

DEVELOPMENT OF THE TEST SYSTEM FOR MEASURING THE IMPACT ENERGY OF A HYDRAULIC BREAKER

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ABSTRACT

A hydraulic breaker for construction machinery generally used for the destroying and disassembling of buildings, crashing road pavement, breaking rocks at quarry and so on. So the measurement of the impact energy of a hydraulic breaker is very important thing to prove its capability to manufacturers and customers. In this study, the test system for measuring the impact energy of a hydraulic breaker was designed and constructed. The test system was consisted with hydraulic cylinders for mounting a breaker, impact absorbing base and frames, pressure and flow sensors, high speed and accurate data acquisition system, diesel engine driven hydraulic power pack and etc. The test process of the developed system was carried by measuring guide for tool energy rating for hydraulic breakers which was developed by the CIMA (Construction Industry Manufacturers Association) USA. The developed test system can be applied to measure the impact energy for various kind of hydraulic breakers.

KEY WORDS

Hydraulic breaker, Measuring impact energy, Test system, Strain gauge equipment, Tool impact energy calculation

NOMENCLATURE

A_t : Cross-sectional area of the test tool at strain gage assembly location	P_s : Hydraulic supply line pressure
CF : Correction factor from static calibration	P_r : Hydraulic return line pressure
E_i : A single blow impact energy of the tool	Q_i : Breaker inlet oil flow
E_t : Young's modulus of the test tool material	T : Operating oil temperature
f_i : Blow frequency	t : Time
H : Distance between the strain gage assembly and the tip of the test tool	t_l : Starting time of integration
k : Gage factor (must be the same for all active gages)	t_n : Ending time of integration
K_a : Amplification factor of the amplifier ($K_a=1$, if amplifier not used)	Δt_i : Integration interval, $\Delta t_i = (t_{ni} - t_{li})$
L_p : Length of the piston	U : Bridge output voltage
ρ_t : Mass density of the test tool material	U_B : Bridge supply voltage
P_{in} : Total hydraulic input power	ε_i : Measured strain
	ν : Oil kinematic viscosity

INTRODUCTION

A hydraulic breaker for construction machinery

generally used for the destroying and disassembling of buildings, crashing road pavement, breaking rocks at quarry and so on. A hydraulic breaker is composed of cylinder, piston, valve, back head, chisel and power cell and these components are fixed by bracket. The section view of the general structure of a hydraulic breaker is shown in Figure 1.

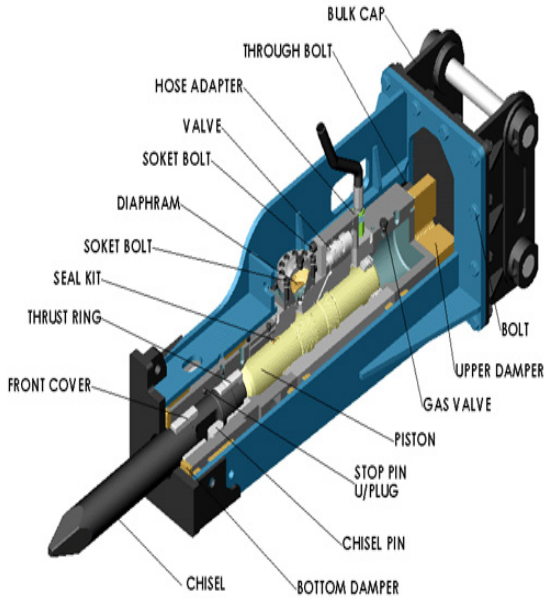


Figure 1 General structure of a hydraulic breaker

A hydraulic breaker blows an object using kinetic energy that is transferred by impacting chisel with reciprocating piston via hydraulic power from an excavator. So the measurement of the impact energy of a hydraulic breaker is very important thing to prove its capability to manufacturers and customers. But a hydraulic breaker is operated by very large kinetic energy, so that the accurate measurement of impact force has been considered too difficult problem.

