ZESZYTY NAUKOWE POLITECHNIKI ŚLĄSKIEJ 1989

Seria: GÓRNICTWO z. 180 Nr kol. 1043

INTERNATIONAL CONFERENCE: DYNAMICS OF MINING MACHINES
DYNAMACH '89

Henryk HAWRYLAK
Zbigniew KORZEŃ
Marek SOKOLSKI

Technical University of Wroclaw
Institute of Machine Design and Performance

EXPERIMENTAL INVESTIGATION OF DYNAMICAL PHENOMENA IN HYDRAULIC HAMMERS APPLIED IN MINING INDUSTRY

Summary. Program and results of investigation of dynamical phenomena occuring in hydraulic hammers used in mining industry are discused. In particular, investigation techniques are characterized and method of numerical processing of measurement signals is presented. Results of identifikaction of working characteristics and of hydraulic efficiency of a prototype hammer design are given as an example of experimental techniques applied.

INTRODUCTION

Hydraulic hammers are extensively used in mining and quarrying. Their application includes breaking oversized boulders, scaling works in mines, trenching in frozen and hard ground, tunnelling and the like.

In development of hydraulic hammers a comprise must be sought for between the tendency to achieve maximum efficiency of transforming the hydrostatic energy of working medium (oil) into the energy of tool and the necessity to attenuate the negative effect of the impact on both the hammer structural system itself and the hammer mounting and displacement systems. That is why it is worthwhile to search for the new and to verify the existing calculation and measurement methods in the first place with the aim to achieve:

- more rational shaping of load-carrying structures and driving mechanisms or hydraulic hammers,
- more precise evaluation of performance efficiency of hydraulic hammer heads.

The paper presents the experimental techniques and the methods of numerical processing of recorded measurement signals applied by the authors in their investigation on the problems outlined above.

STRUCTURAL SCHEME OF TOTAL EFFICIENCY OF HYDRAULIC HAMMER

When the traditional structure of hydraulic hammer of piston type used in mining is considered as a dynamical system, three stages of energy transform can be distinguised (Fig. 1):

Stage I:

- transformation of hydraulic medium energy into kinetic energy of the piston (in both working and return cycle)

Stage II:

- transformation of piston energy into the energy of the tool

Stage III:

- transformation of tool energy into the work of rock breaking.

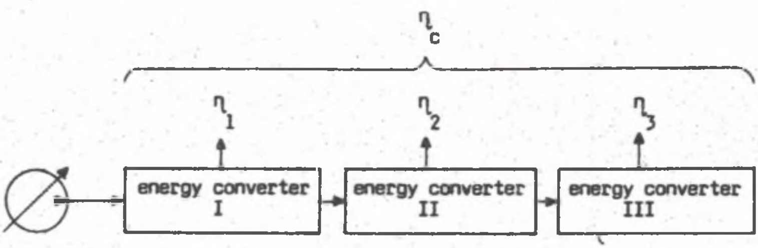

Fig. 1. Flow diagram for energy transformation in a typical structure of hydraulic hammer

An efficiency η_i; i = 1,2,3 can be ascribed to each of those stages, where:

η_1 - hydraulic efficiency,

η_2 - efficiency of the impact,

η_3 - rock breaking efficiency

while the total efficiency η_c of hydraulic hammer is determined by the relation:

$$\eta_c = \prod_{i=1}^{3} \eta_i \tag{1}$$

Problems of the analysis of the efficiences η_2 and η_3 were considered by the authors in the papers [2, 3, 4].

The present paper is devoted to the investigation problems concerning the experimental analysis of hydraulic efficiency η_1 of hydraulic hammers.

Remark

The specific conditions of energy transformation characteristic of non-traditional solutions of hammers, e.g.:

- hydraulic hammers with the accumulator of recuperation energy in the return motion of the piston [1],
- hydraulic hammers in which impact of the type "metal-inermediate medium- metal" occurs [5],

are not taken into account in the structural scheme of the total efficiency of hydraulic hammer presented in Fig. 1.

