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ABSTRACT

The torsional stiffness of a vehicle's chassis significantly affects its handling characteristics and is therefore an important parameter to measure. In this work a new twist fixture apparatus designed to measure the torsional stiffness of a Winston Cup series race car chassis is described. The twist fixture is relatively light weight, adjustable, and easily transportable by one person for quick set-up on different chassis. Measured values of torsional stiffness are reported for several different chassis. The fixture applies vertical displacements (using linear, jack-screw actuators) at the front spring perches of the chassis while holding the rear perches fixed. Conventional race car scales located under the front assembly measure the resulting reaction forces due to the displacements. Dial indicators are placed at selected locations along the chassis to measure deflections. Using the dial indicator readings, the measured reaction forces and the chassis geometry, the torsional stiffness of the chassis can be calculated. Ball-joint connections between the twist fixture and chassis have been carefully designed to minimize unwanted rotational restraints. A typical test involves twisting the chassis in increments up to a set point and then untwisting it back to the starting point. The average torsional stiffness value is determined from a least-squares fit. An uncertainty and repeatability analysis of typical data is presented to determine the sensitivity of the stiffness measurement as a function of uncertainty in scale readings, dial indicators and geometry measurements. To help validate the twist fixture, the torsional stiffness of a standard frame structure with a known stiffness value based on an analytical mechanics solution is measured and compared. Tests conducted using the standard resulted in measured values of torsional stiffness slightly higher (about 6%) than the analytical prediction. The difference between measured and predicted values is within the expected uncertainty of material constants, geometry, dial indicator measurements and the assumptions inherent in the analytical solution.

INTRODUCTION

The torsional stiffness of a NASCAR Winston Cup Series chassis can have a significant effect on its handling [1]. In order for the suspension to control the vehicle's motion, chassis flexibility must be minimized. Winston Cup chassis are primarily constructed of mild steel tubular and box beam members. The floor-pan and firewall are constructed of thin gauge, steel sheet metal. An illustration of a chassis is shown in Figure 1. Although much of the chassis' geometry is dictated by NASCAR rules [2], there are several modifications and additions that can be made to significantly alter the torsional stiffness. Much effort has been made to predict the torsional stiffness of alternative Winston Cup chassis designs using finite element analysis (FEA) [3,4,5,6]. In order to validate these finite element models an experimental method is needed to directly measure torsional stiffness. The purpose of this project is to design and build a twist fixture for measuring the torsional stiffness of alternative Winston Cup chassis designs. The rapid measurement of torsional stiffness allows different chassis designs to be evaluated and compared. The measured data may also be used to validate finite element models.

The following design constraints were applied to the twist fixture design:

1. ability to twist the chassis in both a clockwise and counter-clockwise direction about the chassis' longitudinal axis,
2. ability to measure torsional stiffness with a total error (from uncertainty and regression analyses) of less than 5%,
3. adjustable to different chassis geometries including lateral and longitudinal widths of attachment points,
4. repeatable measured data.

The following design criteria were applied to the twist fixture design:

1. does not require removal of major suspension components in order to measure chassis stiffness,
2. light weight and easily transportable,
3. low cost of materials and maintenance,
4. minimum constraints on chassis during twist.

To satisfy the constraints and meet the objectives, a twist is designed and analyzed. To twist the chassis, known equal and opposite vertical displacements are applied to the front spring perches. The displacements are applied using linear actuators (jack-screws) and measured with dial indicators. Reaction forces are measured using standard race scales. The applied torque is calculated from the reaction forces. The chassis twist angle is calculated from the applied displacements and the lateral distance between displacement actuators. The torsional stiffness is then calculated by dividing the torque by the twist angle.

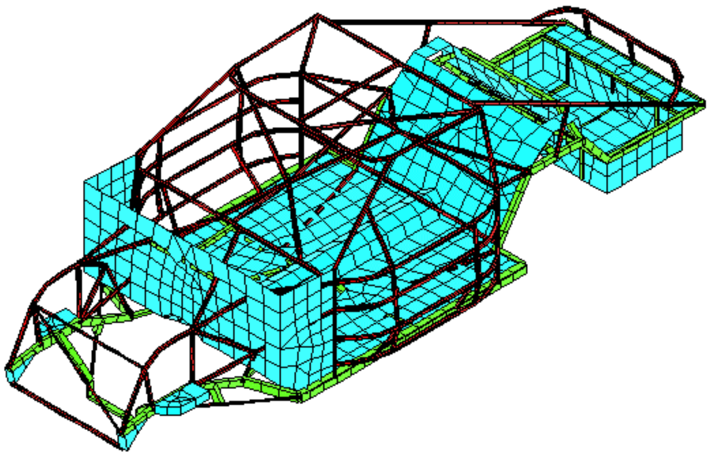


Figure 1. Finite element model of a typical Winston Cup chassis showing steel tubing, box-beams, floor pan and firewall.

LINEAR JACK-SCREW CONCEPT

A new twist fixture design is introduced which uses linear, jack-screw actuators at the left and right posts to apply equal and opposite vertical displacements to twist the chassis about a virtual pivot point close to the vertical chassis center (see Figure 2). This ensures the chassis is twisted in pure rotation, resulting in an accurate measurement of the absolute chassis stiffness. Furthermore, controlling independent jack-screws on the left and right side allows the chassis to be twisted precisely about its centerline by adjusting each actuator's travel accordingly.

CONSTRAINT CONDITIONS

In order to determine minimum constraint conditions at the ends of the twist fixture posts, which allow the chassis to rotate freely yet maintain a stable configuration, a finite element analysis is performed. The finite element model used for this constraint study consists of a typical Hopkins Chassis model [6], a model of the twist fixture and the constraints between them. The coordinate system used for this study has the positive x-axis longitudinally oriented towards the rear of the chassis, the positive y-axis laterally oriented towards the right of the chassis and the positive z-axis is vertically oriented towards the top of the chassis.