In this study, the test system for measuring the impact energy of a hydraulic breaker was designed and constructed. The test system was consisted with hydraulic cylinders for mounting a breaker, impact absorbing base and frames, pressure and flow sensors, high speed and accurate data acquisition system, diesel engine driven hydraulic power pack and etc. In addition the process of measuring impact energy and the consideration of the test result was discussed.[1][2][3]

DEVELOPMENT OF TEST SYSTEM

The test system, shown in Figure 2, was developed to evaluate the impact energy of hydraulic breakers. As shown in Figure 2, the developed test system holds a breaker by 4 hydraulic cylinders and can evaluate the impact energy for various sizes of breakers by adjusting the stroke of 4 hydraulic cylinders. In addition to, the

developed system has another hydraulic cylinder on the upper part of it to regulate blowing angle in testing.

Target base was constructed with accumulating vibration isolating materials like as sands, broken stones, trees and rubbers after 5m depth foundation work to absorb shock and vibration at blowing. The schematic diagram of the target base is shown in Figure 3.

Hydraulic power for operating breaker is supplied by tandem pump that has maximum rated supply flow rate 580LPM and maximum rated supply pressure 450bar. The tandem pump is driven by diesel engine to realize similar operating condition of excavators. The tandem pump and diesel engine that was equipped in the developed test system are shown in Figure 4.

Data acquisition equipment has above 125 kHz cutoff frequency and 4 MHz sampling frequency to detect shock wave accurately. The data acquisition equipment is controlled by real time operating system and software was developed to carry test process automatically.[5]

Pressure, turbine type flow and temperature sensors are used for monitoring the status of test system and breaker and measuring parameters to evaluate impact energy. Data acquisition equipments are shown in Figure 5 and the schematic diagram of the hydraulic circuit of the test system is shown in Figure 6.



Figure 2 Mechanism of test system

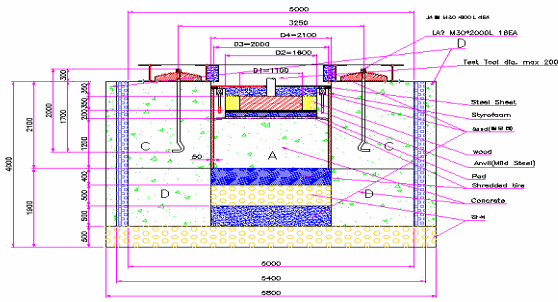


Figure 3 Target base of test system

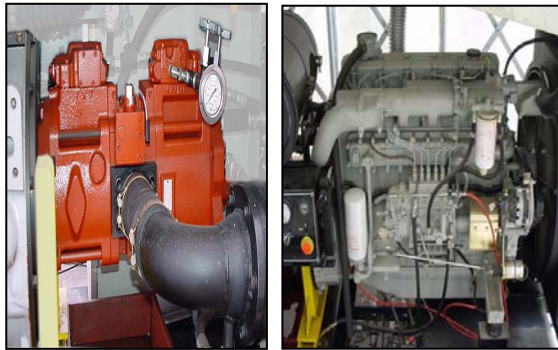


Figure 4 Hydraulic power unit of test system

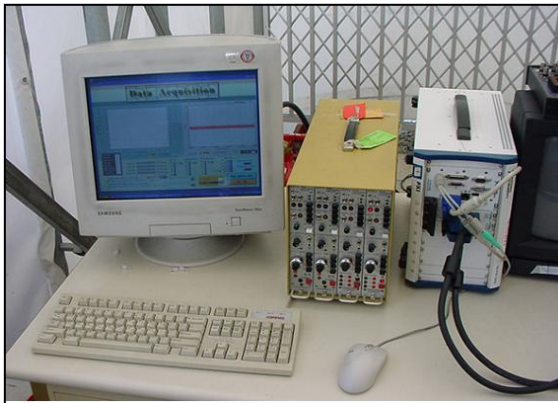


Figure 5 Data acquisition equipment of test system

IMPACT ENERGY EVALUATION

The developed test system evaluates the impact energy of hydraulic breakers, after measuring the strain of chisel with strain gauge.[4] Strain gauge attached test tool is shown in Figure 7.[6][7]

To evaluate the impact energy of a hydraulic breaker, we have to proceed as following process.

