

## Research of metal flexible torsional clutches applied in mining machines

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*On the job one introduced the description of investigative stands and methods of marking of static, quasi-dynamic and dynamic characteristics. One introduced the course of torque at start of metal clutch about the large torsional susceptibility and reaction of clutch on extortion with impulse turning moment.*

**Key words:** mining machines, construction of machines, driving device, couplings

### Introduction

The load of drives of mining-machines, determines usage in systems of driving clutches about large torsional susceptibility, resistant on influence of definite loads. With suitable construction can prove the metal flexible torsional clutch [2, 3, 4].

The flexible clutch is characterized with both definite resilient features as and damping which have a basic influence on the work of driving system across change of course and stabilization of torsional twitches and torque [1, 6, 9].

At use of flexible clutches about inadequate characteristics, one can bring to state of incorrect work of all driving system. In that case, a necessity becomes the qualification of static characteristics, quasi-dynamic and dynamic flexible clutches. It's also necessary qualification of course changed by the clutch of course of torque, working on the metal flexible torsional clutch, as reaction of system on extortion in moment of start and at given impulse load. Such acquaintance will assure correct work of drive of working machine.

The constructional analysis of flexible clutches which the most possesses the composite construction and contains couplers flexible about with difficulty definable physicals guilds makes for motion that a most suitable and profitable manner of delimitation of characterizations of flexible clutches, is removal of experimental research on suitable investigative stands. Accordingly one worked out research project for new metal flexible torsional clutch which an aim was delimitation of exchanged earlier characteristics.

Research were passed on the clutch with situated in it set of disk springs, consisting of 14 packs for 4 springs in the pack. One applied springs about measurements 40 x 20,4 x 2 mm (DIN 2093). The set was so well-chosen, so that at established maximum moment turning, carrying out  $M_{max} = 100$  Nm, springs work below margin of work, i.e. 75 % diffractions of maximum.

### Stand to research mechanical clutches

In the Institute of Mining Mechanization, Faculty of Mining and Geology at the Silesian University of Technology investigative stand was built intended to investigation of mechanical clutches (Fig. 1). This stand lets on leadership of following research [5]:

- marking of the static characteristics of clutch,
- marking of course changed by clutch of torque, working on the metal flexible torsional clutch, as reaction of system on extortion called out with motor starting, i.e. work of the clutch during start of driving system,
- marking of course changed by clutch of torque as reaction of system on extortion in form of given impulse load, i.e. work of the clutch at impulse-load of driving system.

A driving element of investigative stand is electric motor (1), about the power 5,5 kW and nominal rotational speed of 1455 min<sup>-1</sup>. The power supply of motor can be realized in two ways, across the transducer of frequency which lets on smooth regulation of rotational speed from 0 to 1700 min<sup>-1</sup> or at power supply with tension 380 V with omission of system of switch star-triangle. Such solutions assure the liquid and gentle start of system of driving stand or start quick and dynamic.

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With the motors shaft is joint torque meter (5), the domestic to measurement of torque  $M_o$  of working on drive unit of stand. The measuring range of torque meter carries out from 0 to 200 Nm.

To the exit shaft of torque meter is joint directly one of elements of investigated flexible clutch (2). The second element of the clutch - the exit shaft, joint is with the hydraulic disc brake (3).

