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Design and Analysis of Connecting Tie Rod Assembly for Automotive Application

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Abstract. The tie rod end is one of the most elementary parts of a steering mechanism, which has direct and crucial importance in terms of driving safety. The tie rod end is used to ensure that the wheels are aligned. It provides the adjustment for the wheel to align and keeps the tires free from wearing out on the inner as well as outer edges. Hence the functioning of the tie rod is crucial for steering as well as suspension performance of the vehicle. Today's world is competitive. Market demands the advanced technology at a lower price. This reflects in making the technology cheaper. Hence every industry determined for the cost-effective product at a lower price and within minimum period for 'time to market. This puts a lot of pressure on engineers to consistently strive to design the more effective products at the lower price. The work is focused on the functioning of the tie rod. Generally, tractor connecting tie rod gets failed due to the overload applications. This paper focuses on modifying the old tie rod design and material. Finally, analysis the load causes of existing and modified design using ANSYS software. This modelling approach, the stress variations and deformation characteristics of each component are investigated for high operational loading conditions.

Keywords: thru-hole, clamp structure, front axle, ANSYS, deformation.

1 Introduction

Tie rod ends support (Figure 1) thru the steering of a vehicle and variety it possible to capture a tire. These devices occur in pairs on each tire. This sanctions for cornering and angling of the tire minus affecting too much torque on the trundlenopestaple how deep the seizure [1]. Tie-rod is certain as driving adherent for slanting the panel (along with panel mounting frame) from horizontal to vertical position and vice versa. In principal, tie-rod will have essential coupler with nail rods on sides, one through left hand thread and another through right hand thread [2]. The coupler has identical threads to put up these eased tie rods [3]. On spinning the coupler is turned, together the rods will spread or withdraw based on the trend of rotation of coupler. The ends of the rods are moreover eye or fork expiration type [3, 4].

Further research will be aimed at research the adjustable front axle with adjustable tie rod (Figure 1).

This origination relays to a tractor and more specifically to unregulating front axle for a row crop farm tractor. In farm tractors of the row produce type it is crucial to afford for widening and narrowing the stamp of the ambition wheels where a three wheel tractor is fretful [5]. A four wheel rumpus crop tractor requires that both front and rear wheels be adjustable squarely, in directive to travel between the plants in the rows [6]. The peak common scheme of varying the width of the wheel tread on ruckus crop tractors currently is to dispose the wheels hubs and tire rims in such routine that by reversing the wheels in relative to the hubs the stamp may be amplified or narrowed [7]. While the development above described may perform to be artlessearnings of amending the stride of the wheels of the tractor, however such amending mechanism fills a long desired want of stingily and easily altering the width of the tread of façade wheels of row crop tractors [8].

Figure 1 – Adjustable tie rod

2 Research Methodology

2.1 EN8 carbon steel material

EN8 is typically abounding organic but can be supplied to edict in the stabilized or finally heat salted (appeased and tempered to "*Q*" or "*R*" properties for off-putting ruling subdivisions up to 63 mm), which is ample for a widespread range of applications. EN8 is suitable for the assembly of quantities such as general-tenacity axles and shafts, gears, bolts and studs [6, 9]. It can be auxiliary hardboiled typically to 50–55 HRC by initiation processes, producing modules with enriched wear resistance. For such tenders the use of EN8D (080A42) is prudent. EN8 in its heat frozen rehearses possesses virtuous homogenous metallurgical structures, philanthropic unfailing machining properties [9]. Virtuous heat treatment grades on segments grander than 63 mm may still be attainable, but it should be illustrious that a fall-off in mechanical properties would be superficialpotential the epicentre of the bar [10, 11]. Table 1 gives mechanical properties of material.

Table 1 – Material Properties

Material	Yield strength, N/mm^2
EN8	465
EN8D	443
EN5D	451
EN5C	438

When compared to mechanical property and cost EN8 is the best one for design the product and economical one [12].

2.2 Existing thru-hole design parts

The previous research papers are useful for deciding the analysis strategy. There were numerous conference papers, reference manuals, book by Robert cook Concepts and applications of FEA will be helpful for the project. From some of the research work it is being observed that the existing thru hole design model.

The existing geometrical model is created as a solid works 2016 software and analysis in ANSYS Workbench, The geometrical model constitutes of the socket (Figure 2), radial ball joint (Figure 3), tube (Figure 4) and axle ball joint (Figure 5).

While neglecting the parts that are thought as negligible in the analysis. Figure 6 shows that existing tie rod design using solid works software.

2.3 Problem identification

In the existing design nut and bolt joints are used to connect the socket and tube, so it can't withstand more compressive load and tensile load. It leads to bend which causes breakage in the tie rod. Also, the thru-hole design is applicable to load only below 2 000 kg and when the load increases the tie rod bends. So it cannot withstand more than 2 500 kg tensile load and compressive load.

