Design and fabrication of a twist fixture to measure torsional stiffness of a pick up chassis

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Abstract. Torsional stiffness is important parameter of chassis that affect the handling performance of chassis. Torsional stiffness can be determined using Finite Element Method (FEM) in early stage design of its. In order to validate the FEM result, experimental work needs to be done. The fixture has been design in simpler stucture, flexible for any kind of chassis and using a simple measurement's equipment such as dial indicator and load cell. Twist fixture has been designed for measuring of torsional stiffness of TATA cab chassis indirectly. The fixture measured the deflection caused by torsion subjected to the chassis. The torsional stiffness was calculated based on measured displacement of chassis. The result of comparison shows that the experimental results in agreement with the simulation results. Therefore, the simulation results of TATA cab chassis model are valid.

1 Introduction

Increased torsional stiffness of a truck chassis improves vehicle handling by going away the suspension components to control a larger percentage of a vehicle's kinematics. In summation, a truck chassis must have adequate torsional stiffness so that chassis structural dynamic modes do not adversely couple with the suspension dynamic modes. The torsional stiffness of a vehicle's chassis significantly affects its handling characteristics and is thus an important parameter to evaluate.

Pick up chassis used in vehicles has almost the same appearance since the models were built up more than 30 years ago. Many researches have been carried out to analyze the torsional stiffness of chassis designs using finite element analysis (FEA) [1, 2, 3, 4, 5]. In order to validate these finite element models, an experimental method is needed to directly measure torsional stiffness. The purpose of this work is to design and fabricate a twist fixture for measuring the torsional stiffness of TATA Cab chassis.

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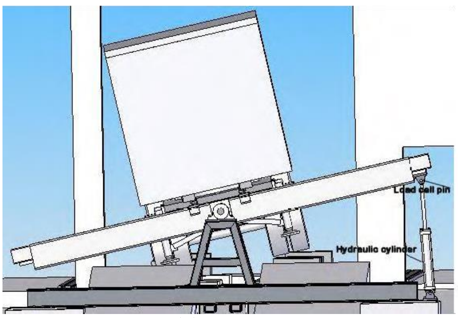
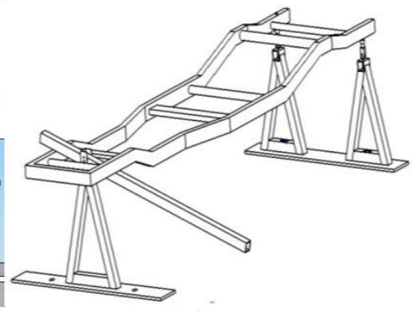
2 Twist Fixture Design

Many factors should be taken into consideration in designing of the test rig or twist fixture in order to get the best design. Some alternatives design also should be considered to fulfill the needs of designer. Three designs were prepared for this project and will be marked based on some parameters such as cost and machineability of each design in order to choose the best design. The design with the highest mark will be chosen as the best design. Table 1 shows the mark of three alternative designs of fixtures.



(a)



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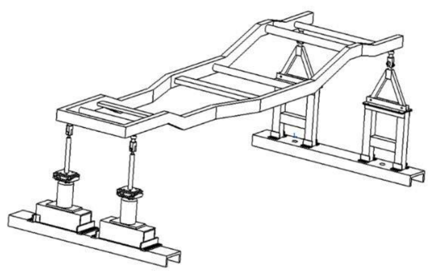

(c)

Fig. 1. Alternatives design for twist fixture of chassis; (a) design 1; (b) design 2; (c) design 3

Table 1. Marks for alternatives design of fixtures

Design	Cost	Fabrication	Strength	Weight	Set-up	Total Marks
1	2	2	5	2	2	13
2	3	4	3	4	4	18
3	2	3	3	3	3	17

*Rate scale: 1 (Dismal), 2 (Low), 3 (Moderate), 4 (High), 5 (Exceptionally good)

From the Table 1, design number 1 are low in cost, fabrication, set up and weight, but the advantages is very good in strength. For design 2, cost of the rig is moderate, means cost material not expensive and weight the rig is also high, it means the weight of the fixture is not too heavy. Design 2 also has a high mark for set up, it means it is quite easy to assembly the fixture. Design 3 has a low mark for cost, it means the cost for this design is high. The mark for fabrication, strength, weight, and set up are moderate. Design 2 has the highest mark, therefore design 2 was chosen as the best design and will be proceed for fabrication.

3 Experimental Set up and Torsional Stiffness Calculation

In this section, the procedures used to calculate torsional stiffness using the twist fixture for a typical TATA Cab chassis are discussed. Figure 2 showed the schematic diagram of the experimental set up for measuring the torsional stiffness of TATA Cab Chassis. Figure 3 represented the real experimental set up. Twisting moment has been given to the chassis due to two same single force in opposite direction at front of chassis.

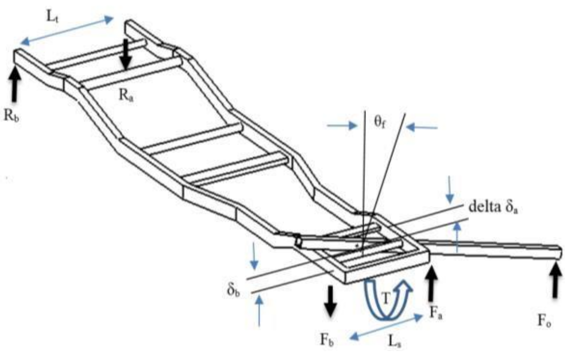

Fig. 2. Schematic diagram of experimental set up

Fig. 3. Real experimental set up

Dial indicators are used to measure the equal and opposite applied vertical deflection δ, at the left and the right chassis. A dial indicator monitored angle chassis displacement, insuring that the mounting fixture was a rigid, zero displacement constrain relative to applied load. The outer face of the dial indicator can be moved so that the zero can be positioned over the pointer. In this experiment, resolution for the indicator is 0.01 mm. The twist angle can be calculated by the formula:

