Development of Leaf Spring Fatigue Tester for Lyceum of the Philippines University Cavite - Mechanical Engineering Laboratory

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***Abstract*: The purpose of this study is to give an idea to the Mechanical Engineering Students of the Lyceum of the Philippines University- Cavite on how the fatigue strength of a leaf spring is tested before it gets through the market. The researchers believe that the study will broaden the knowledge of mechanical engineering students about the behavior of a leaf spring on an actual service work. The researchers made a prototype that can demonstrate fatigue testing in the leaf spring and conducted the three sets of testing with three trials on each set to ensure the reliability of the equipment. The actual data gathered by setting the load and measuring the deflection of the using the prototype were compared to the theoretical data from the computation using the formulas from the book of Design of Machine Elements by Faires. After the actual data and the theoretical data were gathered, the researchers got a percentage of error of 9.09%, 9.09% and 4.04% for the three trials. The percentage error gathered after conducting three trials are acceptable for a testing apparatus that will be used for educational purposes. Hence, it can be concluded that the prototype is reliable, and it can be used as a laboratory apparatus for the Mechanical Engineering students of LPU-C.**

Keywords: **Fatigue tester, laboratory apparatus, leaf spring, and LPU-Cavite.**

I. INTRODUCTION

In today's automobile industry, leaf springs are commonly use in heavy-duty vehicles. A leaf spring is a simple form of spring commonly used as a suspension in wheeled vehicles. Fatigue is responsible for 90% of the failures that occur in an industry. Fatigue testing equipment is used to determine the fatigue life or fatigue strength of a material. Mechanical Engineering students are having a hard time visualizing on how manufacturers determine the fatigue strength of a leaf spring. This is because the professors only teach the concepts and theories about leaf spring, and there is no actual representation on how the testing of leaf spring really works. The prototype that the researchers created can produce a cyclic load into the leaf spring to test the endurance strength of the leaf spring. The load will come from an electric motor and will be transmitted to a hydraulic cylinder using hydraulic fluid; then, the hydraulic cylinder delivers the power to the leaf spring. The hydraulic cylinder will imply the repeated load into the sample. This information gives the researchers the idea of conducting this research. The output of this research could be a great help for the mechanical engineering students especially for those that are taking machine design. Mechanical Engineering students will know the importance of determining the fatigue strength of a leaf spring, because in the industry, fatigue strength is a major aspect on how the leaf spring will perform in actual service.

Demonstrators are the most significant resource applied to the laboratory experience (Rice, Thomas & O'Toole, 2009). The benefits of demonstration as a teaching method are a better learning experience in the classroom for students; the generation interest in the subject; help in developing the spirit of inquiry; students cooperating in the teaching-learning process; and the process of learning becoming permanent in the student's life.

II. LITERATURE REVIEW

According to Dwivedi1 and Jain (2016), a spring is an elastic body, which expands in size when load is applied and regain its original shape when removed. Leaf spring is the simplest form of spring used in the suspension system of vehicle. It absorbs automobile vibrations, shocks and loads by springing action and to some extend by damping functions. It absorbs energy in the form of potential energy. The increase of spring absorbing capability depends on the number of steps. For heavy vehicles, multi leaf spring is used, while in light vehicle, mono leaf spring can be used. Although there are two main types of leaf springs mentioned above, considering the number of plates, there are also various shapes of leaf spring such as the semi elliptical, elliptical, quarter and three quarter elliptical and transverse. Since semi- elliptical is the most common and trusted leaf spring shape (Sanderson Leaf Spring Ltd) the researchers chose this type.

Fatigue is responsible for 90% of the failures that occur in an industry. In the 19th century, fatigue was considering mysterious and it led to the belief that fatigue was an engineering problem. The engineering come up of fatigue testing machine to easily analyses the factors that affect the failure of fatigue by the number of load cycles experienced, range of stress and mean stress experienced in each load cycle and presence of local stress concentrations. Testing leaf spring using the regular procedure consumes a lot of time (SAE manual, 1990.). There are major factor affecting the endurance strength such as the surface finish, material factor, type of stress factor, and reliability factor. However, generalized data are difficult to acquire for all factors. Special testing or additional literature must be done. Nayagan (2016) stated that hydraulic are capable to produce high load than the pneumatic systems. The oil inside the hydraulic is incompressible; thus, there will no pressure loss, and it is more precise and accurate in providing linear movement. It is lighter compared to the pneumatic counterparts. The overall efficiency of hydraulic pump is between 0.7 and 0.95 which is higher than the pneumatic cylinder which is much less around 0.1. The leaf spring fatigue tester components are consisting of electric motor, pump, pressure control valve. The researcher used the pressure relief valve, gear pumps, valves, directional control valves, reservoir, hydraulic fluids and hydraulic cylinders.

