Adam POLAK, Janusz GRZYBEK, Selim OLEKSOWICZ
Cracow University of Technology, Cracow

SYSTEM FOR OBSERVATION OF TRIBOLOGICAL PHENOMENA OF VEHICLE DISC BRAKE SURFACES

Key words

Brake, wear phenomena, friction phenomena, abrasive particles.

Summary

A number of difficulties are encountered when performing observational and measuring examinations of vehicle disc brake surfaces, thus inducing the necessity to build a special research stations for preliminary tests. The paper describes one such station for observational and measuring tests of disc brakes in the presence of hard abrasive particles. The paper is divided into two parts. The first part presents the main functional systems, measuring systems and software being used. The second part includes examples of the results of measurements.

Introduction

The main factors determining the development of vehicle structure are safety, reliability and durability and manufacturing costs. Current state of technology requires specialized tools to be used to improve test quality as a primary factor directly affecting functionality.

The direct contact of disc brake friction couple components with the environment allows hard abrasive particles to be present, thus leading to out-of-control friction force changes, higher wear rate and other unwanted effects [1–3, 6–9].

1. Test stand

It was impossible to examine the effect of hard abrasive particles on tribological phenomena in vehicle disc brakes on a real object due to several serious problems affecting both the results and conclusions.

The disc brake test stand design was decided by the following factors;

- difficulties in recording phenomena occurring in road conditions,
- lack of control of quantity and size of hard abrasive particles existing in the friction couple environment,
- problems with use of optical measuring instruments,
- uncontrolled system vibrations.

The preliminary analysis of adverse conditions that accompany the real test object enables us to design and built a fully functional observational and measuring system (Figs 1 and 2).

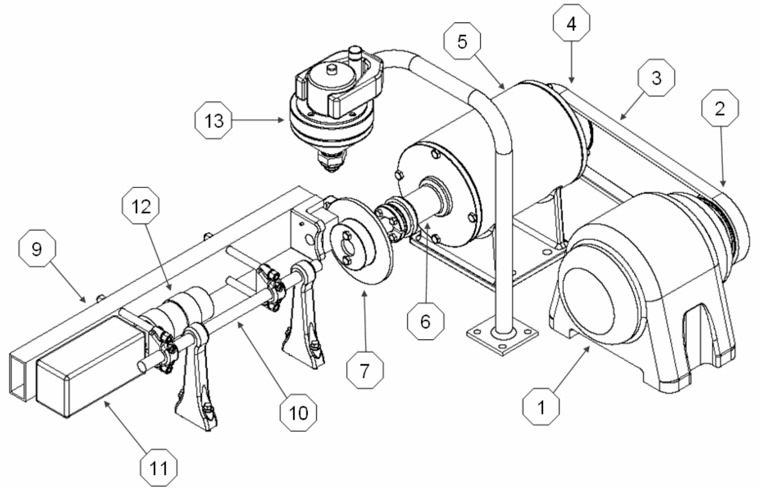

Fig. 1. Schema of the test stand. 1– electric motor, 2 – drive wheel, 3 – belt, 4 – driven wheel, 5 – housing of spindle, 6 – spindle, 7 – brake disc, 8 – hydraulic caliper, 9 – beam of caliper, 10 – calibration bar, 11– camera, 12 – lenses, 13– feeder of sand, 14 – transparent pad, 15 – passive pad, 16 – clutch, 17 – passive calliper

The main aim of the test is to perform a thorough observation of phenomena occurring at the contact of mating components in the presence of hard abrasive particles. To meet these conditions, one of the friction couple components was made of transparent material. A recording camera enabling a micro and macro photography was used. Hard abrasive particles of required size are fed at strictly set quantity into the friction zone by using a solenoid valve.

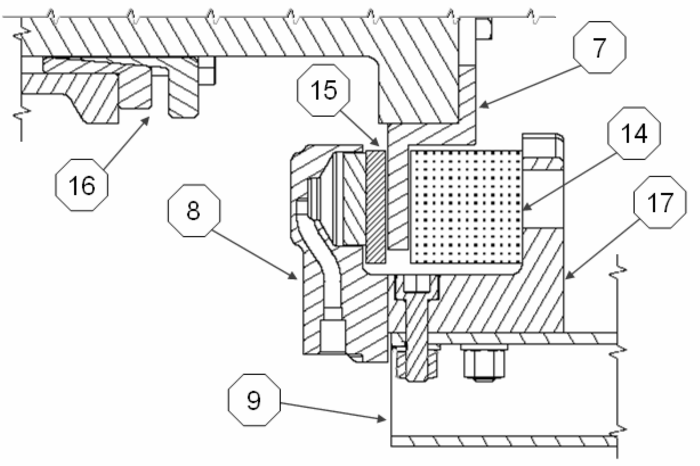

Fig. 2. Cross section of brake assembly

By preliminary setting of requirements it was possible to design a system for model testing.

