International Journal of Latest Engineering and Management Research (IJLEMR)
ISSN: 2455-4847
www.ijlemr.com || Volume 07 - Issue 09 || September 2022 || PP. 12-17

Proposing design option for horizontal axial tensile-compression fatigue testing machine for carbon steel

Hoang Huy Duong[1], Nghia Trong Hoang[1], Dien Van Tran[2], Long Duc Nguyen[1], Lam Tien Dang[1], Minh Phat Le[1], Long Nhut-Phi Nguyen[1]
[1]*Faculty of Mechanical Engineering, HCMC University of Technology and Education (HCMUTE), Ho Chi Minh City, Viet Nam*
[2]*School of Engineering and Technology, Tra Vinh University (TVU), Tra Vinh Province, Viet Nam*

Abstract: Fatigue strength is one of the important mechanical properties in designing and manufacturing machine parts and machine clusters. The implementation of design and manufacture of experimental machine to help students and students access knowledge intuitively and vividly and reduce investment costs in the machine of the University is essential. This article presents a design option for horizontal axial tensile-compression fatigue testing machine for carbon steel with compact structure, ease of assembly, low cost, and accuracy when put into fabrication. The main operating principle of the device is based on the slider-crank mechanism, and the design is done in Solid works software.

Keywords: Fatigue strength, experimental machine, tensile-compression fatigue, carbon steel, slider – crank mechanism

---

I. INTRODUCTION

Fatigue is the gradual accumulation of failure in the material itself under the influence of time-varying stresses. This changing stress causes fatigue cracks, which develop and lead to material failure. Fatigue is mainly concerned with parts and components that are subject to variable loads and have a limited service life. These details are ubiquitous in moving structures like motorcycles, cars, trains, planes, propellers, etc., or static structures like bridges, rigs, etc. Fatigue testing plays a very important role in the design of machine parts and affects the load capacity and life of the parts. Determining fatigue strength helps develop optimal design options for the parts.

Most machine parts work in a time-varying stress state, which can fail when subjected to much lower stress than in the case of constant stress. Observe the failure when the stressed part changes: the fatigue failure process starts from the micro-cracks generated in the area of the machine part under relatively large stress; when the number of duty cycles of machine parts increases, these cracks also expand gradually, machine parts become increasingly weak and eventually break occurs [1].

At present, fatigue research is quite diverse and rich with different methods, each school, each research method requires many different machines and experiments, leading the research increasingly complex and costly. However, research results in different ways sometimes do not bring the same results [2].

The rotating beam fatigue test method is an age-old fatigue testing method. This test uses a test specimen placed in the machine and subjected to a force that produces bending moments on the shaft through weights suspended from the specimen. This force causes tensile stress on one side of the test specimen (usually upwards) and compressive stress on the opposite side. At the beginning of the test, the specimen will rotate at the desired speed. This rotation will subject the upper and lower surfaces to alternate tensile and compressive stresses until the failure of the specimen. The electronics will count the number of cycles the sample has been loaded and display it on the screen. After testing a few times, the fatigue curve S-N of the sample will be found [3].

In the torsion beam fatigue test method, the test sample is introduced into the work area and clamped by self-centering clamps. Constantly variable torque is generated through a mechanism that turns the motor's rotation into a swinging motion to reverse the torque. The system is integrated with a counter and sensor to calculate the number of cycles of the sample under torsion fatigue load when the specimen is fatigued [4].

The bending fatigue test method supports the test specimen on two curved edges of a defined radius. The force will alternately act on the center of the test specimen causing the test specimen to undergo cyclic bending [5].

The horizontal axial tension-compression fatigue test method is a test in which we create a cyclic load with a constant force in the direction of the test sample. The procedure for generating cyclic loads uses a crank-slider mechanism and a spring to transmit the tensile-compression load to the test sample [6].

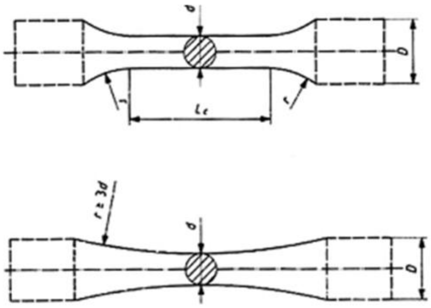
II. TEST SAMPLE

Select the test specimen made of EN S235JR steel.