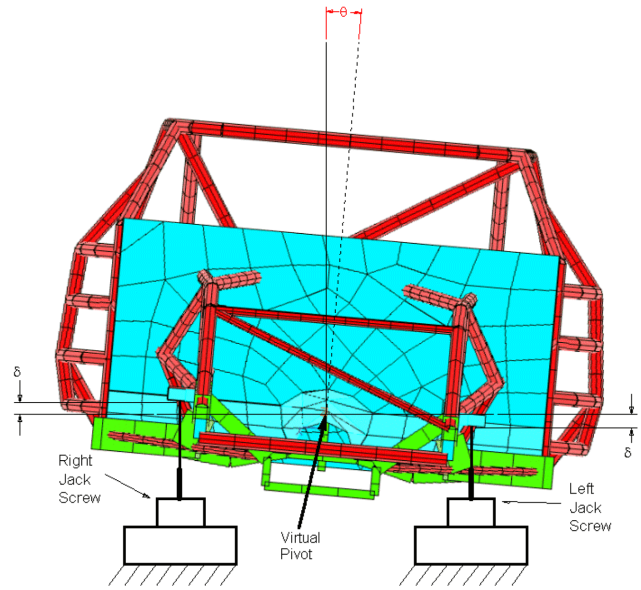


Figure 2. Illustration of twist fixture based on linear, jackscrew actuators.

To simulate ball joint constraints, translational degrees of freedom between the posts and the chassis are coupled and rotational degrees of freedom are left uncoupled. Hinge joints at the base of a post are modeled by fixing translational degrees of freedom in all directions and fixing rotational degrees of freedom about the x-axis (q_y = free). A solid attachment is modeled by coupling both rotational and translation degrees of freedom. To twist the chassis about the longitudinal axis, the bases of the front posts are translated in the vertical direction, equal and opposite on each side. The vertical reactions at the bases of the front posts are used to calculate the torque. Stiffness is calculated from the torque divided by the applied twist angle.

Based on the finite element study, the minimum constraints are determined as:

- (LR) Left-Rear Post: Fixed degrees of freedom at the bottom, free rotation about all axes (ball joint) at the top.
- (RR) Right Rear Post: Ball joints at the bottom and top.
- (LF) Left-Front Post: Free rotation about the y-axis with all other degrees of freedom fixed at the bottom, ball joint at the top.
- (RF) Right Front Post: Ball joints at the bottom and top.

These boundary conditions showing free translational motion of the chassis are illustrated in Figure 3. These constraint conditions allow for free translation of the tops of the right posts in both the longitudinal and lateral directions. They also allow free longitudinal translation at the top of the left-front post.

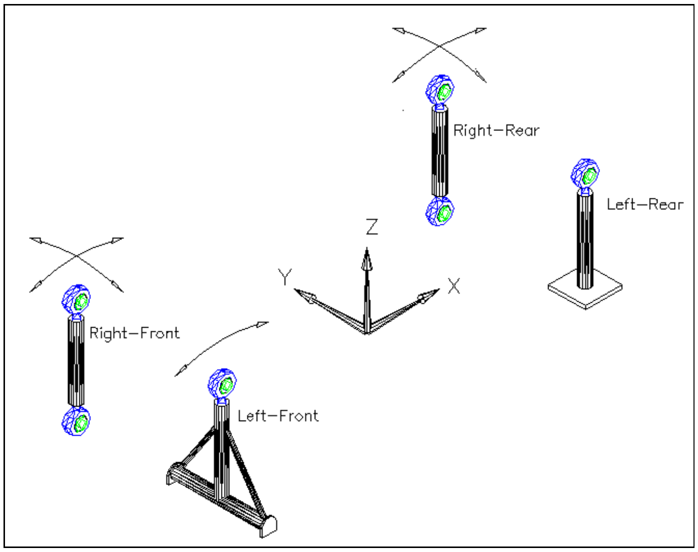


Figure 3. Minimum constraint boundary conditions showing free translational motion of the chassis.

In order to simplify construction set-up, several alternative constraints are considered. The alternative constraint conditions are based on eliminating degrees of freedom at the bottom of the posts.

Alternative constraint set-ups:

1. Minimum constraint set-up.
2. Case 1 with fixed x and z rotation at the base of the RR post.
3. Case 2 with fixed y rotation at the base of the RR post.
4. Case 3 with fixed x and z rotation at the base of the RF post.
5. Case 4 with fixed y rotation at the base of the LF post.
6. Case 4 with fixed y rotation at the base of the RF post.
7. Case 4 with fixed y rotation at the base of both front posts.

The torsional stiffness for each case is compared to the minimum constraint set-up in Figure 4. The results indicate that the difference for all the cases considered is less than 0.25% from the minimum set-up. For ease of construction, the constraints corresponding to case 4 are used for the twist fixture design. Figure 5 illustrates the constraints used on the actual fixture.

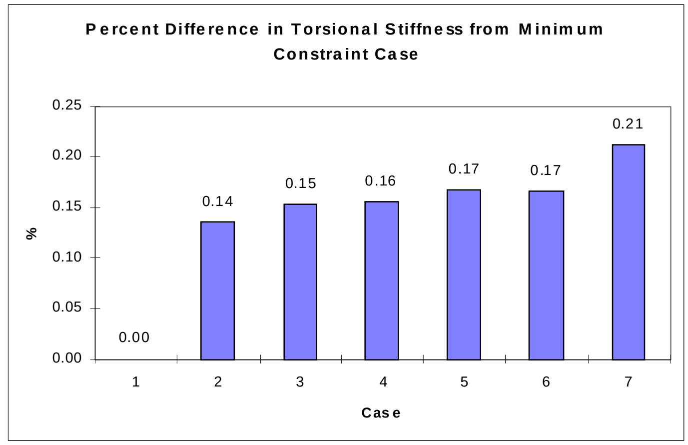


Figure 4. Percent difference in stiffness of different constraint cases compared to minimum constraint case.