Description of the test stand:

1. Main functional systems:
   - Brake disc drive enabling stepless adjustment of rotational speed,
   - Braking system allowing braking force to be set up,
   - Particular hard abrasive particle feeder enabling adjustment of moment and amount of hard abrasive particles being fed.
2. Stand measuring systems:
   - Brake disc rotational speed measurement,
   - Braking force measurement,
   - Temperature measurement (thermocouple in the pad or pyrometer),
   - Wear measurement (weight or displacement transducers),
   - Recording camera.

The stand was equipped with a three-phase motor with a frequency inverter (Apator, type: AMD 0038).

The following was adopted for the system purposes:

- Commercial disc brake hydraulic caliper complete with a hydraulic piston pump equipped with a loading system,
- Electromagnetically driven feeding head controlled with *PLC SR-12MTDC* equipped with transistor outputs,
- *Spider 8* measuring system with the *Catman 3.0* software using a set of sensors,
- Recording system: Camera *Panasonic WV-CL 920A* with the software *Pinnacle Studio 8 video*.

To enable automatic operation of the stand, a controller of *SR* type fitted with calendar and clock was used. This allows automation of devices controlled by the *SR* controller. The controller enables repeatable cycles – time loop to be operated. The controller panel has a *LCD* display, four programmable pushbuttons and four function keys (Fig. 3).

Fig. 3. Front panel of *PLC* controller

The controller of *SR* type is programmable with the computer program *SuperCad* (Fig. 4). The program uses such basic logical elements as *AND*, *OR* as well as advanced functional blocks *TOND*, *TPBL.* The program language is based on a set of logical elements and functional blocks available in the library.

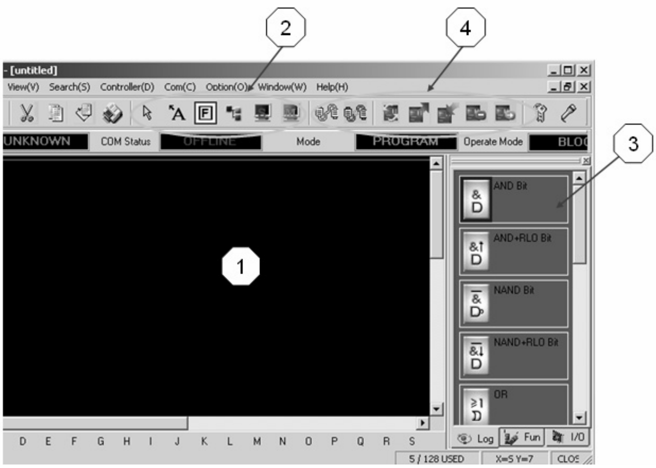

Fig. 4. *SuperCad* general window: 1 – field used for object-oriented programming (drawing), 2 – system navigation icon group, 3 – library of available logical components and functional blocks, 4 – icon group related to communication between the program and the controller.

In addition to object-oriented programming function the program *SuperCad* enables the program to be checked for proper functioning before sending it to the controller. This allows the programming process and operation verification to be separated from the test stand. The computer simulation enables signal run from inputs to outputs to observed and functional blocks to be checked for proper functioning (Fig. 5).

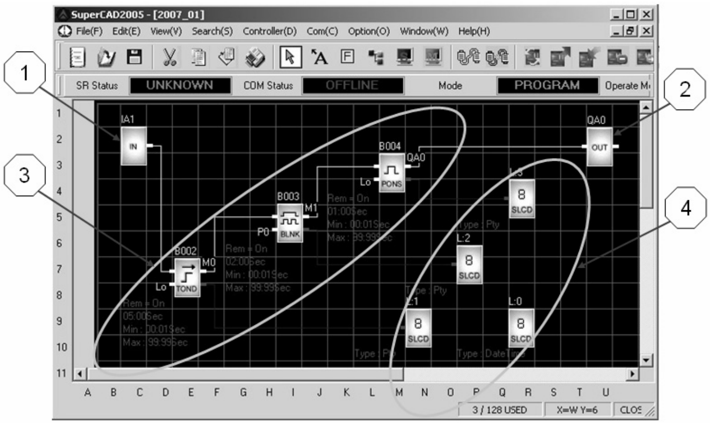

Fig. 5. SuperCad window with a feeder supporting program: 1– symbol of controller input, 2 – symbol of controller output, 3 – function blocks, 4 – *I/O* status and set value blocks

