterra.

### **3.2.3 Effect of Heat Treatment on the Impact Strength of Stabilizer Rod**

The impact test results of the heat treated samples are as shown in Table 3.2 and their corresponding microstructure in Fig. 3.1(d-f). Comparing the results of the impact strength as obtained and heat treated samples, it is observed that the impact strength of the Ford increased when heat treated to 82.71J, Toyota increased to 28.47J but Xterra was observed to have reduction in impact strength when heat treated to 24.40J. These changes in impact strength were also shown in the microstructures observed in Fig. 3.1(d-f). The slight increase in impact strength of the heat treated Toyota sample from the microstructure observation shows that there was reduction in spherical cementite in the ferrite matrix.

### 3.3 SUMMARY OF THE RESULTS

This project investigated the cause of failure in the stabilizer rods of three different vehicles Ford, Toyota and Xterra with the aim of proffering most appropriate solution to the stabilizer rod of Xterra models which is reported to break most often in service compared to the other vehicles. Chemical analyses of the samples were determined using an optical emission spectrometer. Metallurgical microscope was used to observe as-received and heat treated samples after they have been prepared for metallographic purpose. The impact strength of both as-received and heat treated samples were done using a Charpy impact testing machine.

The results showed that Xterra stabilizer rod has a relatively lower amount of Nickel which improves impact strength and a relatively higher amount of manganese and phosphorus which are detrimental to the impact strength of low alloyed steel. While heat treatment by tempering was observed to increase the impact strength of Ford largely, and Toyota slightly, it reduces the impact strength of Xterra stabilizer rod. It is also noted that failure can be attributed to the amount of nickel, manganese and sulphur in Xterra stabilizer rod compared to other vehicles. Heat treatment by prescribed tempering procedure is not adequate to improve the impact strength in the case of Xterra compared to increase in the impact strength of Toyota and Ford.

## 4.0 CONCLUSIONS AND RECOMMENDATIONS

### 4.1 CONCLUSIONS

From the investigation conducted on the fracture of stabilizer rod of Xterra models, it was observed that various elemental components such as copper, nickel, phosphorus, manganese and sulphur are combinations component used in the manufacturing of stabilizer rod of vehicle. The stabilizer rods investigated namely Toyota, Ford and Xterra have low alloy steel with carbon content ranges from 0.2 – 0.7 wt%.

While fracturing have been reported often in Xterra models, it is due to low nickel content with high content of manganese and phosphorus compare to Toyota and ford models. The possibilities of thermal stresses on the rod are factors responsible for the fracturing of Xterra model type. However, heat treatment process conducted on the Xterra rod was not adequate and hence impact

strength could not be improved, but tempering increases the impact strength of Toyota and Ford models.

## 4.2 RECOMMENDATIONS

To improve the impact strength devoid of breakage as experienced, the following are thus recommended:

- Determination of the actual percentage nickel that will be proportionate for strengthening the Xterra model stabilizer rod.
- Determination of the actual percentage reduction in manganese and sulphur.
- Determination of the acceptable thickness and length that can withstand both twisting and elongation tendency as a result of suspension movement.
- Adoption of the heat treatment process that could promote a strengthening effect of the stabilizer rod in Xterra models.

## REFERENCES:

- [1] Gummadi, N.B. and Cai, H. (2003). Bushing Characteristics of Stabilizer Bars, *SAE Paper Number: 2003-01-0239*.
- [2] Pravin, B., Kshitijit, T., Amit, P., and Ganesh, K. (2014). Design, Analysis and Optimization of Anti-Roll Bar, *International Journal of Engineering Research and Applications, Vol. 4, Issue 9 (Version 4), pp. 137-140*
- [3] Kelvin Hubert (2005). Spartan chassis: Anti-Roll Stability Suspension Technology, *SAE PP. 2005-01- 3522*
- [4] Shibahata, Y. (2005). Progress and Future Direction of Chassis Control Technology. *Annual Reviews in Control, vol. 29, no. 1, p. 151-158*
- [5] Yim, S. and Jeon, K., Yi, K. (2012). An Investigation into Vehicle Rollover Prevention by Coordinated Control of Active Anti-Roll Bar and Electronic Stability Program. *International Journal of Control, Automation, and Systems, vol. 10, no. 2, p. 275-287*.
- [6] Stone, E.J. and Cebon, D. (2008). An Experimental Semi-Active Anti-Roll System. *Proceedings of Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, vol. 222, no. 12, p. 2415-2433*
- [7] Topaç, M.M., Enginar, H.E., and Kuralay, N.S. (2011). Reduction of Stress Concentration at

the Corner Bends of the Anti-Roll Bar by Using Parametric Optimization. *Mathematical and Computational Applications*. Vol. 16, No. 1, pp.148-158

[8] Marzbanrad, J. and Yadollahi, A. (2012). Fatigue Life of an Anti-Roll Bar of a Passenger Vehicle. *International Journal of Mechanical Aerospace, Industrial Mechatronic and Manufacturing Engineering*. Vol. 6, No. 2

[9] Cerit, M., Nart, E. and Genel, K. (2010). Investigation into Effect of Rubber Bushing on Stress Distribution and Fatigue Behaviour of Anti-Roll Bar. *Engineering Failure Analysis*. Vol.17 (5), pp. 1019-1027

[10] Bayrakceken, H., Tasgetiren, S. and Aslantas, K. (2007). Fracture of an Automotive Anti-Roll Bar. *Engineering Failure Analysis*, Vol. 13 (5): pp. 732-738

[11] Durali, M. and Kassaiezadeh, A. (2002). Design and Software Base Modeling of Anti-Roll System. SAE Technical paper. 10.4271/2002-01-2217