For the formulas in getting the dimensions of the design, calculations and analyzation of leaf spring, the researchers referred to the book “Design of Machine Elements, (1968)” by Virgil Morning Faires, and to the book "Elements of Mechanism, (1954)” by Doughtie and James. These books, studies, articles and journals stated above are the references used by the researchers for the research study.

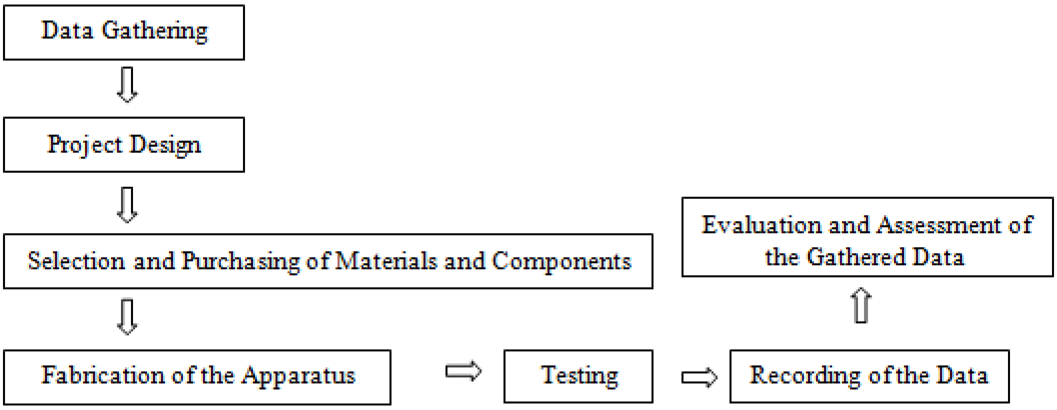
III. METHODOLOGY

In this part of the study, the researchers used quantitative type of research in order to gather information and data necessary to the study. The proponents used quantitative research to measure the fatigue strength by applying repeated load to the leaf spring using hydraulic principles and used to gather views and other defined variables. This study applied the principles of hydraulic system which includes engineering design, planning and analysis to attain the research objectives. A systematic method of acquiring related information was used to suitably design an apparatus that is able to carry out the necessary processes needed to accomplish the desired objectives. Knowledge in machine design and machine elements is also necessary to the study to create a model that is effective and economical. Analysis of the result of the prototype was done by catalog as the reference to ensure its right result produced by the leaf spring fatigue tester.

The following materials were the materials used to develop the device:

- Leaf Spring (Semi Elliptical Type)
- Hydraulic Cylinder (150mm stroke, 80mm bore size, 25mm rod)
- Multi Range Analogue Timer (AH3-NB Type)
- Weighing Batching Controller (90-260V AC/DC Power)
- S Type Load Cell
- Motor with 3.5 HP power
- Directional Control Valve
- Hydraulic Hose (3/8in diameter)
- Hydraulic Oil (#65 oil)
- Roller (2inch Diameter)