$$\theta_f = \frac{2\delta}{L_f} \quad (1)$$

Where L_f is the lateral distance between the front dial indicators. Force at the left front and right front, denoted Fa and Fb, respectively, are measured by scales. The torque is calculated from

$$T = \left[\frac{(F_a)}{2} + \frac{(Fb)}{2}\right] x\, L_s \qquad (2)$$

The twist angle is adjusted by subtracting the deflection at the rear. The twist angle at the rear θ_t is calculated from the measured displacements in the extremities of the longitudinal rails,

$$\theta_t = \frac{[(\delta_a) + (\delta_b)]}{Lt} \qquad (3)$$

where δ_a and δ_b are the measured vertical displacements in the dial indicators, separated laterally by a distance L_t. The torsional stiffness at each increment is calculated by:

$$K = T/\theta \text{ (Nm/rad) and, } \theta = \theta_f - \theta_t \qquad (4)$$

Where $\theta = \theta_f - \theta_t$. The increment is chosen such that at least 10 data points are obtained.

4 Results and Discussions

The FEM simulation results for 60 kg and was presented in Figure 4. It is shown that the maximum deflection occurred at the left side of front chassis. It is also shown that the deflection at the right side has a very close value to the maximum value. The deflection distribution for other loads is similar to that of 60 kg. The calculated twist angles under various loads and the torsional stiffness is then obtained from Equation (4) as tabulated in Table 2.

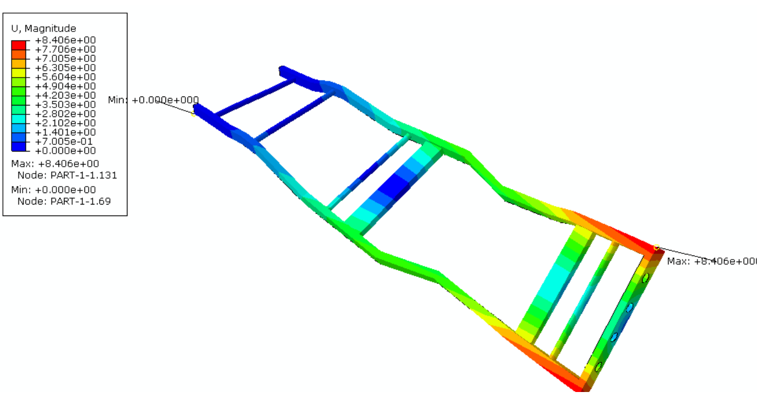

Fig. 4. Deflection of model caused by twisting moment of 60 kg of force

Table 2. Twist angle and torsional stiffness under various load magnitudes obtained from simulation.

Load (kg)	Twist angle (°)	Torsional Stiffness (Nm/deg)
30	0.010252	94071.84
60	0.020485	94162.38
90	0.030801	93937.35
120	0.041287	93438.57
150	0.05163	93401.34
180	0.061032	94814.58

Table 2 shows the average of twist angle of chassis at the right side and left side. The magnitude of load has significant effect to the twist angle. The higher the load magnitude, the larger the twist angle of the chassis. However, the magnitudes of torsional stiffness are mostly similar for all load values.

The calculated twist angle and torsional stiffness from the experiment are tabulated in Table 3.

Table 3. Twist angle and torsional stiffness of various loads obtained from experiment.

Load (kg)	Twist angle (°)	Torsional Stiffness (Nm/deg)
30	0.009770	98717.43
60	0.020010	96396.34
90	0.030569	94648.97
120	0.040514	95222.94
150	0.050379	95719.57
180	0.060051	96364.11

In order to validate the FE simulation result with the experiment, comparison between experiment results and simulations were done. The comparison result is shown in Figure 5.

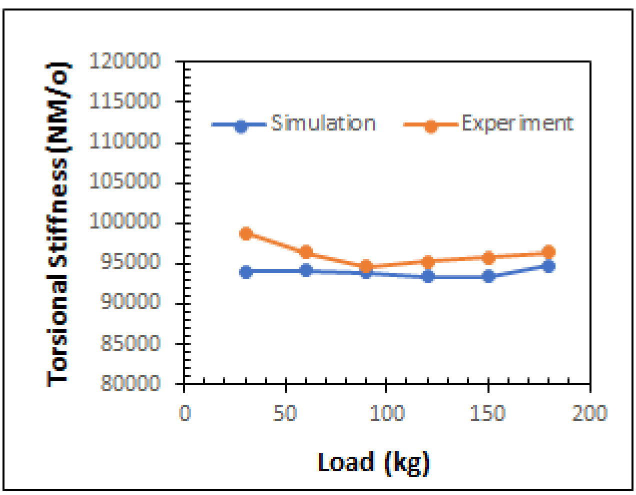

Fig. 5. Comparison of torsional stiffness between experiment and simulation.

From Figure 5, it is shown that the measurement results agree well with the simulation results. The maximum difference between simulation and experimental results is 4.71%. The average difference is 2.28%.

5 Conclusions

Rig test fixture for torsional stiffness measurement has been developed successfully. The measured value of torsional stiffness of TATA Cab chassis was 96178.23 Nm/°**.** Based on the comparison result, it is shown that for each load value, the torsional stiffness's obtained from the experiment agree well with the simulation results with maximum percentage difference of 4.71 % for load of 30 kg. The average percentage difference between experiment results and simulation results is 2.28%.

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