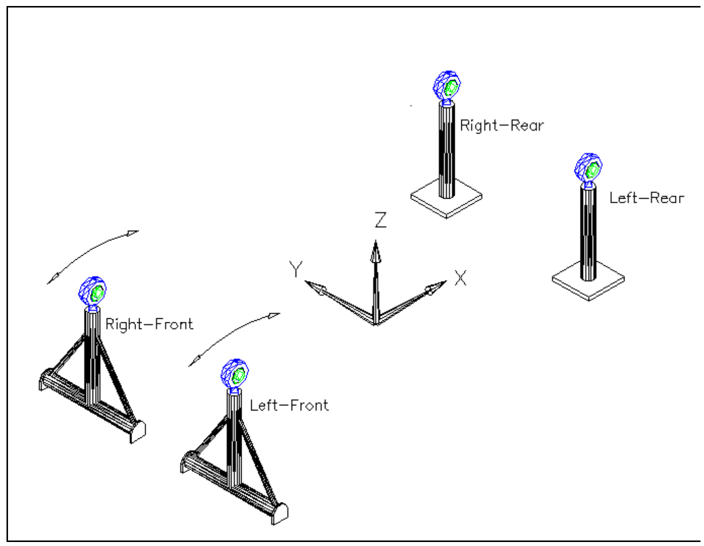


Figure 5. Constraints used on actual twist fixture.

At the top ends of the vertical posts, ball joints are used to allow for the rotational degrees of freedom of the chassis connection to be decoupled from the twist fixture. At the rear, the bases of the vertical posts are bolted solidly to the support platform. At the front, a hinge joint is used between the posts and the jackscrews to allow rotation about the lateral axis only.

TWIST FIXTURE DESIGN

In this section a twist fixture design is presented based on the jack-screw concept for twisting the chassis which uses support stands bolted to the floor. Vertical posts connect the jack-screws to the chassis at the front spring perch. In the rear, vertical posts connect the chassis directly to bolted support stands. The rear assembly consists of two identical stands, one of which is illustrated in Figure 6. Figure 7 shows a photograph of the actual rear stand. A triangular post on the stand is used to facilitate attachment to the chassis without removal of the rear trailing arms. A ball joint is used at the attachment to the chassis and allows all rotational degrees of freedom to be decoupled. Since the stands are bolted solidly to the floor, all rotations and translations are fixed at the base. Slots are milled in the stands to allow for lateral adjustment of the spacing between the two stands.

Figure 8 shows an illustration of the front assembly. Pieces of angle iron are welded to the ends and sides for bolts that fix the assemblies to the floor. Slots are also milled in the front assemblies to allow for adjustments both laterally and longitudinally. The attachments at the chassis and the jack-screws use ball joints at the top of the posts where they attach to the chassis and hinge joints at the bottom where they attach to the jack-screws. Figure 9 shows a photograph of the actual front assembly.

The front assemblies of the fixture weighed approximately 83 lb. each while the rear assemblies weighed approximately 48 lb. each. Both the size and weight of the assemblies of the bolted fixture allowed a single person to transport it. The jack-screw, hinge joint and post can also be removed (in one piece) from the front assembly to reduce the total amount of weight that is carried at one time. This would separate the front assembly into two components weighing 54 lb. and 29 lb. each.

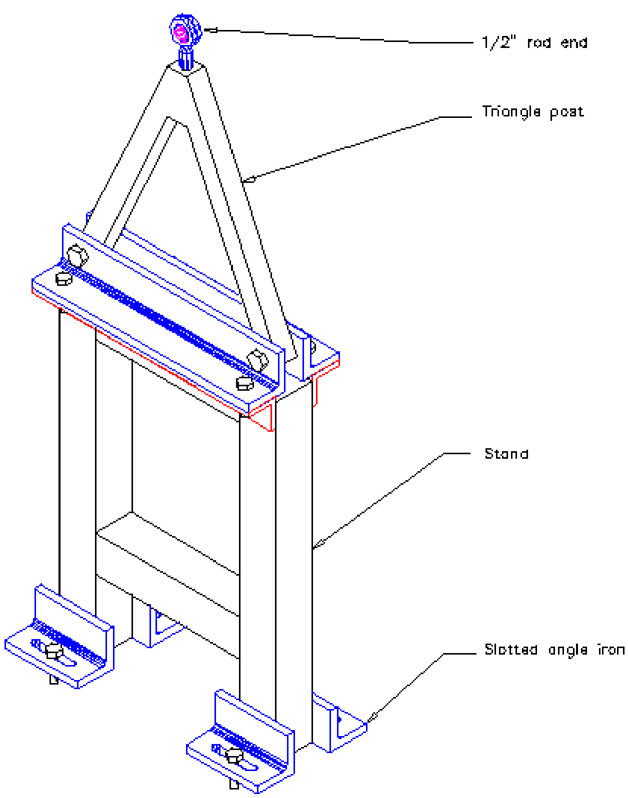


Figure 6. Illustration of rear stand for twist fixture.

Figure 7. Photograph of rear stand for twist fixture.

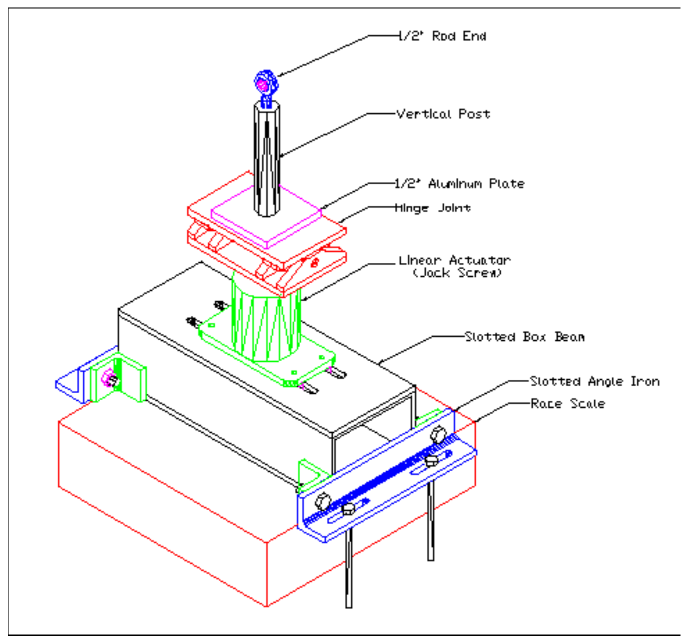


Figure 8. Illustration of front assembly for twist fixture.