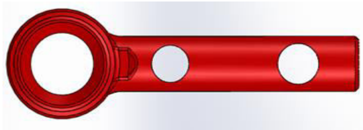

Figure 2 – Socket

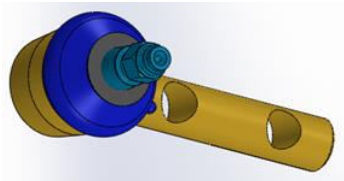

Figure 3 – Radial ball joint

Figure 4 – Tube

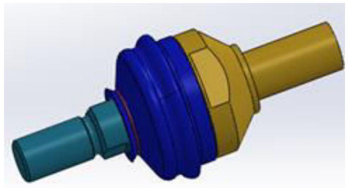

Figure 5 – Axle ball joint

Figure 6 – Existing tie rod design

2.4 Designs of tie rods

2.4.1 Proposed new design

The tie rod is continuously under random loading there can be more chances of developing the cracks at the critical areas and chances of failure. Also the manufacturing process of this existing design is critical and time consuming. Hence it is necessary to make the design simple and cost effective such that it gives overall effectiveness in terms of weight, cost, load carrying capacity and easy of manufacturing process. The main task in this study is to find the critical buckling load for the existing design. Observe the deformation and stresses induced in the Tie rod. Set up the benchmark for the proposed design.

Figure 7 shows proposed new connecting tie rod design, thru-hole clamped design used to connect the tube and socket. Because of groove and clamp withstands more compressive and tensile load compare to exiting design.

Figure 7 – Proposed new design

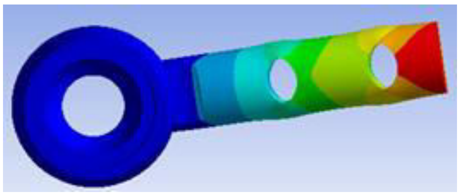

Figure 11 – During compressive load

2.4.2 Existing model tie rod analysis

The existing tie rod model has carried out static analysis using EN8 carbon steel material,while applied the load upto 2 000 kg in exiting model, it's can't shows any deformation. Figures 8–9 show that thru-hole design applicable only below 2 000 kg load.

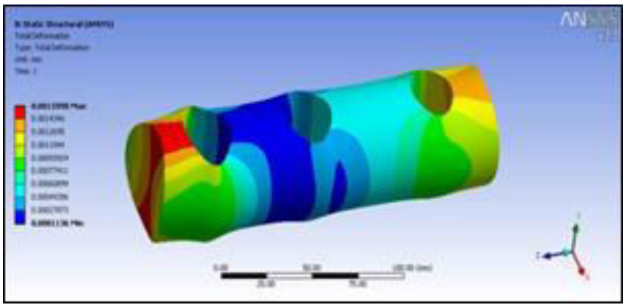

Figure 8 – Compressive load

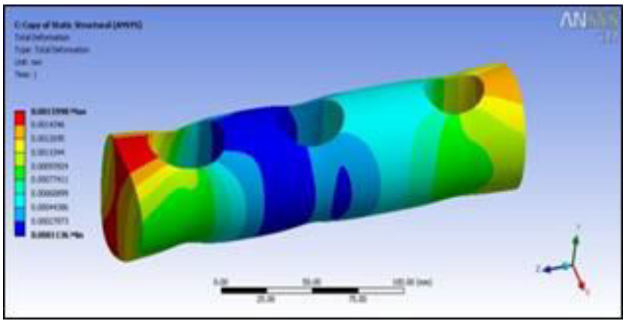

Figure 9 – Tensile load

Increasing the tensile compression loads up to 2 500 kg, existing model tie rod getting failure and its goes to deformation. Figures 10–11 show failure action of tie rod during 2 500 kg load.

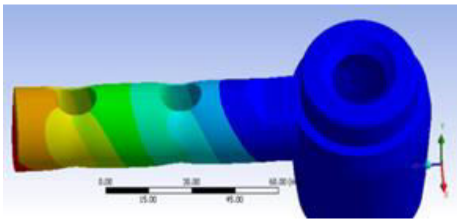

Figure 10 – During tensile load

2.4.2 Sample groove design with hollow construction (Existing Design)

When compared to thru hole this groove design withstands more load during compression load. From the Figure 12, groove design with hollow construction cannot withstand more than 2 500 kg of compressive load. So, this designs also not suitable for the tie rod.