A. Project Construction Procedures



B. System Model

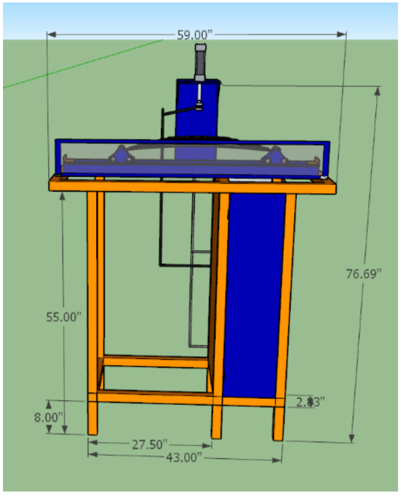


Fig. 1. Front view of leaf spring demonstrator

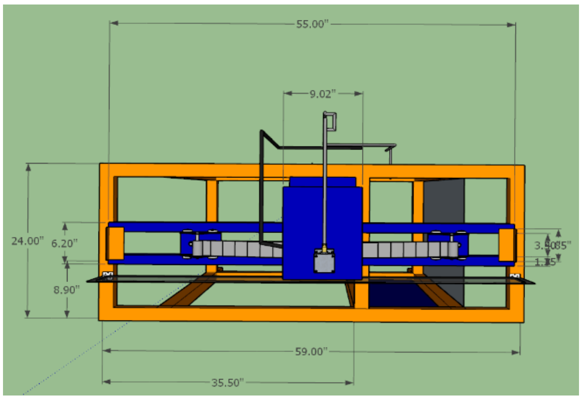


Fig. 2. Top view of leaf spring demonstrator

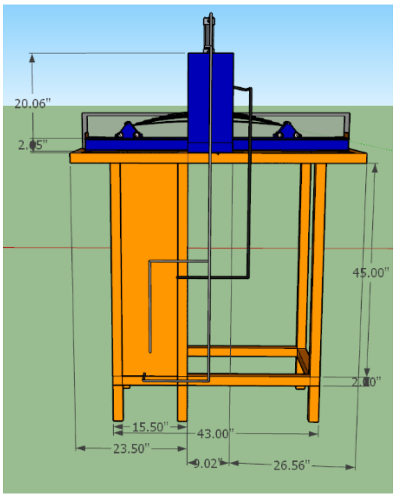


Fig. 3. Back view of leaf spring demonstrator

C. Schematic Diagram

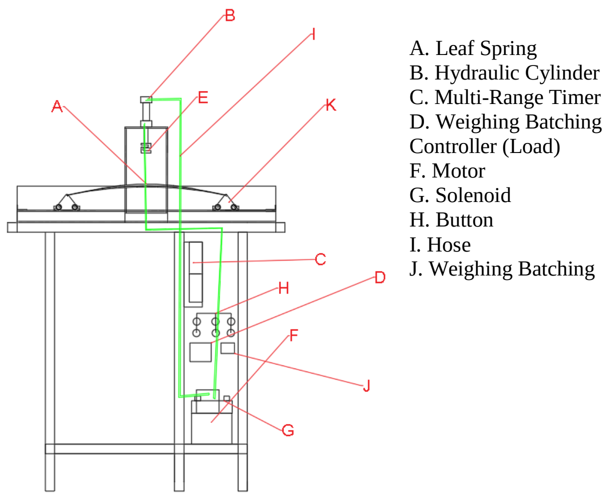


Fig. 4. Schematic diagram of leaf spring tester system

When the switch is turned on, the hydraulic motor will start producing power that will start the gear pump. Then the gear pump will deliver the hydraulic fluid from the hydraulic reservoir into the double acting hydraulic cylinder through high pressure rubber hoses. The hydraulic fluid will be filtered by inline cartridge filter type before it goes to hydraulic cylinder to prevent clogging. The double acting hydraulic cylinder will transmit the power to the semi-elliptical leaf spring. The power that will be transmitted should be repeated to get the fatigue strength of the leaf spring. The force applied by the hydraulic cylinder can be determined by the use of the weighing batching controller. Then, the operator of the equipment can adjust the load also by setting it on the weighing batching controller. The operation of the system is composed of a mechanical and electric part. The mechanical part is the mainframe of the project. The source of the power is from the electric motor that will drive the gear pump, and then the gear pump will deliver the hydraulic fluid from the hydraulic reservoir to the double-acting hydraulic cylinder through high-pressure rubber hoses. The standard pressure required will be set to be able to produce repeated loads. The inline cartridge filter is used to prevent clogging in the hydraulic cylinder. The load cell is used to determine the pressure applied by cylinder and to adjust the pressure of a hydraulic fluid the weighing batching controller is used. Directional control valves are used, because they allow fluid flow into different paths from one or more sources.

The weighing batching controller and the load cell was used to test the fatigue strength of the semi elliptical leaf spring. The desired load was entered on the weighing batching controller and the load was censored by the load cell. The weighing batching controller is a digital type. It is a measurement instrument that takes weight-based input from load cells and generates control using potential free relay outputs. The researcher used a ruler to measure the deflection of the leaf spring in terms of inches.