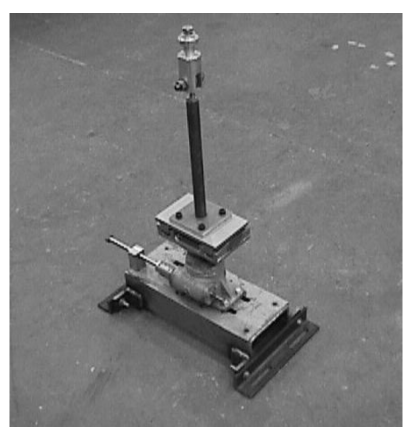


Figure 9. Photograph of front assembly for twist fixture.

The race scales are placed directly under the front assemblies. At large enough twist angles the reaction force at one of the front posts changes from compression to tension. As a result, this scale no longer reads the reaction force since it is only capable of measuring compressive loads. Use of tension/compression load cells in place of the scales would allow tension to be recorded, however this is not necessary. Since the tops of all four posts have ball joints, which uncouple the rotational degrees of freedom from the chassis, the change in magnitude of the tension load on one scale is the same as the change in magnitude of the compressive load on the other scale, i.e., $|\Delta R_r| = |\Delta R_l|$. As a result, only the scale with the compressive load is used to record reactions. The validity of this observation is evident in test data and from analysis. Both the test data for different chassis and the finite element data from the chassis model described earlier show that the changes in the reaction forces after twisting the chassis any set amount are equal in magnitude and opposite in direction. To clarify the use of only the compressive reaction, an analysis was performed of a simplified asymmetric chassis structure with applied equal and opposite displacements [7]. The analysis shows that for an asymmetric structure supported with ball joints at the corners, the left and right side reaction forces are equal and opposite.

Aluminum adapters are constructed to attach the ball joints of the twist fixture to the chassis. They are inserted from below into the threaded openings on the spring perches. A bolt is then threaded into the insert from the top of the opening to secure it to the chassis. Figure 10 shows a photograph of the adapters. Figures 11 and 12 show the fixture and adapters installed on a chassis.

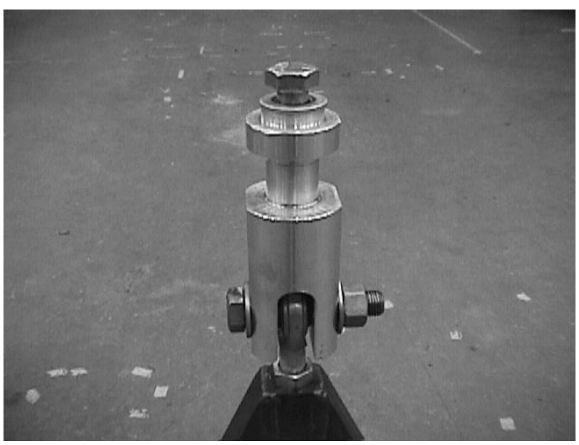


Figure 10. Aluminum mounting adapter used to connect fixture to chassis.

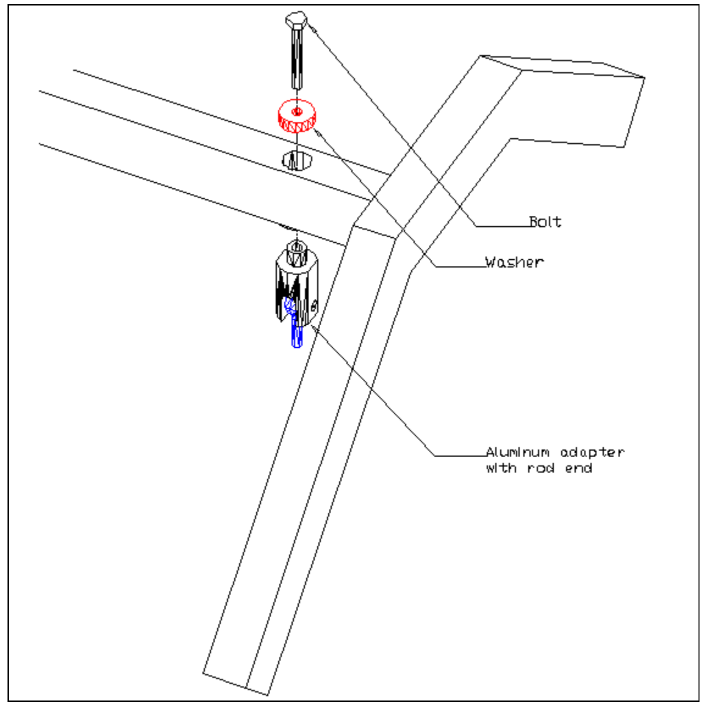
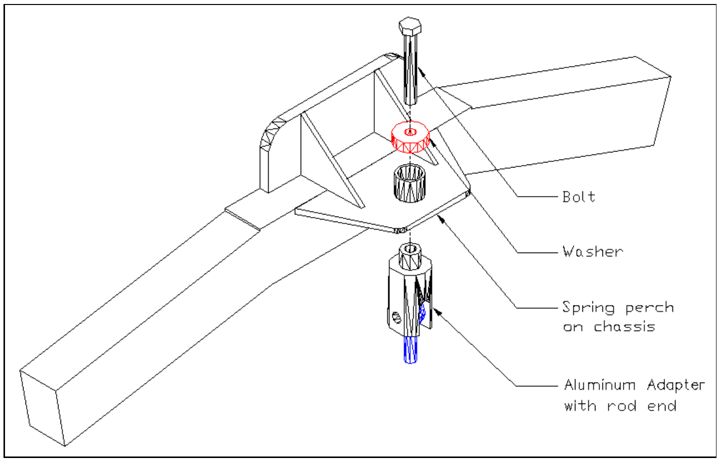


Figure 11. Connection of rear adapter to chassis. (Bottom Left) Illustration, (Above) Photograph.