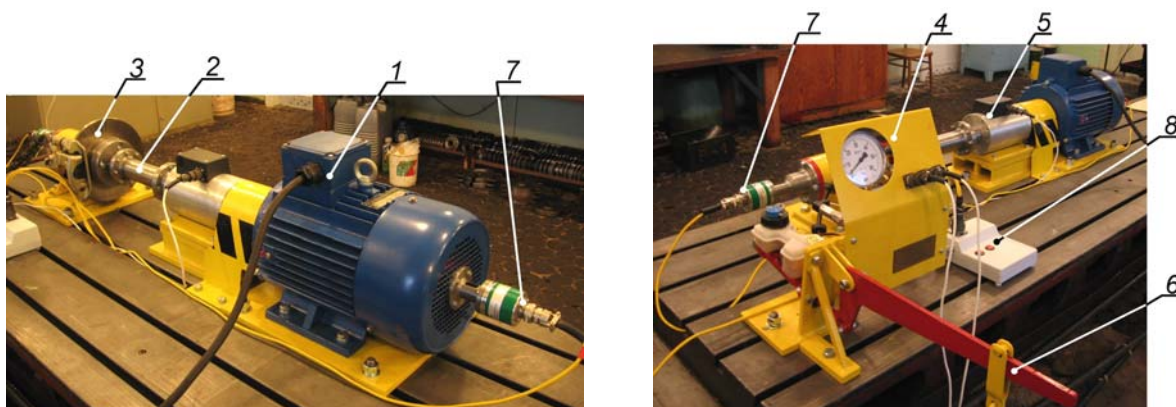


Fig. 1. The test stand for investigation of flexible torsional clutch, where: 1 – electric motor, 2 – investigated mechanical clutch, 3 – disc brake, 4 – hydraulic control system of brake, 5 – torque meter, 6 – lever with weights, 7 – absolute encoders, 8 – control of absolute encoders.

The controlled brake is by means of hydraulic control system (4), consisting of the hydraulic pump, the manometer, the system of lines and the block of annexation valve and the clamp of disc brake. The change of pressure in the hydraulic system, and consequently the change of brake force of disc brake, is realized across the system of levers (6).

The investigative stand was provided into the precise electronic system to measure of angle of relative turn of elements of the clutch. Main elements of this measuring system are two single absolute encoders of type AS58AV1 (7), with analog output  $0 \div 5$  V. Encoders are situated on both sides of the clutch, i.e. one of them is joint directly with shaft of electric motor (1), and the second with shaft of disc brake (3).

All measuring signals are sent to set of apparatus recorder and measuring, introduced in Fig. 2.

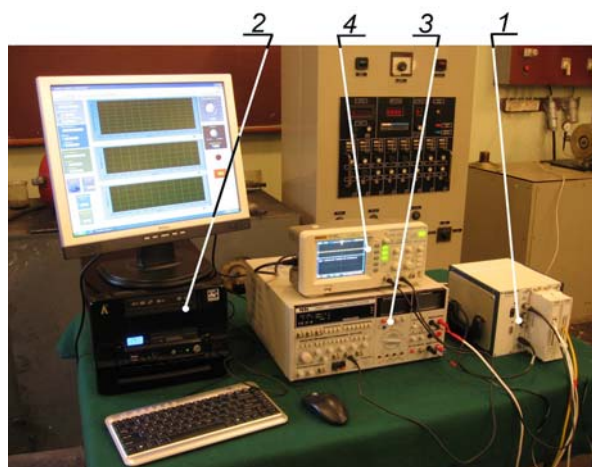


Fig. 2. The set of measuring apparatus of investigative stand, where: 1 – modular measurement system type SCXI, 2 – measuring computer, 3 – universal set of feeding and measuring, 4 – two channel digital oscilloscope.

### The investigative stand for marking of quasi-dynamic and dynamic characteristics of clutches

Marking of dynamic characteristics of clutch one executed on modernized investigative stand in the Department of Logistics and Mechanical Handling, Faculty of Transport in Katowice (Fig. 3) [5, 7, 8].

On this stand one explored which let on delimitation:

- characteristics quasi-dynamic of the metal flexible torsional clutch,
- characteristics dynamic of the clutch.

This stand makes it also possible to research and measurement of other sizes characterizing of the clutch. It permits on:

- infliction impromptu continuous, the constant of component of torc,
- generating during variable component of torc,
- measurement of resultant torc,
- measurement of relative steering angle between elements of the clutch.

Elements of principle stand investigative, shown in fig. 3, are: inductive motor M1 (1), inductive motor M2 (2), torque meter (3), measuring-system of relative steering angle of elements of the clutch (5). The investigated clutch (4) together with torque meter (3) is situated between motors (1) and (2). Both controlled motors are across inverter and microprocessor driver.

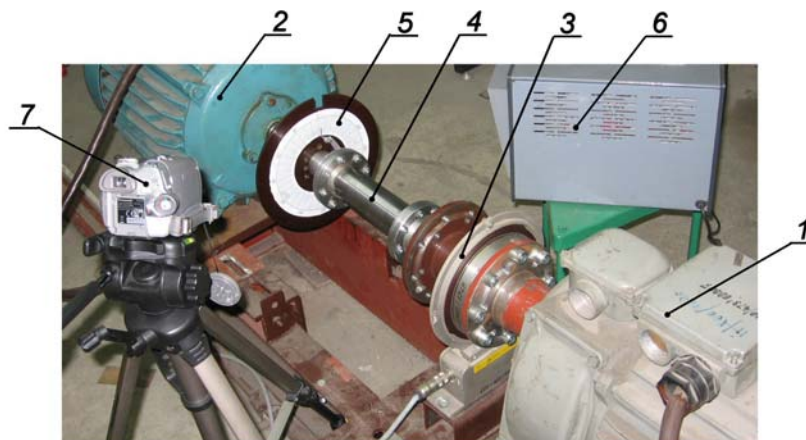


Fig. 2. The test stand view for quasi-dynamic and dynamic characteristic determination of clutches.