Table 1
Parameters of initial values when calculating for test specimen are steel EN S235JR

	Symbol	Unit	Value
Tensile strength	σ_b	MPa	457,4
Yield strength	σ_{ch}	MPa	235
Elastic strength	σ_{dh}	MPa	198
Fatigue strength	σ_{max}	MPa	196,68
Fatigue force	$F_{kt} = P$	kN	6

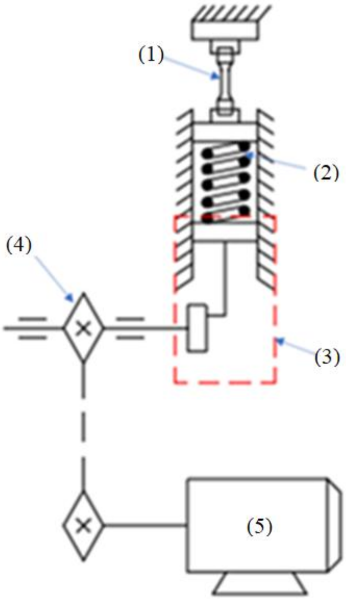
Specimen size according to TCVN 8185:2009 (ISO 1099:2008) standard (shown in Figure 1)



d (mm)	r (mm)	D (mm)	Lc (mm)
6	12	12	30

Figure 1. Drawings and dimensions of test specimen as per standard

III. MECHANICAL PRINCIPLE DIAGRAM



(1) Specimen, (2) Spring, (3) Slider-crank mechanism, (4) Chain, (5) Motor
Figure 2. The principle diagram of the equiqment

IV. CALCULATOR

Based on the mechanical properties of EN S235JR steel (shown in Table 1), as well as to expand the fatigue test range for many different steels, the article selects the force range under which the compression spring can operate as F_{min} = 4000 N to F_{max} = 8000 N.

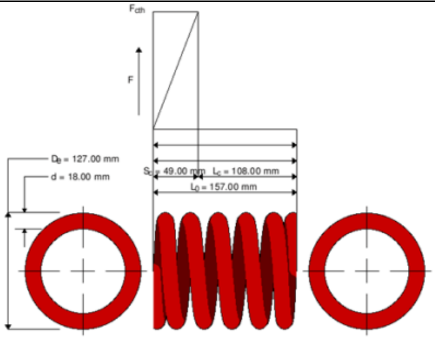


Figure 3. Spring size after calculation and selection

The diagram of force analysis and stitch separation of the slider-crank mechanism is shown in Figure 4.

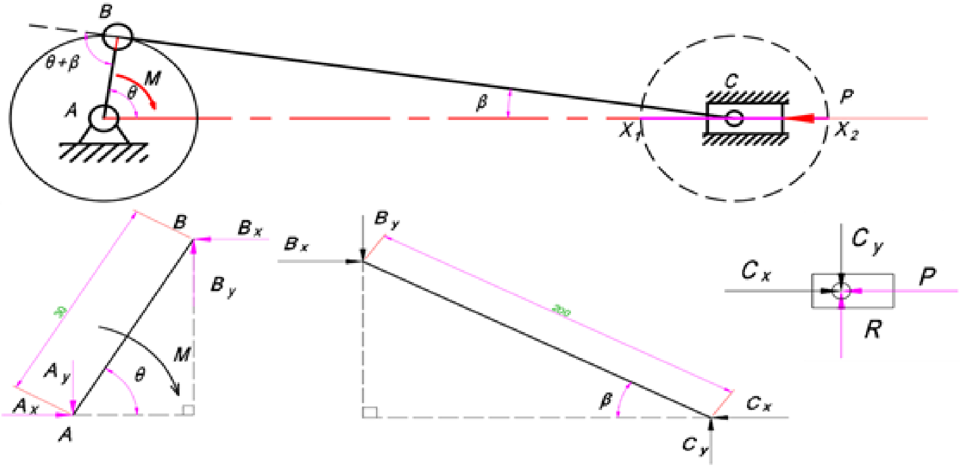


Figure 4. Diagram of determining the AB crankshaft torque moment in the crank-slider mechanism