The controller that operates the particulate hard abrasive particles feeder is fitted with a simple program enabling automation of particulates metering. A binary signal coming from the frequency inverter initiates the process.

After sending the command signal (brake disc rotational speed not equal to zero) to the controller input, the first function block *TOND* (tripping delay – raising edge) sends the signal to the next block after elapsing the set delay time.

The delay time for the first block system t_1 allows the brake disc to reach the nominal rotational speed. Time t_1 has been selected functionally.

The next time-constant t_2 of the function block *BLNK* (pulse generator) is characterized by a time interval between starts of consecutive particulate hard abrasive particles dosing.

The amount of particles used in the experiment per one cycle is adjusted by time-constant t_3. Time t_3 is directly proportional to the amount of particulates fed. After downloading the program to the controller, the user can change time-constants manually by editing the function block setting on the display.

The recording system includes the *Panasonic WV-CL 920A* camera enabling observations to be made in black and white or color modes at poor lighting conditions. The maximum sensitivity of 1/2” camera transducer is 0.3 *lx* at *F1.4* (color mode), 0.02 *lx* at *F1.4* (black and white mode).

The camera is equipped with the following set of lenses:

- *Panasonic WV-LM4R5A* (observations in macro scale),
- *Computar MLH10×*,
- Extender *Computar EX2CS*,
- *Computar VM 100 Tube Kit* (observations in micro scale).

A convenient and precise feature is the ability to adjust the camera manually, e.g.: shutter (Fig. 6). As observations are made by using external lenses, the camera has been adjusted manually to operation at poor lighting conditions. The output signal is the *VHS* signal of 25 frames per second.

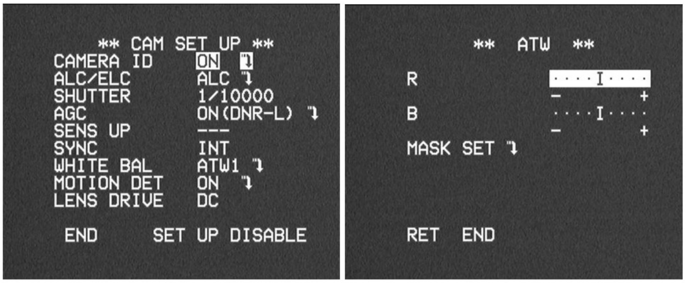

Fig. 6. Examples of camera set-up screens

The camera output signal is sent to the *PC* with the *Pinnacle Studio 8 video* program installed by using the *Pinnacle video system*. The *Pinnacle Studio 8 video* program enables images to be stored as avi files on the computer's disc (Fig. 7). The program allows the stored data to be edited and images to be preliminary analyzed. The shutter set manually at the level of 1/10000 allows image analysis without any reservations about quality of individual frames. The main advantage of the program is ability to select individual recorded frames and store them as individual frames in any format (e.g.: *JPG*, *BMP*).

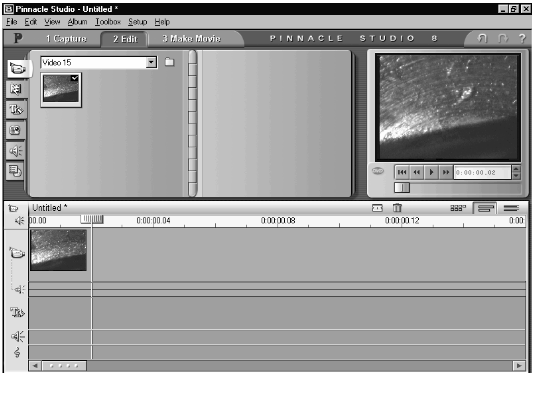

Fig. 7. The view of *Pinnacle Studio 8* system display

The measuring system is the solution offered by *Hottinger Baldwin Messtechnik GmbH* comprising CPU – *Spider 8* of 0.2% accuracy class and measuring elements. The strain gauge *HBM C2* of 0.2% accuracy class was used as a measuring element. The measuring system is operated by using the program *Catman 3.2*. The measuring system we used enables the measurements to be stored on the computer hard disc.