Mechanism of action of investigative stand consists in load variation of mechanical between two cooperative motors M1 and M2. The load is called out by change of rotational speed motor M2 as result of change of his frequency feeding with relation to of rotational speed motor M1. This makes possible impromptu controlled generating of moment turning. Motor M1 is connected directly to system feeding 380 V, 50 Hz and rotates with constant of speed rotatory (eg.  $n_{obr} = 1470 \text{ min}^{-1}$ ). Motor M2 is supplied through mediation of inverter. Across change of frequency of power supply of motor follows change of his characterization which causes change of rotational speed. The change of rotational speed of motor M2 with relation to motor M1 lets on producing variable or stable moment turning which comes into being the result of shift the point of work on the mechanical characteristics of motor M1 with relation to the point of work of motor M2.

The moment turning  $M_{qdyn}$  is measured by torque meter T10F. In system feeding one used converter of frequency of type SIMOWERT 6SE2122-2AA01.

The control system was provided into microprocessor driver of type DLM-080. This driver makes it possible to measure and project of value of moment turning and to give in definite temporary cycles of stable as and variable load of flexible clutch. The level of moment turning the clutch, which permits the program of driver carries out from -30 Nm to 130 Nm with period of changes of this moment within range from 0,1 s to 25,5 s.

To measurement of angle of mutual twist of elements of the clutch, one used disk with scale angular, fast to one element of the clutch in relation to which moves the advice secured to the second element of clutch. The lecture of gyral arrangement disk - advice one made at use the stroboscopic lamp (6), what makes possible apparent stop of picture and immediate lecture of angle. The carried out is  $\pm 1^\circ$  accuracy of reading. For the purpose of enlargement of correctness of lecture and elimination of possible errors, one made registration cycle measuring angle with digital camera (7).

### The methods of marking of static characteristics of metal flexible torsional clutch

In the chance of marking of static characteristics, on investigative stand introduced in Fig. 1. After installing the clutch on investigative stand, one stopped hydraulic brake what marks that one blocked possibility of one turn of elements of the flexible clutch. Across inverter is started the electric motor and gradually is enlarged torc  $M_{stat}$ . The gradation of this moment  $M_{stat}$  one fixed with step 10 Nm to maximum value  $M_{max} = 100 \text{ Nm}$ . For every value of the moment one made the lecture of the angle the relative turn elements the clutch  $\varphi_{stat}$ , by means of system absolute encoders. The exactitude of made lecture carried out  $\pm 1^\circ$ . Lectures of dependence of torc  $M_{stat}$  from the angle of relative turn  $\varphi_{stat}$  was made both at burdening, as and to easing the clutch. An aim of so accepted procedure was qualification of hysteresis loop, representative course of suppression of mechanical energy in arrangement [1, 5, 6].

The example of the static characteristics of investigated metal flexible torsional clutch is introduced in Fig. 4. In Fig. 4 one marked areas of sizes characterizing course of suppression of mechanical energy, i.e.:  $A_r$  – the work of suppression during one duty cycle and the  $A_s$  – the work of elastic strain on one duty cycle.

The static characteristics of flexible clutch is a dependence of torque  $M_{obr}$ , turning clutch for definite turning angle  $\varphi$  of boundary strip an element active and passive of clutch [5].

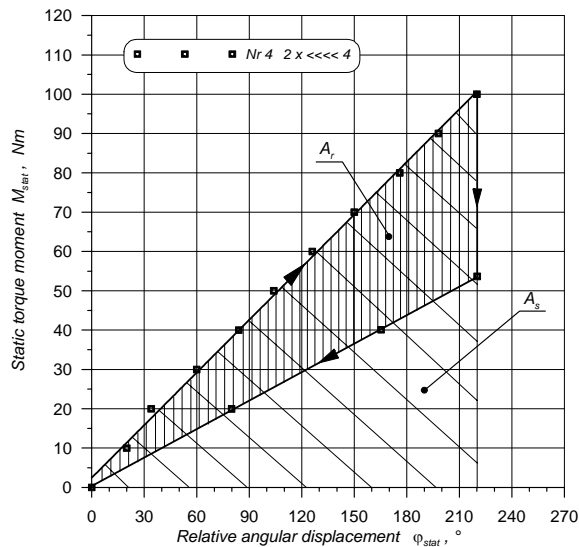


Fig. 4. The illustration of static characteristic of metal flexible torsional clutch.