Consider the moment equilibrium equation at point A:

$$\sum M_A = -B_x \times AB \times \sin\theta - B_y \times AB \times \cos\theta + M = 0 \qquad (1)$$

$$\Rightarrow M = \frac{P \times AB}{\cos\beta} \times \sin(\theta + \beta) \qquad (2)$$

Where P = 6000 N, AB = 20 mm, $\beta = 87{,}14^0$; $\theta = 2{,}86^0$ substitute for Equation (2):

$$\Rightarrow M = 60\ \text{kN} \times \text{mm}$$

According to TCVN 197:2014 standard, the allowable speed when testing steel samples EN S235JR: before plastic deformation S = 15 MPa/s, after plastic deformation V= 20 mm/min. On that basis, the AB crankshaft's revs are 1.34 rpm. Since test specimen typically have a cycle count of 10^3 to 10^6 cycles, the number of revolutions when testing the sample is assumed to be 300 rpm.

The motor's calculated power is 1,875 kW, including the efficiency of the transmission. Choose the motor with a capacity of 2.2 kW, with an instant reducer, and the output is 600 rpm.

The gear ratio of the chain drive is 2.

V. DESIGN ELECTRICAL AND CONTROL DIAGRAMS

After clamping the test specimen to the clamping device, to allow the clamp to be positioned, the hand wheel through the stepper motor brings the crank length to zero. After the position of the sample is fixed, use the computer to set the mode of the tester (crank length, speed) and send the run command down to the actuator, encoder from the actuator motor will read the number of revolutions corresponding to the number of cycles acting on the product, the signal through the control board and displayed on the control interface on the computer. The signal transmission cycle takes place continuously during the fatigue test. The optical sensor is used to detect the tensile test specimen. When the test specimen is pulled due to fatigue, the optical sensor will send a signal to the controller, receive a signal from the sensor, and the controller will send a signal to stop the motor of the actuator and stop transmitting the number of duty cycles on the counter interface and terminate the fatigue test.