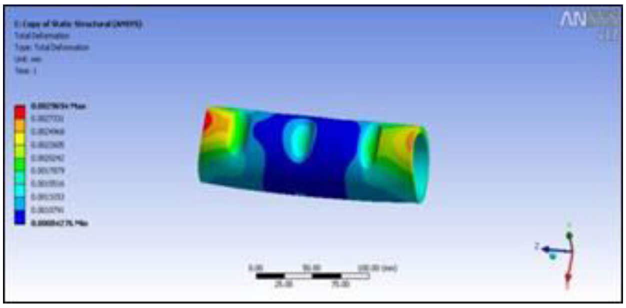

Figure 12 – Compressive load test for hollow groove design

2.5 Proposed new design analysis

2.5.1 Sample solid groove design

The solid groove design has analysis using EN8 carbon steel in Figures 13–14. Hence, Solid groove design withstands more loads when compared to both hollow groove and thru-hole design. It cannot withstand up to 3 500 kg of compressive load and tensile load. So this the suitable design for the adjustable tie rod.

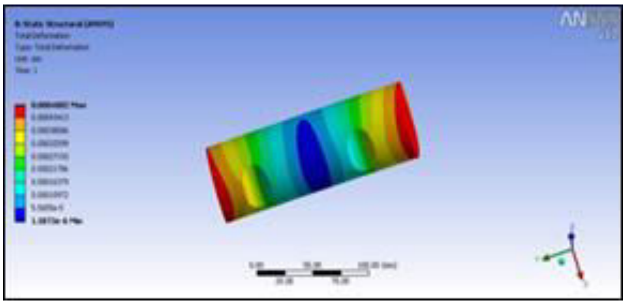

Figure 13 – Compressive load test on solid groove design

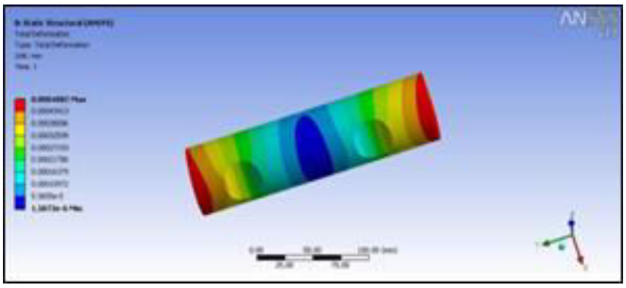

Figure 14 – Tensile load test solid groove design

2.5.2 Tensile and compression load analyses of adjustable tie rod

Below Figures 15–16 show the thru hole design failed to withstand the 3000kg tensile load, but grooved design can withstands more load when compared to thru hole design in tie rod.

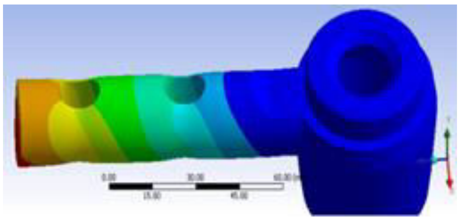

Figure 15 – Thru hole design

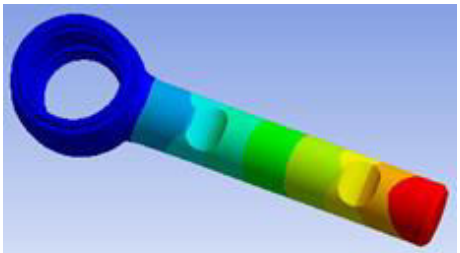

Figure 16 – Clamped design

2.6 Comparison of analysis result

Tables 2–3 show static analysis results for existing and proposed new design using EN8 Carbon steel.

Table 2 – Socket with through hole

Load, kgf	Max stress, N/mm^2	FOS
2 500	365	0.77
3 000	438	0.64
4 000	583	0.48

Table 3 – Socket with groove

Load, kgf	Max stress, N/mm^2	FOS
2 500	151.7	1.85
3 000	182.4	1.54
4 000	243.2	1.15

From the results, maximum stress has acted on the through hole design, and proposed design has less deformation is obtained compare to exiting tie road model. Tie rods are merely subjected with more compressive forces. From the above analysis shows that proposed design has more damping capacity and can withstand more compressive forces. This is due to because of carbon flake distribution in the material. Carbon flake distribution is better in EN8 carbon steel.

2.7 Buckling of thin cylindrical shells subject to axial loads

Clarifications of Donnell's eight order differential equation provides the innumerable buckling approaches of a thin cylinder underneath compression. But this analysis, which is in harmony with the slight refraction theory bounces much sophisticated morals than shown from tryouts [13]. So it is habitual to find the precarious buckling load for countless erections which are cylindrical in silhouette from pre-existing design cambers where perilous buckling load FCR is intrigued along side the ratio R/t, where R is the radius and t is the thickness of the cylinder for innumerable values of L/R, where L is the length of the cylinder. If cut-outs are modern in the cylinder, life-threatening buckling loads as well as pre-buckling slants will be exaggerated [14–15].