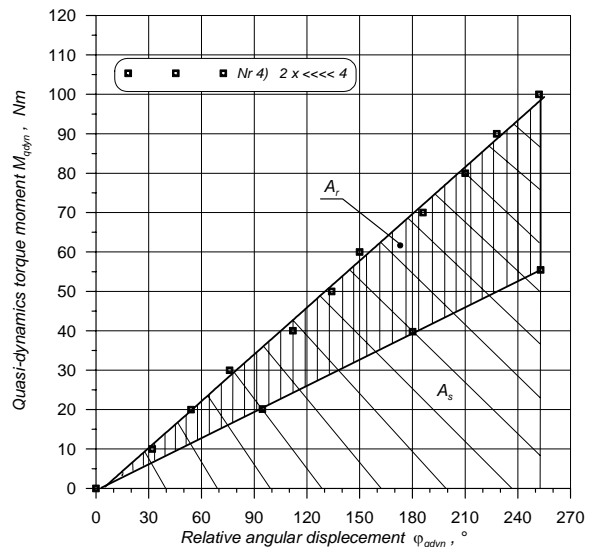


Fig. 5. Quasi-dynamic characteristic of torsionally flexible metal clutch.

### The methods of marking of quasi-dynamic characteristics

After start of investigative stand introduced in Fig. 3, motors together with clutch rotate with constant with rotational speed  $n_{obr} = 1470 \text{ min}^{-1}$ . During the work of stand is changed torque  $M_{qdyn}$ , incrementing drive unit with the clutch with step 10 Nm, until maximum value  $M_{max} = 100 \text{ Nm}$ . Simultaneously is read angle of relative turn of elements of the clutch  $\varphi_{qdyn}$ .

The quasi-dynamic characteristics which the example introduces drawing 5, expresses dependence between torque  $M_{qdyn}$  incrementing clutch, and with angle of mutual turn of elements of clutch  $\varphi_{qdyn}$ , for assumption that following growing values of torque are given comparatively slowly at simultaneous lecture answering to their values of angle  $\varphi_{qdyn}$ , during rotation of all driving system together with clutch [5].

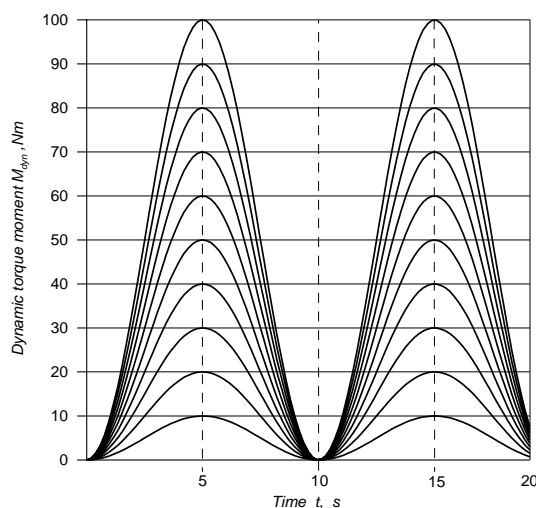


Fig. 6. The course of changes of torque  $M_{dyn}$ , burdening driving system with clutch.

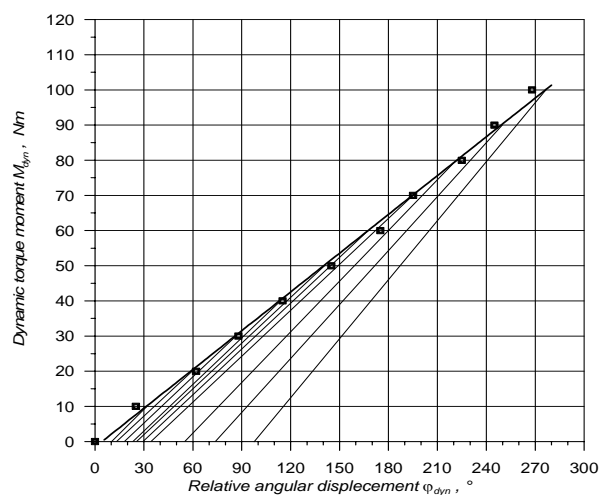


Fig. 7. Dynamic characteristic of metal flexible torsional clutch.