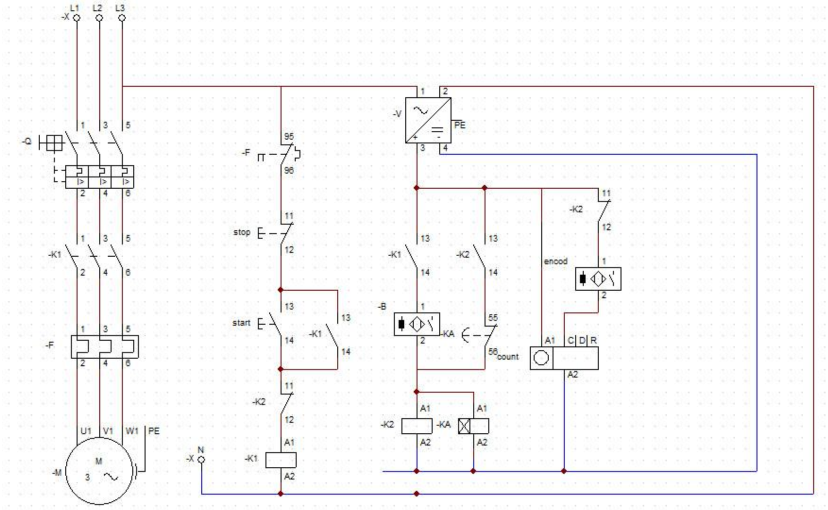


Figure 5. Control circuit diagram

VI. DESIGN DRAWINGS

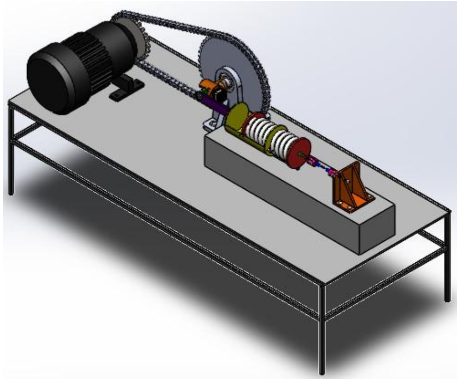


Figure 6. The 3D model of the machine

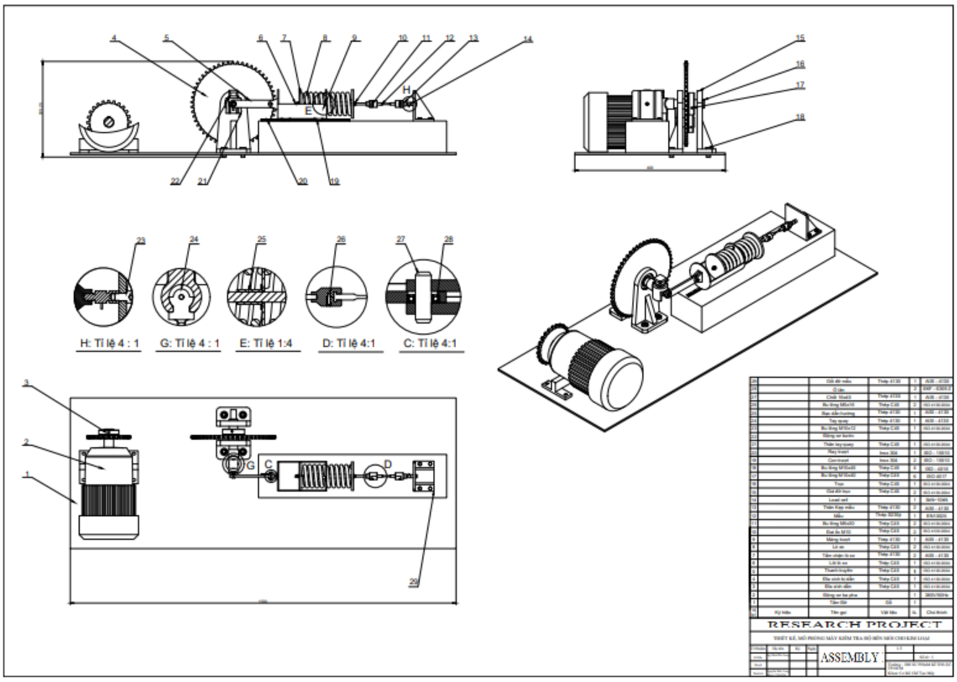


Figure 7. The assembly drawing of the device

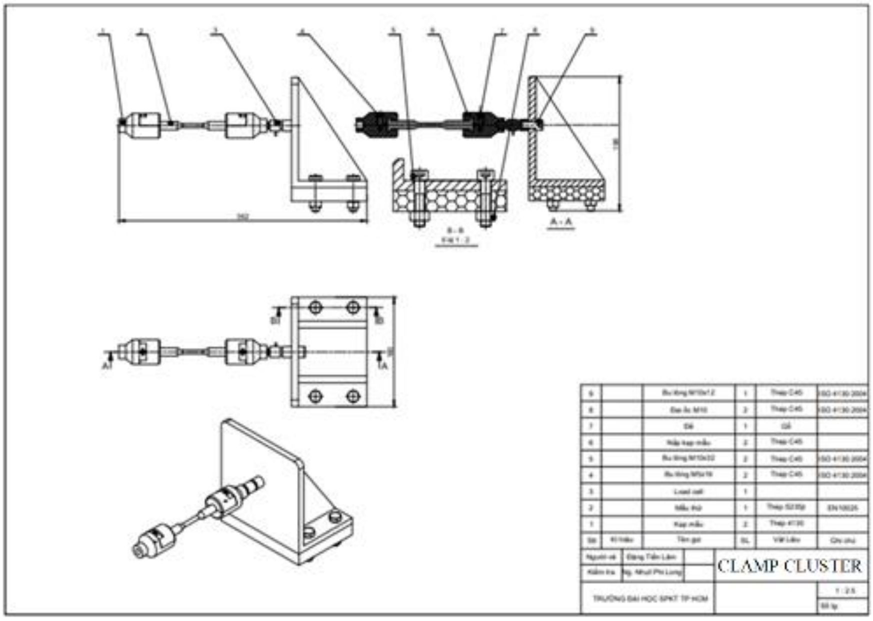


Figure 8. The assembly drawing of the clamp cluster

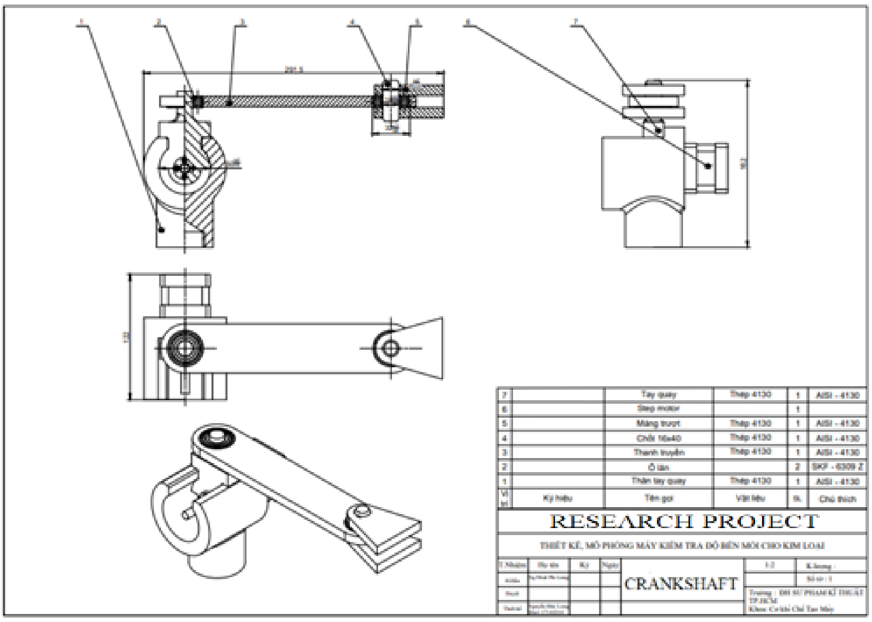


Figure 8. The assembly drawing of the crankshaft

VII. CONCLUSION

The article presented the horizontal axial tensile-compression fatigue tester design. The sample is selected in the calculation, the design is made of EN S235JR steel, and the dimensions are according to the TCVN 8185:2009 (ISO 1099:2008) standard. This horizontal axial tensile-compression fatigue testing machine operates on the principle of slider-crank mechanism, with a compact structure, easy to disassemble, and feasible to manufacture.

This machine can be developed in the future to test different types of steel and diverse test samples, such as plates and bars, by replacing the clamping mechanism accordingly.

VIII. ACKNOWLEDGEMENTS

This work belongs to the project grant No: T2021-09 funded by Ho Chi Minh City University of Technology and Education, Vietnam.