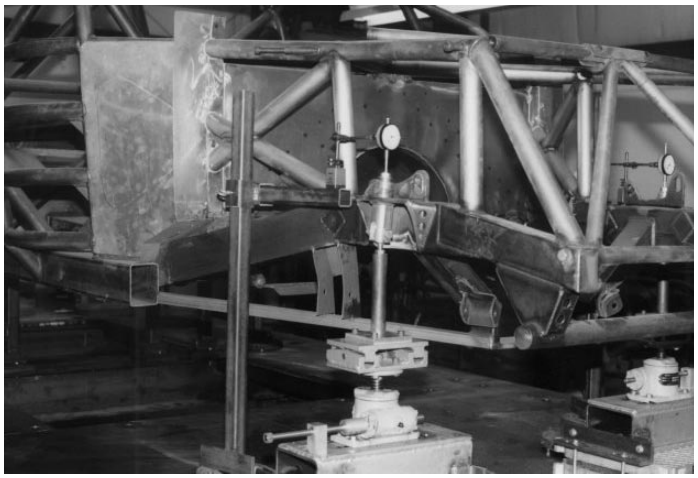


Figure 12. Connection of front adapter to chassis. (Top) Illustration, (Bottom) Photograph.

Since the fixture is bolted to the floor, holes must be drilled in the floor to accommodate the bolts. These holes must be accurately located in order to ensure that the fixture lines up with the chassis. Two methods can be used to determine the hole locations.

The first, and easiest method, is to install the fixture to the chassis and simply transfer the hole locations to the floor. Before the holes are marked, the chassis is leveled and the front posts are aligned vertically. Once the holes are marked, the chassis and fixture are moved and the holes are drilled. This method ensures that all holes line up correctly.

The other method involves measuring the chassis first and then determining the hole locations from the chassis' geometry. The aluminum adapters that mate with the twist fixture are installed and then the measurements can be taken. The following three measurements are needed: lateral distance between front adapters, d_f, lateral distance between rear adapters, d_r, longitudinal distance between front and rear adapters, L. Measurements must be made to the centerlines of the bolts that will attach the fixture to the adapters. Once these measurements are determined, the exact hole locations can be calculated. To ensure that the fixture's adjustment will be sufficient for all chassis measured, choose the hole locations to be half way between the minimum and maximum calculated locations. Details for the layout and drilling procedures are given in [8].

MEASUREMENT OF TORSIONAL STIFFNESS AND UNCERTAINTY ANALYSIS

In this section, the procedures used to calculate torsional stiffness using the twist fixture for a typical Winston Cup chassis are discussed. Measurements from a fully assembled car are used to illustrate the uncertainty in the design. Dial indicators are used to measure the equal and opposite applied vertical deflections δ, at the left and right front spring perches. For given small deflections δ, the front twist angle is

$$\theta_f = \frac{2\delta}{L_f} \ (radians) \tag{Eq. 1}$$

where L_f is the lateral distance between the front dial indicators. Force reactions at the left front and right front, denoted R_l and R_r, respectively, are measured by scales. The torque is calculated from

$$T = \left(\frac{|R_r| + |R_l|}{2} \right) L_s \tag{Eq. 2}$$

where L_s is the lateral distance between the scales. The twist angle is adjusted by subtracting the deflection at the rear. The twist angle at the rear, θ_r, is calculated from vertical deflections measured near the rear spring perches.

$$\theta_r = \frac{|\delta_r| + |\delta_l|}{L_r} \ (radians) \tag{Eq. 3}$$

where δ_r and δ_l are the right and left vertical deflections measured (by dial indicators) near the rear spring perches and L_r is the lateral distance between the rear dial indicators. The torsional stiffness at each increment is calculated by

$$K = \frac{T}{\theta} \tag{Eq. 4}$$

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

Test results for torque vs. relative twist angle q for the fully assembled car are given in Figure 13. The chassis is twisted in increments, with data recorded at each step. After several steps the twist angle is reversed until reaching zero. A least-squares regression is performed on the data with q as the dependent (x) variable and the torque as the independent (y) variable. The y-intercept is forced to zero since zero twist angle results in zero torque. The slope of the least-squares regression line represents an average stiffness value over the range of twist angles measured. Note that there is some hysteresis in the data, which is likely due to friction. The least-squares fit accounts for the hysteresis since it fits a line through all of the data.

For the data shown in Figure 13, the slope is 14423 ft-lb/deg with a standard error of ±67.5 (with 95% confidence). To get an estimate of a 95% confidence interval for the slope, the standard error is multiplied by two and then added and subtracted from the slope. This results in a 95% confidence interval of K = 14423±135 ft-lb/deg. From this point forward, the standard errors specified are actually the standard error multiplied by two.

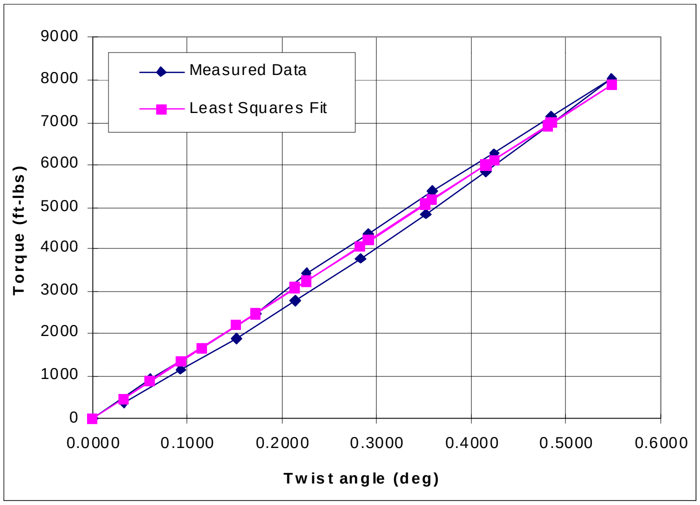


Figure 13. Data and least-squares regression line of twist angle vs. torque for test of fully assembled car.