### The methods of marking of dynamic characteristics

Marking of dynamic characteristics of clutch one led on investigative stand from Fig. 3. During the work stand torque  $M_{dyn}$ , incriminating drive unit together with clutch, is changed periodically every 5 s from value  $M_{dynmin} = 0$  Nm to temporary maximum value of moment  $M_{dynmax}$ . The temporary value of maximum moment is changed with step 10 Nm, to value 100 Nm. The courses of these changes are shown on the Fig. 6.

The rule of lecture changing in cycles torque and lecture and registration of answering to him relative turn of elements of the clutch  $\varphi_{qdyn}$ , follows so as at marking of the quasi-dynamic characteristics.

The example of obtained on basis research, the dynamic characteristics of the metal flexible clutch, introduces the Fig. 7 [5].

### The work of the clutch during the start of driving system

Research of the metal flexible torsional clutch, targeting delimitation of course of changes of torque incriminating clutch, as reaction of arrangement on resultant extortion during the start of electric motor, propellant the investigative stand which was introduced in Fig. 1.

During the start of driving system exists surplus of torque incriminating the clutch which is called out an inertia of driven elements. In driving system of investigative stand, these are elements of disc brake and itself clutch.

In progress of given cycle of research, the starting of electric motor followed by immediate connecting of full tension feeding on his windings. This causes dynamic start of all driving system. Additionally, during the start, clutch is loaded a working torque  $M_h$ , produced by brake of investigative stand. The all course start is measured real-time by torque meter and recorded by measuring apparatus. Registered course of changes of torque makes it possible removal of his analysis which takes into account the influence of flexible clutch on the start of driving system [5].

The example of registered course of changes of torque, transferred by the arrangement with the metal flexible clutch at the start with stable moment of applying of brake  $M_h$ , is introduced in Fig. 8.

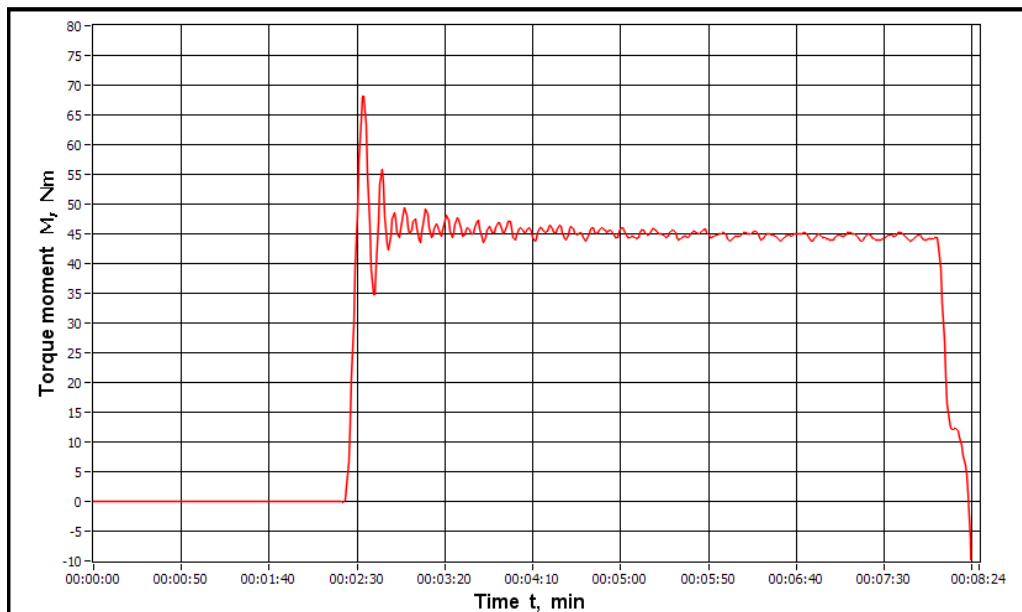


Fig. 8. The course of changes of rotatory moment, transferred by system with the flexible clutch during the starting.