Single blow impact energy can be calculated from the measured strain using the equation (1) and this can be derived by elastic strain energy method for an impact loading.

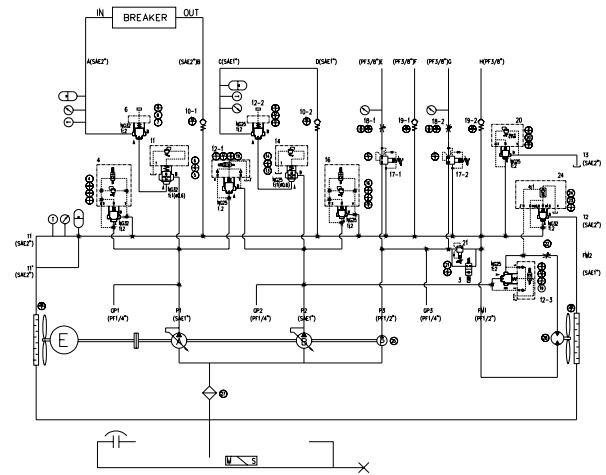


Figure 6 Schematic diagram of test system

$$E_i = \frac{CF^2}{A_t \cdot \sqrt{E_t \cdot \rho_t}} \int_{t_1}^{t_n} \epsilon_i^2 \cdot dt \quad (1)$$

Where, $\epsilon_i = 4 U / (2.6 k U_B K_a)$

The integration interval t_1 through t_n must be defined for each measurement to identify and isolate the effect of the hydraulic breaker static preload on the test tool strain and to prevent accumulation of stress from the next pulse or reflected stress wave.

The 25 energy measurements must be recorded in a steady state operation with test breaker's specifications.

The 25 measurements can be divided into sets of 5 consecutive blows minimum. Each measured energy value shall be within $\pm 10\%$ of the average value calculated in final tool impact energy. Final tool impact energy can be calculated by equation (2). Energy values out of this range must be disregarded and measurement shall be taken again. Total output efficiency can be calculated by equation (3).

$$E = \frac{1}{25} \sum_{i=1}^{25} E_i \quad (2)$$

$$\eta_{tot} = \frac{E \cdot f}{(P_s - P_r) \cdot Q} \quad (3)$$

The complete measuring equipment and installation must be calibrated by comparing the strain ϵ_{meas} calculated from the measuring equipment output voltage with the calibrated force F_{cal} applied on the test tool and measured by a calibrated load cell. Calibration will be carried out by compressing the test tool (without breaker) against a force transducer (load cell) for example in a hydraulic press. Correction factor CF can be calculated by equation (4).

$$CF = \frac{F_{cal}}{\varepsilon_{meas}} \quad (4)$$



Figure 7 Strain gauge attached chisel

TEST RESULT

Detection of the Shock Wave

The detected shock wave of impact energy strain is shown in Figure 8 and the test result of blow frequency is shown in Figure 9. The integration limits t_1 through t_n must be defined for each pulse to identify and isolate the effect of the static preload of the breaker on the test tool strain and to prevent accumulation of the strain from the next pulse. Before impact, the test tool will begin to unload due to recoil of the hydraulic breaker body. Time t_1 must be measured in this region of the curve. The baseline of integration will be taken at the point t_1 . The last time recorded, t_n , for each pulse, must be separate and distinct from the next pulse or reflected stress wave. Time t_n should be measured at the point where the pulse curve becomes negative in relationship with the baseline. Integration will stop when the curve reaches the same strain level that was found at time t_1 . However, the maximum integration interval $t_n - t_1$ must be less than $2H/c_t$ with, $c_t = \sqrt{E_t/P_t}$. Usually the distance $H = 1.2L_p$ is sufficient, if not, the stress wave may combine with the reflected wave causing incorrect instrumentation readings and energy results. This can occur especially, when the piston cross-sectional area A_p is greater than the tool cross-sectional area A_t . In this case the test tool is too short and distance H should be at least $2L_p$. [4]

Total uncertainty of the test result

From equation (1), the uncertainty of the tool impact energy measurement can be calculated by equation (5) and the total uncertainty with $\pm 2\sigma$ value, 95.7% probability in normal distribution can be calculated by equation (6).