IDENTIFICATION OF HYDRAULIC EFFICIENCY OF HAMMER

The identification of the efficiency of hydraulic hammers used in the technology of rock breaking can be most easily carried out on the base of the so called working characteristics of hydraulic hammers. Those characteristics are defined as follow:

a) energy characteristic gives the dependence of impact energy E_u ot the piston on the controllable parameters of hydraulic head, determined in general by the vector $\mathbf{H}_E$, i.e.:

$$E_u = \Phi_E(\mathbf{H}_E) \tag{2}$$

b) frequency characteristic expresses the dependence of impact frequency f_u of the piston on the controllable parameters of hydraulic head, determined in general by the vector $\mathbf{H}_f$, i.e.:

$$f_u = \Phi_f(\mathbf{H}_f) \tag{3}$$

From experimental investigation [3] it follows that with the accuracy sufficient for practical applications working characteristics (2) and (3) can be presented in the form linearized relations of the form:

$$\left.\begin{aligned} E_u &= k_p(p_h, V_a) \cdot p_h \\ f_u &= k_Q(p_h, V_a) \cdot Q_h \end{aligned}\right\} \tag{4}$$

With these relations allowed for, the efficiency η_1 of the hydraulic head of the hammer that expresses the effectiveness of transformation of hydrostatic energy of oil stream of intensity Q_h and pressure p_h into kinetic energy of piston $E_u = 1/2\ m_b v_b^2$ (m_b, v_b denoting mass and velocity of the piston respectively) can be expressed as:

$$\eta_1 = \frac{E_u \cdot f_u}{p_h \cdot Q_h} = k_p(p_h, V_a) \cdot k_Q(p_h, V_a) \tag{5}$$

where: k_p [J/MPa], k_Q [1/s] - coefficients of linearized working characteristics (4) of the hammer.

Numerical values of the coefficients k_p and k_Q can be approsimately assessed theoretically in the way presented by the authors in the paper [3].

Numerical values of coefficients k_p and k_Q for prototype hammers, for hammers after modernization or overhaul etc. can be corrected on the base of the series of diagnostic tests carried out according to the method given below.

TESTING STAND AND MEASURING APPARATUS

Experimental investigation of the working process of hydraulic hammer has been carried otu on a model testing stand comprising hydraulic impact head, set, of hydroaccumulators, load-carrying structure and hydraulic power pack.

Reciprocating motion of the piston is obtained in the conditions of continuous supply of high-pressure oil stream into the front working chamber of impact head cylinder, while the back chamber is alternatively connected to high-pressure line (working motion) or to flow-off line (return motion). Working principle of hydraulic impact head applied in the experimental stand is explained in Fig. 2.

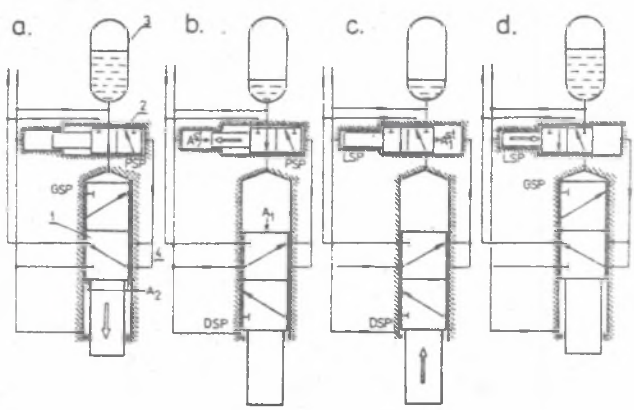

Fig. 2. Working principle of hydraulic impact head used in the testing stand

1 - hammer, piston, 2 - slide valve piston, 3 - set of hydroaccumluators

Set of hydroaccumulators consists of four bladder-type accumulators, each of 2,5 dm^3 capacity, independently connectable to the installation.

Basic parameters of the model testing stand are as follow:

- nominal range of working pressure p_h = 10-20 MPa,
- nominal range of oil flow Q_h = 30-40 dm^3/min,
- capacity of the set of accumulators V_a = 0-10 dm^3,
- blow frequency of piston f_u = 0-800 impacts/min,
- blow energy of piston E_u = 0-250 J,
- maximum piston stroke s_b = 10-18 mm,
- working medium: hydrol 30 oil,
- head mass ca 40 kg.

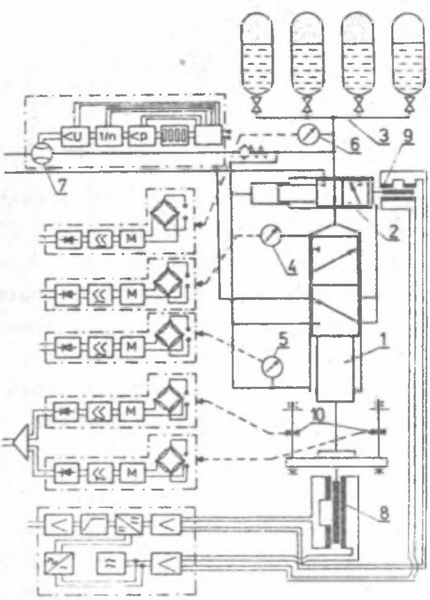

Fig. 3. Block diagram of an investigation method of working process of hydraulic hammer