REFERENCES

[1] Bao Hoai Tran (2008), *Study of fatigue cracking on torsion spring and mechanical shaft parts*, master thesis, HCMC University of Technology and Education (HCMUTE), Ho Chi Minh City, Viet Nam, 2008.

[2] Tien Le Pham, *Study and evaluation of fatigue strength and fatigue life of the navigation bracket and wheel hub of the D19E locomotive applied on Vietnam railways*, Ph. D. thesis, University of Transport and Communications, Ha Noi, Viet Nam, 2011

[3] Isakov, M., Rantalainen, O., Saarinen, T. et al, Large-Scale Fatigue Testing Based on the Rotating Beam Method, *Exp Tech* (2022). https://doi.org/10.1007/s40799-022-00571-8

[4] Ogawa F, Shimizu Y, Bressan S, Morishita T, Itoh T, Bending and Torsion Fatigue-Testing Machine Developed for Multiaxial Non-Proportional Loading, *Metals*, 2019; 9(10):1115. https://doi.org/10.3390/met9101115

[5] Xue, H. & Tao, H. & Montembault, F. & Wang, Qingyuan & Bathias, C., Development of a three-point bending fatigue testing methodology at 20kHz frequency, *International Journal of Fatigue*, 2007, 29, pp. 2085-2093. https://doi.org/10.1016/j.ijfatigue.2007.03.018

[6] Shawki, G. S. A. “A Review of Fatigue Testing Machines.” (1990).