An uncertainty analysis is performed to determine the uncertainty in the measured torsional stiffness. The following data was measured and assigned an uncertainty:

- L_f - distance between front dial indicators (in)
- L_r - distance between rear dial indicators (in)
- L_s - distance between scales (in)
- R_r - right change in scale reading (lb)
- R_l - left change in scale reading (lb)
- δ - front dial indicator readings (in)
- δ_r - right rear dial indicator reading (in)
- δ_l - left rear dial indicator reading (in)

The uncertainties are obtained from the resolutions of the dial indicators, tape measure and scales. The dial indicators are graduated in thousandths so the uncertainty in the dial indicator reading was chosen to be ±0.001". A tape measure is used to measure the distance between the dial indicators. Although the tape measure is graduated in sixteenths, it is very difficult to accurately place the tape measure exactly where the dial indicators are placed. Therefore, to be conservative, the uncertainty was chosen to be ±0.25". The scales read in one pound increments and their accuracy is 0.25% of the full scale reading.

Combining equations (1) through (4) we obtain an expression for the torsional stiffness in terms of the measured parameters

$$K = \frac{1}{2}\frac{\left(|R_r| + |R_l|\right)L_s}{2\dfrac{\delta}{L_f} - \dfrac{|\delta_r| + |\delta_l|}{L_r}} \qquad \text{(Eq. 5)}$$

Organizing the measured data in vector form,

$$\underline{X} = \begin{Bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \\ X_6 \\ X_7 \\ X_8 \end{bmatrix} \end{Bmatrix} = \begin{Bmatrix} \begin{bmatrix} L_f \\ L_r \\ L_s \\ R_r \\ R_l \\ \delta \\ \delta_r \\ \delta_l \end{bmatrix} \end{Bmatrix} \qquad \text{(Eq. 6)}$$

The stiffness can be expressed compactly as a function of the measured data X by

$$K = K(X) = f(L_f, L_r, L_s, R_r, R_l, \delta, \delta_r, \delta_l). \qquad \text{(Eq. 7)}$$

A measure of uncertainty is obtained by the norm,

$$U_K = \sqrt{\sum_{i=1}^{8}\left(\frac{\partial K}{\partial X_i}dX_i\right)^2} \qquad \text{(Eq. 8)}$$

In the above, dX_i is the uncertainty in the measured data and $\partial K/\partial X_i$ is the sensitivity of the stiffness with respect to the measured variable X_i.

The contribution from each variable to the uncertainty is

$$t_i = \frac{\partial K}{\partial X_i}dX_i \qquad \text{(Eq. 9)}$$

The uncertainty in the stiffness is

$$U_K = \sqrt{\sum_{i=1}^{8}(t_i)^2} \qquad \text{(Eq. 10)}$$

The results of the uncertainty analysis show that the terms proportional to the dial indicator uncertainties (t_6, t_7 and t_8) and the term proportional to the uncertainty in L_f (t_1) contribute the most to the uncertainty in K.

The uncertainty analysis of the data at approximately half the max twist angle (±0.08") gives a value of ±222 ft-lb/deg or 1.5%. The standard error of the slope from the least-squares regression is added onto the uncertainty number in order to obtain the total error. The standard error from the least-squares regression is ±135 ft-lb/deg. So the best estimate of the stiffness is K = 14423±357 ft-lb/deg or 2.5% error (with 95% confidence).

An estimate of the twist angle required to obtain a specified uncertainty value can be obtained by twisting the chassis an arbitrary amount and measuring the reaction forces and dial indicator readings. The reaction forces and dial indicator readings at higher displacements can be estimated easily since the reaction forces vary linearly with displacement. A twist angle is determined which gives approximately 1 % uncertainty at the maximum twist angle (which ensures only 2-3% uncertainty at half the max twist angle). A detailed description of the uncertainty analysis results, test procedure and twist fixture set-up is given in [8].

VALIDATION USING A STANDARD

To validate the twist fixture, a standard is constructed with a known torsional stiffness. The standard is a simple circular "torque tube" with rectangular sections welded to the ends to interface with the twist fixture (see Figure 14). The circular center section is a piece of structural steel tubing with an outside diameter of 2" and an average wall thickness of 0.110". The square beam sections on the ends are made of 2x2" square structural steel with an average wall thickness of 0.1875".

Welded to the ends of the square sections are special adapters (see Figure 15) that were constructed to allow the insertion of a rod-end (ball joint). The adapters also allow the displacements from the twist fixture jack-screws to be applied directly at the center of the cross-section of the square members.

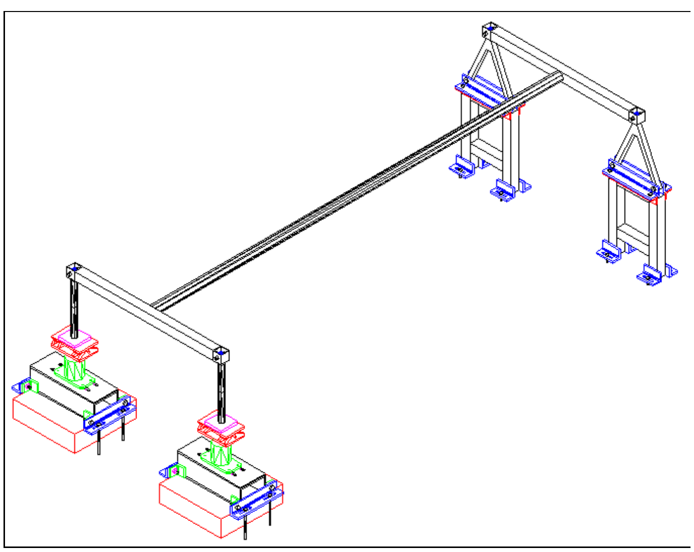


Figure 14. Illustration of standard and twist fixture.

