DESIGN OF TEST RIG FOR BENDING AND TORSION OF VEHICLE STRUCTURE

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This report was submitted in accordance with the partial requirements for the honor of Bachelor of Mechanical Engineering (Automotive)

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"I verify that this report is my own word except summary and extract that every one of it I have clarify the resource"

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Dedicated

To my beloved Mum and Dad,

To my respectful Supervisor,

To my honorable Lecturers,

&

To my fellow Friends.

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ABSTRACT

Test Rig for bending and torsion on vehicle structure was used to measure the deformation of the structure and measuring the loads produce on all tires during bending and torsion case. In designing this test rig, the total loads from the vehicle structure have been identified under bending and torsion case. The test rig function to produce the torsion and bending case and the loads is measured by using the load cell. The test rig is attached to the vehicle structure using a universal vehicle-test rig attachment. Finite element method is used to validate the design whether it is strong enough or not. If not, then the several researches will be done to repairing the design.

ABSTRAK

Rig ujian bagi kilasan dan lenturan terhadap struktur kenderaan in digunakan atas tujuan untuk mengukur herotan yang terhasil pada struktur, dan juga untuk mengukur daya yang bertindak pada kesemua tayar semasa keadaan lenturan dan kilasan pada struktur kenderaan. Dalam merekabentuk rig ujian ini, keseluruhan daya yang terhasil dari struktur kenderaan semasa kilasan dan lenturan perlulah dikenalpasti. Rig ujian ini berfungsi dalam mewujudkan keadaan lenturan dan kilasan selain daya yang bertindak semasa keadaan-keadaan tersebut diukur menggunakan 'load cell'. Rig ujian ini akan disambungkan pada struktur kenderaan melalui penyambung universal struktur kenderaan-rig ujian. Setelah siap rekabentuk terakhir bagi rig ujian ini, Kaedah Unsur Terhingga digunakan untuk memastikan bahawa rig ujian ini selamat digunakan atau tidak. Jika rig ujian ini tidak selamat digunakan, beberapa kajian tambahan akan dilakukan bagi memperbaiki rekabentuk sedia ada.

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LIST OF SYMBOLS

F	=	Force, kgm/s^2 (N)
A	=	Area, m^2
τ_{max}	=	Shear stress, N/m^2 (Pa)
T	=	Torque, Nm
J	=	Polar moment of inertia, m^4
c	=	Radius of the shaft to its outside surface, mm
r	=	Radius of gyration, mm
I	=	Moment of inertia of the cross section, m^4
L_e	=	Effective length, mm
K	=	Constant dependent on the end fixity
C_c	=	Column constant
E	=	Modulus of elasticity / Modulus young, N/m^2 (Pa)
N	=	Safety factor
σ_y	=	Yield strength, N/m^2 (Pa)
P_{cr}	=	Critical load, kgm/s^2 (N)
P_a	=	Allowable load, kgm/s^2 (N)
P	=	Actual applied load, kgm/s^2 (N)
M_{zs}	=	Dynamic load factor in bending
M_{zns}	=	Dynamic load factor in torsion
R_F	=	Load on front axle, kgm/s^2 (N)
R_R	=	Load on rear axle, kgm/s^2 (N)
L	=	Wheelbase, mm
L_F	=	Distance from centre of gravity to front axle, mm
L_R	=	Distance from centre of gravity to rear axle, mm
M_B	=	Bending moment, Nm
σ_B	=	Stress due to the bending, N/m^2 (Pa)

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CHAPTER 1

INTRODUCTION

1.1 Background

Test Rig for bending and torsion on vehicle structure has been widely used by automotive car manufacturers and researchers to measure the vehicle strength and stiffness on a static bending and static torsion case of the vehicle structure. By using that rig, an artificial situation of bending and torsion can be produced. Moreover, the load and the stiffness of the vehicle can be measured for static bending and static torsion condition. Most of researcher and automotive manufacturer will then measure the stiffness of the vehicle structure on bending condition and torsion condition. By then, based on the result, the car manufacture or the researchers will estimate the vehicle stiffness and modification on the vehicle structure design will be done if needed.

1.2 Problem Statement

In Universiti Teknikal Malaysia Melaka, the learning process for subject Vehicle Structure Analysis on Torsion and Bending has been done theoretically. It is because, currently, there is no such laboratory equipment to conduct a test for bending and torsion on vehicle structure. So, in a short term period, there is a need for student to design and develop such equipment to help faculty on providing the laboratory equipment (specifically; test rig) to support laboratory use for testing the bending and torsion on vehicle structure to increase the students (specifically; Automotive's student) understanding on that matter.

1.3 Objective

This thesis is done to design and analyze a test rig for measuring torsion and bending on vehicle structure.

1.4 Scopes

- Understanding on principal of bending and torsion on vehicle structure
- Study of structural design and analysis
- Design of test rig; design selection, geometrical dimension, material selection, strength calculation and solid modeling
- Strength analysis on test rig solid model using Finite Element Method
- Report writing and documentation

CHAPTER 2

LITERATURE REVIEW

2.1 Background

In designing the test rig for bending and torsion, it is needed to understand the related principle of design and stress analysis. Moreover, the test configuration and previous test rig design must be studied so that the suitable test rigs design, which fulfills the criteria and requirement of the test configuration, can be created.