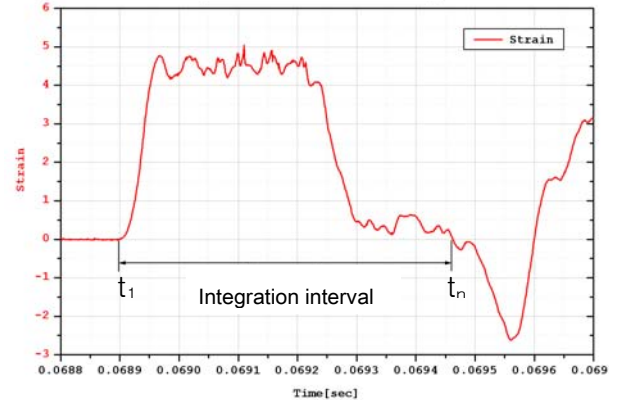


Figure 8 Shock wave of impact energy strain

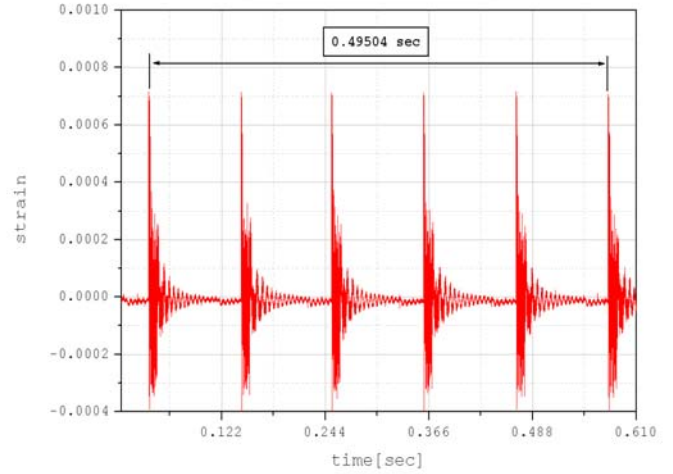


Figure 9 Test result of blow frequency

$$\Delta E = 2 \cdot |\Delta CF| + |-\Delta A_t| + \frac{1}{2} \cdot |-\Delta E_t| + \frac{1}{2} \cdot |-\Delta \rho_t| + |\Delta Integ| \quad (5)$$

$$U_{tot, \pm 2\sigma} = \pm \frac{2}{3} \cdot \sqrt{(\Delta E)^2 + (\Delta p_s)^2 + (\Delta p_a)^2 + (\Delta \varepsilon)^2} \quad (6)$$

The maximum allowed uncertainties of the measured parameters in the equation (5) and (6) are as follows.

$$\Delta P_s = \pm 1\%, \Delta P_a = \pm 2\%, \Delta \varepsilon = \pm 1\%, \Delta CF = \pm 1.5\%$$

$$\Delta A_t = \pm 0.2\%, \Delta E_t = \pm 3\%, \Delta \rho_t = \pm 0.4\%, \Delta Integ = \pm 0.2\%$$

By substituting the maximum allowed uncertainties of

the measured parameters to the equation (6), $U_{tot, 2\sigma}$ can be evaluated as follows.[4]

$$U_{tot, \pm 2\sigma} = \pm 3.8 \% \quad (7)$$

In this study, the total uncertainty was calculated to 3.74%. So the developed test system could satisfy the allowed uncertainties.

CONCLUDING REMARKS

In this study, the test system for measuring the impact energy of a hydraulic breaker was designed and constructed. The test system was consisted with hydraulic cylinders for mounting a breaker, impact absorbing base and frames, pressure and flow sensors, high speed and accurate data acquisition system, diesel engine driven hydraulic power pack and etc. The test process of the developed system was carried by measuring guide for tool energy rating for hydraulic breakers which was developed by the CIMA (Construction Industry Manufacturers Association) USA. The developed test system can be applied to measure the impact energy for various kind of hydraulic breakers and was certified to test cite for breakers by AEM(The Association of Equipment Manufacturers).

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