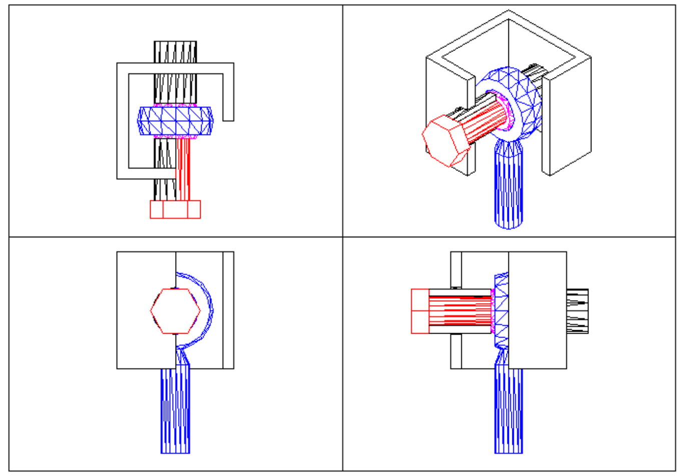


Figure 15. Rod-end adapters used on standard (cutaway view).

The test procedure is the same as that used with the chassis except the maximum twist value is much larger. The standard is twisted in increments of ±0.100" up to a maximum value of ±1.000" measured with the front dial indicators placed 32" apart.Based on beam theory to predict the deflection of the square beams, simple torsion for the circular tube, and with ball joints (free rotations) at each end of the standard, the vertical reactions at the front are equal and opposite with magnitude,

$$B_z = -A_z = \frac{2GJ\delta}{ld^2(1+\frac{2dGJ}{12EIl})} = 100.4 \text{ lb}$$

where

- A_z = Right-front reaction force
- B_z = Left-front reaction force
- G = Modulus of rigidity of steel
- J = Second polar moment of area of circular tube
- δ = Twist fixture jack-screw displacement
- l = Longitudinal distance between front and rear supports
- d = Lateral distance between left and right supports
- E = Modulus of elasticity of steel
- I = Second moment of area of square sections

From the applied twist angle θ = 2δ/d, the torsional stiffness predicted by the analysis is,

$$K = \frac{A_z d}{\theta} = \frac{2GJ\delta}{ld(1+\frac{2dGJ}{12EIl})\theta} = 94.58 \text{ ft-lb/deg}$$

An uncertainty analysis of the analytically determined stiffness was performed resulting in an uncertainty of ±3.23 ft-lb/deg. The uncertainty of the analytical stiffness is then K=94.58 ±3.23 ft-lb/deg (with 95% confidence).

A finite element model was also created to validate the hand analysis, see Figure 16. The finite element model consists entirely of beam elements for both the standard and the twist fixture. The finite element results matched with the analytical solution.

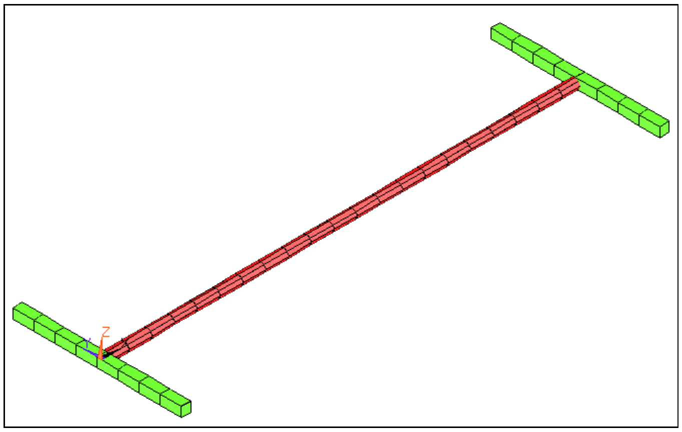


Figure 16. Finite element model of standard.

Figure 17 gives the test results for the standard obtained from the twist fixture. The slope of the regression line represents the torsional stiffness of the standard. With the standard error and the uncertainty (evaluated at ±0.500" of displacement, or half the total twist angle), the best estimate of the stiffness is 99.94±1.51 ft-lb/deg (with 95% confidence). Considering both the uncertainties and the standard error, the measured stiffness of the standard (using the twist fixture) is at least 0.6% higher than the analytically determined stiffness. Ignoring the uncertainties and standard error, the average stiffness is about 6% higher.

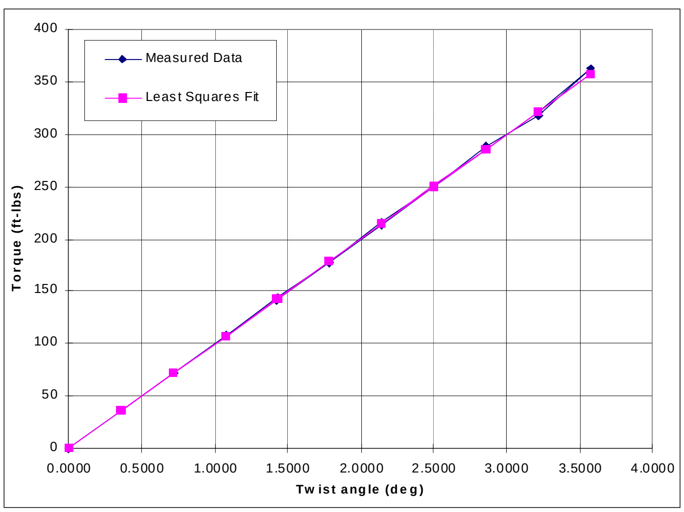


Figure 17. Data and least-squares regression line of twist angle vs. torque for test of standard.

REPEATABILITY – The repeatability of the twist fixture is also tested using the standard. The test was performed once, the fixture was disassembled, and then the twist fixture was reassembled and the test was performed again. The measured stiffness from the first test was 101.8±1.51 ft-lb/deg and for the second test, 100.4±1.64 ft-lb/deg. Since the lower bound of the stiffness measured in the first test overlaps the upper bound of the stiffness measured in the second test, the twist fixture shows good repeatability.