2.2 Principle of Design and Stress Analysis

In designing the test rig, the specifications of the test rig such as *functions, design requirements* and *evaluation criteria* must be defined clearly. According Mott (2004), *functions* tell what the device must do, using general, non-quantitative statements that employ action phrases such as to support a load, to lift a crate, to transmit power or to hold two structural members together. Moreover he said, *design requirements* are detailed, usually quantitative statements of expected performance levels, environmental conditions in which the device must operate limitations on space or weight or available materials and components that may be used. Whereas, *evaluation criteria* are the statements of desirable qualitative characteristics of a design that assist the designer in deciding which alternative design is optimum- that is, the design that maximizes benefits while minimizing disadvantages.

To start a design on the test rig, a lot of factors must be taken into consideration. Mott (2004) has summarized some factors to be taken into consideration, which as listed below:

- Forces exerted by the components of the machine through mounting points such as bearings, pivots, brackets, and feet of other machine elements
- Manner of support of the frame itself
- Precision of the system: allowable deflection of components
- Environment in which the unit will operate
- Quantity of production and facilities available
- Availability of analytical tools such as computerized stress analysis, past-experience with similar products, and experimental stress analysis
- Relationship to other machines, walls and so on

2.2.1 Material

Selection of material has a high effect on the structure strength. The most significant factor to evaluate the material strength is by referring to the yield strength, σ_y and the modulus of elasticity, E of the material. Mott (2004) stated that, yield strength can be defined as the portion of the stress-strain diagram where there is a large increase in strain with little or no increase in stress. He also stated that modulus of elasticity can be define as stress proportionality to strain when the part of the stress-strain diagram is straight. Modulus of elasticity indicates the stiffness of the material or its resistance to deformation.

2.2.2 Stress

Based on Mott (2004), there are three basic fundamental kinds of stress; tensile, compressive and shear. Tensile and compressive stress, called normal stresses, are shown acting perpendicular to opposite faces of the stress element. Tensile stresses tend to pull on the element whereas compressive stresses tend to crush it. Shear stresses are created by direct shear, vertical shear in beams or torsion. In each case, the action on an element subjected to shear is a tendency to cut the element by exerting a stress downward on one face while simultaneously exerting a stress upward on the opposite, parallel face. Stress can be defined as the internal resistance offered by a unit area of a material to an externally applied load.

$$\sigma = force/area = F/A$$

When a torque or twisting moment is applied to a member, it tends to deform by twisting, causing a rotation of one part of the member relative to another. Such twisting causes a shear stress in the member. For a small element of the member, the nature of the stress is the same as that experienced under direct shear stress. However, in torsional shear, the distribution of stress is not uniform across the cross section (Mott (2004)). When subjected to a torque, the outer surface of a solid round shaft experiences the greatest sharing strain and therefore the largest torsional shear stress. The value of maximum torsional shear stress is found from:

$$\tau_{max} = Tc/J$$

where; c *= radius of the shaft to its outside surface*

J *= polar moment of inertia*

T *= Torque*

Based on Mott (2004), the behavior of members having noncircular sections when subjected to torsion is radically different from that for members having circular cross sections. However, the factors of must use in machine design are the maximum stress and the total angle of twist for such members. The formulas for these factors can be expressed in similar forms to the formulas used for members of circular section (solid and hollow round shafts).

$$T_{max} = T/Q$$

where; Q *= section modulus*

Based on Mott (2004), a beam is a member that carries loads transverse to its axis. Such loads produce bending moments in the beam, which result in the development of bending stresses. Bending stresses are normal stresses, that is, either tensile or compressive. The maximum bending stress in a beam cross section will occur in the part farthest from the neutral axis of the section. At that point, the flexure formula gives the stress:

$$\sigma = Mc/I$$

where; M = magnitude of the bending moment at the section

I = moment of inertia of the cross section with respect to its neutral axis

c = distance from the neutral axis to the outermost fiber of the beam cross section

Positive bending occurs when the deflected shape of the beam is concave upward, resulting in compression on the upper part of the cross section and tension on the lower part. Conversely, negative bending causes the beam to be concave downward.

When the dimension is already fixed, the yield strength of the material can be change to make sure the design will not failed due to bending at specify force. So, by using the dimension, calculate the moment of the beam. Then calculate the stress due to the bending and compare it with yield strength of the material. If the stress due to bending is smaller than yield strength of material, thus it mean that the beam dimension with the material used will not failed if the specify force is applied.

2.2.3 Design Factors

Based on Mott (2004), design factor, N is a measure of the relative safety of load-carrying component. He stated that in most cases, the strength of the material from which the component is to be made is divided by the design factor to determine a design stress, σ_d sometimes called the allowable stress. Then the actual stress to which the component is subjected should be less than the design stress. For the case of the buckling of columns, the design factor is applied to the load on the column rather than the strength of the material.