1 - hammer piston, 2 - slide valve piston, 3 - set of accumulators, 4,5,6 - strain gauge manometers, 7 - turbine - type flow meter, 8,9 - differential - transformer pickups, 10 - strain gauge bolts

Measurements of working process parameters were carried out in the following way.

a. Pressure

Head working pressures p_h and p_a and pressures p_1 and p_2 in the chambers of working cylinder were measured with strain gauge manometers with cylinder-shaped thin-walled element, onto which strain gauges were glued in axial and circumferential direction.

b. Flow intensity

Volumetric intensity Q_h of oil flow was measured using an electrodynamic method based on the application of turbinmeter "TURBOQUANT" of the range up to 66 dm^3/min.

c. Displacements

For measurements of linear displacements s_b of hammer piston and linear displacements s_r of slide valve piston was used a passive indictive-type method based on the differential-transformer pickups PJ x 50 of the range ± 25 mm.

d. Impact force

Impact force F_u was measured using a method based on the application of strain gauges. Two independent Wheatstone bridges were glued on the bolts that support a cross-bar against which the hammer strikes. Output signals from particular bridges were summed up in an electronic adder.

Investigation method applied is presented in Fig. 3. Basic set of measuring apparatus consists of:

- six-channel DC strain gauge bridge,
- two-channel set of carrier wave type for linear displacement measurements,
- single-channel turbine-type set for measurements of the intensity of oil flow in impact head pressure line,
- two-channel electronic adder,
- measuring tape recorder of FM type,
- digital oscilloscope.

TESTING PROCEDURE

Analogue recording of measurement signals on magnetic tape was applied using FM system. The signals were then reproduced using A/D converter of the digital oscilloscope and loaded into disc memory of a computer (e.g. of IBM PC/AT type). Signals were analysed with the help of the integrated set for data processing STATGRAPHICS. It includes over 250 various numerical and graphical procedures.

With regard to the experimental investigation of the working process of hydraulic hammer the following procedures of STATGRAFPHICS set are particularly useful:

- TIME SERIES PROCEDURES: Smoothing, Time Series Analysis used for filtering and for differentiation of the recorded signals corresponding to the displacements $s_b(t)$ of the piston with the aim of assessing its velocity v_b necessary for the evaluation of its kinetic energy at the moment of impact,
- ANOVA AND REGRESSION ANALYSIS: Analysis of Variance, Regression Analysis used for statistical treatment of experimental results and for assessing (based on the least square method) of the values of coefficients k_p and k_Q of working characteristics according to (4),
- PLOTTING AND DESCRIPTIVE STATISTICS: Plotting Function that enabled to obtain the measurement oscillograms of required configuration.

Some selected oscillograms are presented in Fig. 4.

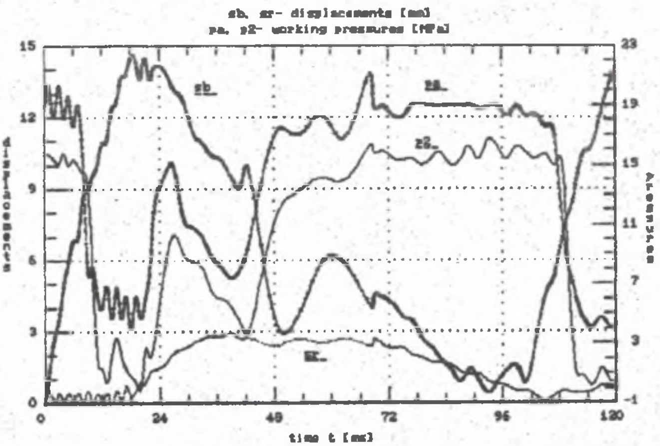

Fig. 4. Typical oscillograms obtained from the experimental investigation of a tested hydraulic hammer

In the aplied variation range of controllable parameters:

$$p_h = 14\text{-}20 \text{ MPa}, \; Q_h = 30\text{-}40 \text{ dm}^3/\text{min}, \; V_a = 0\text{-}10 \text{ dm}^3 \tag{5}$$

the following evaluations of working characteristics were obtained:

$$E_u = k_p(p_h, V_a) \cdot p_h = (0{,}7\text{-}13{,}8) \cdot _h$$
$$f_u = k_Q(p_h, V_a) \cdot Q_h = (0{,}14\text{-}0{,}30) \cdot Q_h \tag{6}$$

The lowest values of the coefficient k_p [J/MPa] correspond to the hammer operation without the application of the set of hydroaccumulators, i.e. for $V_a = 0$. Those values were found to be practically independent of the value of working pressure p_h. Maximum values of k_p [J/MPa] were obtained in the case of oil working pressure $p_h \geq 16$ MPa, when the working cycle of the hammer was assisted with oil stream from the set of accumulators of joint volume $V_a \geq 7{,}5$ dm^3.