TORSIONAL STIFFNESS OF DIFFERENT CHASSIS DESIGNS

Physical testing of several bare chassis were conducted at Winston Cup team race shops using the twist fixture. Three Laughlin chassis, a Hopkins chassis and a SVO chassis were tested. The third Laughlin chassis was tested both with and without the engine and transmission installed to determine their effects on torsional stiffness. Two of the Laughlin chassis were manufactured in different years. One is a newer 1997 chassis that had a slightly different design from the other, older chassis. Both are bare chassis with only the base sheet metal (floorpan and firewall) and no engine or transmission. Figure 18 shows the test results from the newer Laughlin chassis. The uncertainties in torsional stiffness measurement for the new and the older chassis are ±71.8 ft-lb/deg and ±62.0 ft-lb/deg, respectively. The standard errors from the regression analysis are 16.5 ft-lb/deg and 9.7 ft-lb/deg. The stiffness of the newer chassis is 6020±88.3 ft-lb/deg and the stiffness of the older chassis is 5350±71.7 ft-lb/deg (all with 95% confidence). Comparing the lower bound of the new chassis' stiffness to the upper bound of the older chassis' stiffness, the new chassis is at least 9.4% stiffer than the older chassis.

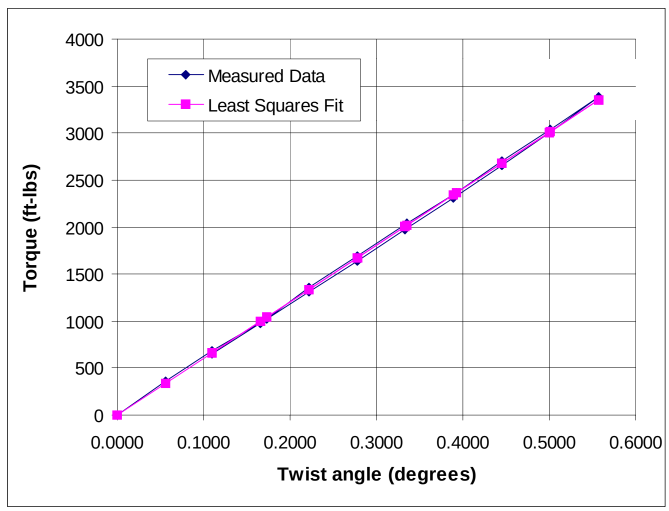


Figure 18. Twist angle vs. torque data and regression line for 1997 Laughlin chassis.

A third Laughlin chassis was tested to determine the effects of the engine and transmission on the torsional stiffness, see Figure 19. This chassis is different from the previous chassis tested in that it had the roof section of the body installed. First the chassis is tested without the engine and transmission. The torsional stiffness is determined to be 7880±175.6 ft-lb/deg. With the engine and transmission installed rigidly (rubber mounts are not used), the torsional stiffness is determined to be 8100±164 ft-lb/deg. Since these intervals overlap, statistically we can not say the stiffnesses are different. Obviously, the engine and transmission must contribute to the torsional stiffness, but the contribution is within the error of the twist fixture. Changes in torsional stiffness less than 2-3% cannot be accurately detected.

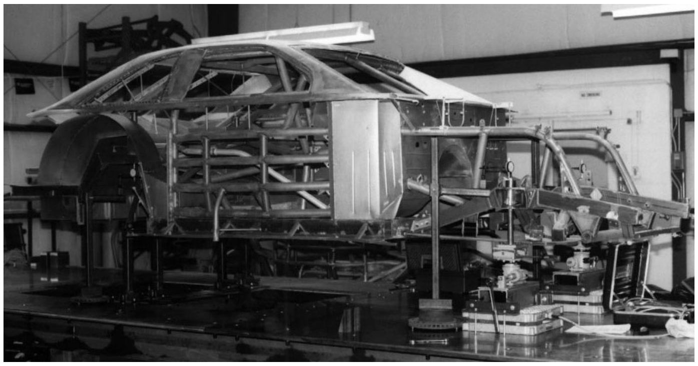


Figure 19. Testing of Laughlin chassis with roof section of sheet metal installed.

The Hopkins and SVO chassis have only the base sheet metal (floorpan and firewall) and no engine or transmission. The stiffness of the Hopkins chassis is 6390±129.6 ft-lb/deg and the stiffness of the SVO chassis is 10950±193.6 ft-lb/deg (all with 95% confidence). Comparing the upper bound of the Hopkins chassis to the lower bound of the SVO chassis, the SVO chassis is at least 65.0% stiffer then the Hopkins chassis. Test results showed that when a section of chassis was removed, the twist fixture measured a decrease in torsional stiffness of at least 11%. This is consistent with results predicted from the finite element analysis of a similar chassis configuration.

CONCLUSIONS

In order to directly measure the torsional stiffness of a Winston Cup chassis, a twist fixture was designed. The fixture was relatively lightweight and portable with the ability to be transported and set-up by one person. The time to set-up and test a chassis was approximately 3-4 hours. Through extensive uncertainty analysis and testing the accuracy of the fixture was found to be within 6%.

Validation of the bolted fixture was performed with a simple structure of known torsional stiffness. Results from the validation showed that the fixture was able to predict the average stiffness of the standard to within about 6% of the analytically determined stiffness (with 95% confidence).

Using the twist fixture design, tests were performed on several bare chassis of different manufacturers. These tests were performed to compare the stiffness values of the different chassis. For all the tests, the uncertainty and standard error were below 5%. Due to this uncertainty in the measured data, small changes in stiffness such as that contributed by the engine cannot be measured reliably with the fixture.

In addition to measuring the overall torsional stiffness of a chassis, the fixture could be used to measure the deflection distribution along the length of a chassis. Using several additional dial indicators located at key locations, the fixture could determine sections of the chassis that deflect more than others. With this information, the chassis could be strengthened in those areas to increase the overall torsional stiffness. The fixture could also be used to track a chassis' stiffness over time. A chassis could be tested after each race to determine if its stiffness is reduced from possible fatigue cracks around welds.

Finally, the twist fixture could be used to help validate finite element models. Several models have been developed to predict the torsional stiffness of the chassis as well as the roll stiffness of the combined suspension/ chassis system. Use of the twist fixture on a chassis that has been measured for a finite element model will be very beneficial in ensuring that the models are accurate. Adapters could also be constructed to connect the fixture to the car's wheel hubs. This would allow the measurement of suspension compliance in addition to the chassis' overall stiffness.

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