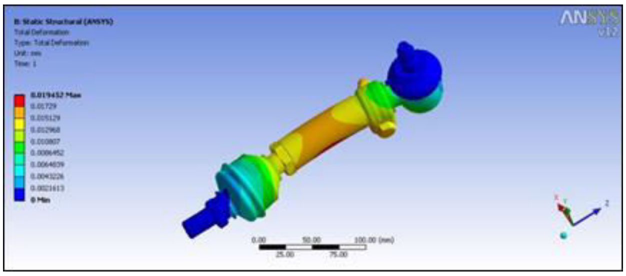

Figure 17 – Buckling load test on adjustable connecting tie rod

Examination of this formula reveals the following interesting facts with regard to the load-bearing ability of slender columns.

Bending load in both ends hinged is given by the following Euler's formula:

$$BL = \frac{\pi^2 EI}{L^2}, \tag{1}$$

where E – Young's modulus; L – length of the tie rod; I – moment of inertia:

$$I = \frac{\pi\left(D^4 - d^4\right)}{64}. \tag{2}$$

E. g., for inner diameter d = 22.5 mm and outer diameter D = 30 mm, moment of inertia $I = 2.72 \cdot 10^4$ mm^4.

Figure 18 shows that bending load calculation for proposed design, it is enough for the rod to withstand compressive and tensile load. When compared to previous design clamped design having more bending loads capacity. Previous design bending load is 25.9 kN. This design bending load is 31.6 kN. So, this design is good when compared to existing design.

Figure 18 – Failure of struts or columns

3 Results and Discussion

Tie rod plays an important role in the steering system and should be carefully selected. EN8 Carbon Steel material selected for this design. Existing and proposed model has done in solid works software in the form of a multibody system, after that solid structure was produced where all interconnected essentials supposed to be perfectly inflexible, and in absolute stage of taxing finite element analysis was executed consuming ANSYS software package. From the accessible results we can arrange that the dissemination of deformation and stress do not overdo the yield strength value and that there are neither indemnities nor failure of Tie rod. The load 2 000 kg has applied in exiting model, it's can't shows any deformation. While increasing the load up to 2 500 kg, thru-hole design getting bend because it cannot withstand the over load, so that thru hole design model has applicable only below 2 000 kg load. The maximum load of 4 000 kgf has acting on thru hole and groove design model.since, the thru hole design results shows stress has act 583.3 N/mm^2, Factor of safety is 0.48, and Groove design model results show that stress has act 243.2 N/mm^2 and Factor of safety is 1.15. Thru-hole design bending load is 25.9 kN and clamp design bending load is 31.6 kN.

4 Conclusions

In this study, existing thru-hole design model has modified toclamp groove design with EN8 carbon steel material. From the static analysis results shows deformation of the proposed tie rod model is lower than existing tie rod, the critical buckling load of proposed tie rod is more than existing tie rod in buckling analysis. From the presented results we can conclude that deformation and stress do not exceed the yield strength value that there are neither damages nor failure to new proposed groove design tie rod. So the proposed tie rod is suitable for tractor.

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Конструкція та аналіз вузлів з’єднувальних тяг для застосування в автомобілебудуванні

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Анотація. Кінцева тяга є однією з найпростіших частин рульового механізму, що має безпосереднє і найважливіше значення з точки зору безпеки руху. Кінцевий штифт використовується для того, щоб колеса були вирівняні. Це забезпечує регулювання, щоб колесо вирівнялось, і воно не знімається як на внутрішніх, так і на зовнішніх краях. Отже, функціонування гальмівного важеля має вирішальне значення для керування, а також для підвіски автомобіля. Сьогоднішній світ є конкурентоспроможним. Ринок вимагає передових технологій за більш низькою ціною. Це відображається у виборі дешевших технологій. Отже, кожна галузь визначається для рентабельного продукту за більш низькою ціною і в межах мінімального періоду часу на момент продажу. Це створює великий тиск на інженерів, які постійно прагнуть розробляти більш ефективні продукти за більш низькою ціною. Робота зосереджена на функціонуванні стяжок. Узагалі існують з’єднання із перевантаженням. Ця стаття зосереджена на модифікацію традиційної конструкції тяги. Наведено аналіз причин завантаження існуючої та модифікованої конструкцій за допомогою програмного забезпечення ANSYS. Цей підхід ґрунтується на дослідженні навантажень і деформацій кожного компонента для високих експлуатаційних умов навантаження.

Ключові слова: монтажний отвір, затискний пристрій, передня вісь, ANSYS, деформація.