IV. ANALYSIS AND PRESENTATION OF DATA

A. Dimension of semi-elliptical leaf spring

TABLE I: DIMENSION OF LEAF SPRING

Name	Dimension (inch)
Width	1.6
Center Distance between two eye	34.75
Thickness of leaves	0.197
Camber	5

B. Actual data of deflection

TABLE II: BOTH ROLLERS ARE MOVING

Applied Load (kg)	Deflection (inch)			Average
	Trial 1	Trial 2	Trial 3	
50 kg	0.5in	0.6in	0.6in	0.6in
100 kg	1in	1.3in	1.2in	1.2in
150 kg	1.8in	1.9in	1.9in	1.9in

TABLE III: FIX LEFT AND FREE RIGHT

Applied Load (kg)	Deflection (inch)			Average
	Trial 1	Trial 2	Trial 3	
50 kg	0.5in	0.6in	0.6in	0.6in
100 kg	1.2in	1.3in	1.3in	1.3in
150 kg	1.7in	1.8in	1.8in	1.8in

TABLE IV: FIX RIGHT AND FREE LEFT

Applied Load (kg)	Deflection (inch)			Average
	Trial 1	Trial 2	Trial 3	
50 kg	0.7in	0.78in	0.7in	0.7in
100 kg	1.1in	1.1in	1.3in	1.2in
150 kg	1.8in	1.7in	1.8in	1.8in

C. Theoretical data of deflection

$$\delta = \frac{12FL^3}{bt^3 E\,(2n_g+3n_f)} \quad (1)$$

TABLE V: THEORETICAL DATA

Applied Load (kg)	Deflection (inch)
50 kg	0.66
100 kg	1.32
150 kg	1.98

D. Percentage error

The percentage error of the actual data vs. theoretical data considering both rollers are moving. First at 50 kg, there is 9.09% error; second at 100 kg there is 9.09% error; and lastly at 150 kg applied load, there is 4.04% error. According to Ernest, (2014), the acceptability of a percent error depends on the application. In some cases, the measurement may be so difficult that a 10% error may be acceptable.

E. Estimated life cycle of leaf spring based on (SAE manual, 1990)

TABLE VI: LIFE CYCLE OF LEAF SPRING

Sample	Initial Stress	Maximum Stress	Expected Life Cycle
Trial 1	0	50	1,000,000+
Trial 2	0	100	1,000,000+
Trial 3	0	150	1,000,000+

F. Result of testing, evaluation and Validation

The technical design of the project was determined by calculating the power required by the motor and the diameter of the hydraulic cylinder in charge of applying repeated load into the leaf spring. The power of the motor is 3.5hp, and it can apply load up to 200 kg. The load needed to be able to deflect the leaf spring is at 180 kg. The diameter of the cylinder is 5 in and have a 7.5 in stroke. The kind of cylinder used by the researcher in this project is a double-acting hydraulic cylinder because it has more control over the movement of the cylinder. The proponents used a two-way directional solenoid valve to control the fluid coming from the motor into the cylinder. To read the required load to deflect the leaf spring, the proponents used load cell as the sensors for the applied load from the hydraulic cylinder to the leaf spring to display on the weighing batching controller. The hydraulic motor and the hydraulic cylinder are connected/attached by the bolt. The proponent chose to use a bolt in the attachment of the hydraulic cylinder to the frame because it is easy to detach when adjustments or repair are needed. For the frame, the proponents used wrought iron, because it has good strength for metal, low cost. It was used primarily for decorative applications.

V. CONCLUSION

The leaf spring fatigue tester can load up to 200 kg into the leaf spring based on the capacity of the hydraulic motor and cylinder. The apparatus can test the fatigue strength of semi- elliptical leaf spring with the dimensions of|:

- Width:1 inch up to 1.75 inches
- Thickness: .5 cm up to .7 cm
- Number of leaves: 1-7 leaves

The data gathered from the equipment were compared with the data from computation. The actual data came from measuring the deflection of the leaf spring, while there was a certain load applied from the equipment. The testing procedure consisted of three sets of loads that were applied to the leaf spring with three trials each set. The theoretical data were obtained by computation using the formula for deflection of leaf spring from the book of Design of Machine Elements by Faires. After all the necessary data were gathered. The researchers examined the actual data and theoretical data by computing the percentage error. The researchers obtained the percentage of error of 9.09 % for both 50kg and 100kg and 4.04 % for 150kg based on the research regarding the acceptable percentage error in measuring a test specimen. The acceptable percentage error is 10%; therefore, the percentage error obtained by the researchers is acceptable.

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