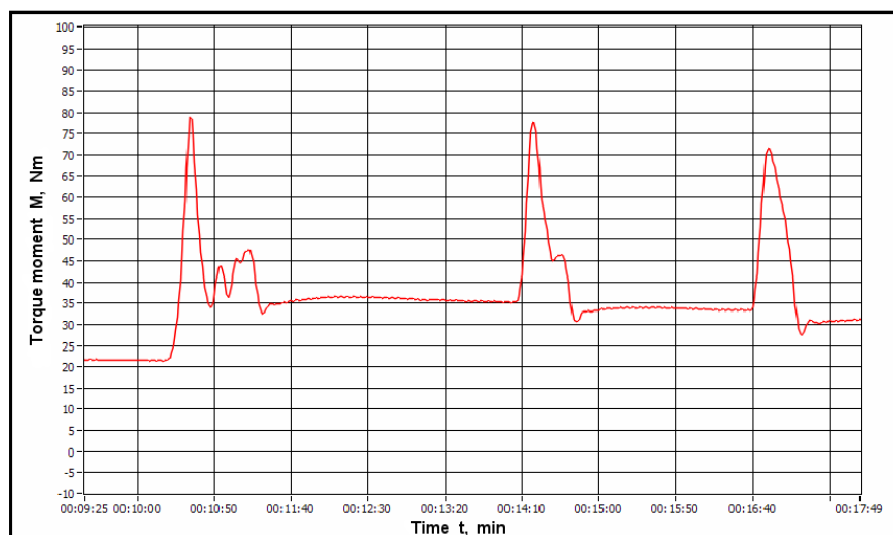
### The work of the clutch at the impulse load of driving system

The methodic of research of clutch in this instance consisted in actuation of drive of investigative stand with settled torque of brake to  $M_h$  and bringing of driving system to achievement of settled rotational speed. Then the arrangement is burdened an additional impulse torque  $M_{imp}$ . In such chance by the flexible clutch on the measuring element, is which torque meter, transfers the moment about diminished value of amplitude. The course of changes of softened torque has a character of damped vibration.

The both incriminating torque of brake  $M_h$  how and additional impulse moment  $M_{imp}$  are generated by hydraulic arrangement of disc brake. The course and value of impulse moment are appointive indirectly across the tonometry the medium in hydraulic arrangement which is proportional to produced torque. Courses of softened torque and pressure the medium are registered real-time and submit to analysis [5].

The example of registered course of changes of torque, as reaction on additional impulse-torque and answering those courses of changes of pressure in hydraulic arrangement of brake, introduces Fig. 9.

a)



b)

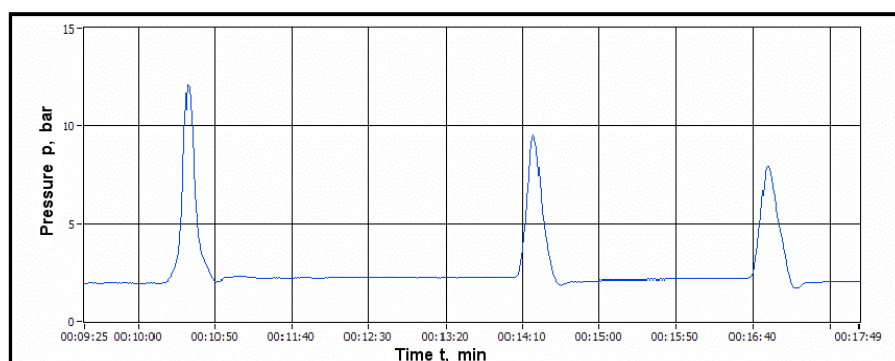


Fig. 9. The work of clutch during the impulse load of rotatory moment, were: a) the course of changes of torque, b) the course of changes of pressure of medium in the hydraulic brake system.

## Conclusions

Explored on two investigative stands, the embracing delimitation of characteristics of metal flexible torsional clutch, let on hanging indent of following conclusions:

- designed and modernized and performed investigative stands, and also accepted methodic of research of characteristics of clutch, let on simple and correct their marking with properly large exactitude and repeatability of obtained results of measurement,
- on these stands can be explored different clutches basing on different investigative methods,
- obtained in progress of research static characteristics, quasi-dynamic and dynamic let on marking of value of coefficients of torsional stiffness  $k$  and suppression  $\psi$  of clutch,
- accepted methods of research targeting the estimation of work of investigated clutch at start how and during extortion with impulse moment, result from practical standard-methods of research of flexible clutches.

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