With regard to the frequency characteristic the upper limits of the range of the values of coefficient k_Q [1/s] correspond to the hammer being fed at the pressure $p_h \geq 16$ MPa with no working cycle assistance, i.e. for $V_a = 0$.

Hydraulic efficiency of the tested impact head assessed on the base of the analysis of measurement results was found to vary within the broad range:

$$\eta_1 = \frac{E_u \cdot f_u}{p_h \cdot Q_h} = 1,0\text{-}21,0\ [\%] \qquad (7)$$

its minimum values $\eta_1 \cong 1,0\%$ being observed in case of the operation with no accumulator application (i.e. for $V_a = 0$). In the conditions of working cycle being assisted with oil stream from the accumulators of total active capacity $V_a \geqslant 7,5\ dm^3$ and under working pressure $p_h \geqslant 16$ MPa considerably higher values of hammer efficiency of the range $\eta_1 = 20\text{-}21\%$ were obtained.

RECAPITULATION

Laboratory investigations confirmed the effectiveness of the developed method of diagnostic testing of hydraulic hammers applied in mining and of investigation of working process occuring in them. Treatment of results if experimental investigations of that type can be successfully assisted by the application of the analogue recording of measurement signals and of the integrated data processing system STATGRAPHICS based on commonly applied computer set of IBM PC/AT type. Application of the suggested diagnostic testing method makes it possible to analyze working characteristics and efficiency of hydraulic hammers of any size in various working conditions.

BIBLIOGRAPHY

[1] Arndt F.K.: Leistungsrückgewinnung bei Hydraulikschlagwerken. Technische Mitteilungen Krupp Nr 2/1986, s. 75-84.

[2] Bereś W., Sokolski M.: Modelowanie działania udarowych maszyn urabiających. IV Szkoła Metodologii Konstruowania Maszyn, Materiały seminaryjne cz. VI, Rydzyna 1984.

[3] Korzeń Z., Sokolski M.: Sprawność procesu pracy młotów hydraulicznych do udarowego urabiania skał silnie zwięzłych. Archiwum Górnictwa, T. 28, Z. 3, 1983, s. 399-431.

[4] Korzeń Z., Sokolski M.: Forschungsprobleme bei Hydraulikhämmern für Erdbewegungsmaschinen. Internationale Fachtagung "Baumaschinen 1987", Magdeburg 17-19 November 1987.

[5] Sokolski M.: Neue Entwicklungsrichtung bei Hydraulikhämmern für Erdbaumaschinen. XIII. Internat. Konferenz "Mechanisierung im Erdbau", Dresden, 6-8 September 1988.

Recenzent: Prof. dr hab. inż. Włodzimierz Sikora

DOŚWIADCZALNE BADANIA ZJAWISK DYNAMICZNYCH W MŁOTACH HYDRAULICZNYCH STOSOWANYCH W PRZEMYŚLE GÓRNICZYM

S t r e s z c z e n i e

Omówiono program oraz wyniki identyfikacji zjawisk dynamicznych w procesie roboczym górniczych młotów hydraulicznych. W szczególności scharakteryzowano stosowane techniki badawcze oraz metodę numerycznego przetwarzania rejestrowanych sygnałów pomiarowych. Jako przykład aplikacyjny stosowanych technik doświadczalnych przedstawiono wyniki identyfikacji charakterystyk eksploatacyjnych oraz sprawności pewnej prototypowej konstrukcji młota.

ЭКСПЕРЕМЕНТАЛЬНЫЕ ИСПЫТАНИЯ ДИНАМИЧЕСКИХ ЯВЛЕНИЙ В ГИДРАВЛИЧЕСКИХ МОЛОТАХ ПРИМЕНЯЕМЫХ В ГОРНОДОБЫВАЮЩЕЙ ПРОМЫШЛЕННОСТИ

Р е з ю м е

Обсуждено программу и результаты испытаниий динамических явлений выступающих в гидравлических молотах применяемых в горнодобывающей промышленности. Особенно охарактеризировано исследовательские техники и представлено цифровую обработку измерительных сигналов. Подано результаты идентифицирования рабочих характеристики и гидравлической прототипной эффективности конструкции молота, как пример применения эксперементальной техники.