3. Results

Operating with presented systems enables versatile kind of investigations to be made. Chosen examples are presented below.

3.1. Operating parameters values and changes

An analysis of measurements clearly indicates a direct relationship between the moment when hard abrasive particles are fed into the friction couple and the change of friction force. Figure 8 shows a radical change of friction force at the moment when hard abrasive particles are fed (t = 60 s). Both, increase of friction force value and increase of friction force fluctuations is observed.

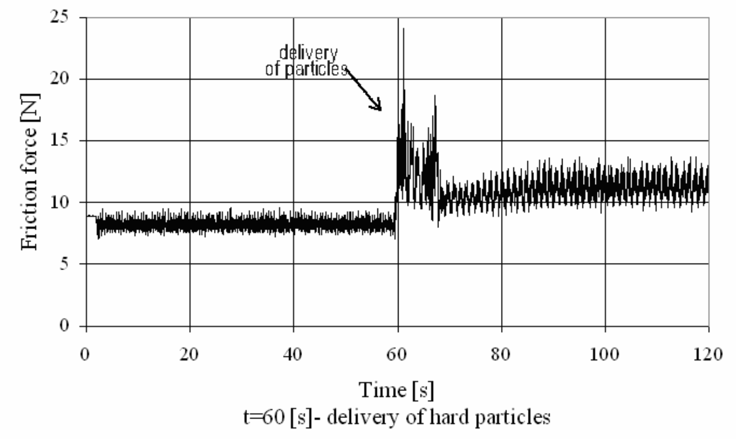

Fig. 8. Friction force recorded during test run where particles were delivered

3.2. Analysis of subsequent video frames

The feedback of measuring system and hard abrasive particles feeding control signal allows individual frames to be selected and separated precisely from the recording material. Fig. 9 shows subsequent shots indicating effect of a hard abrasive particle movement. Figure 10 shows movement of particle in the friction zone (indicating arrows).

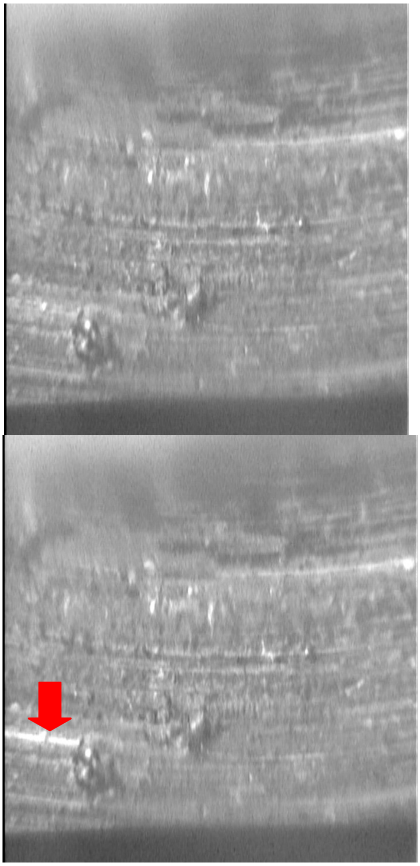

Fig. 9. State of work of frictional pair in presents of hard abrasive particles

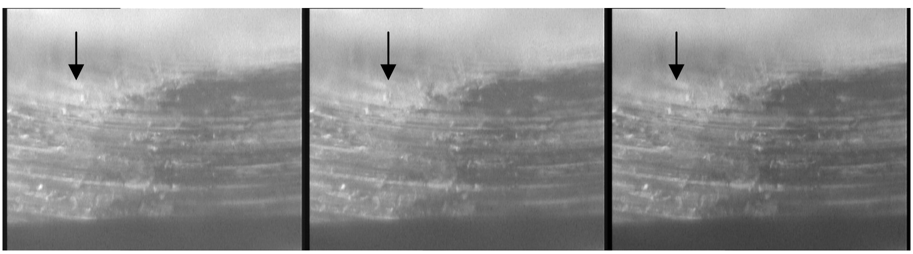

Fig. 10. Movement of particle in the friction zone, three following frames extracted from the video sequence

One of the fundamental items of investigations was comparison of operating parameters for conditions with and without hard particles. Fig. 11 presents an example – comparison of operating temperature.

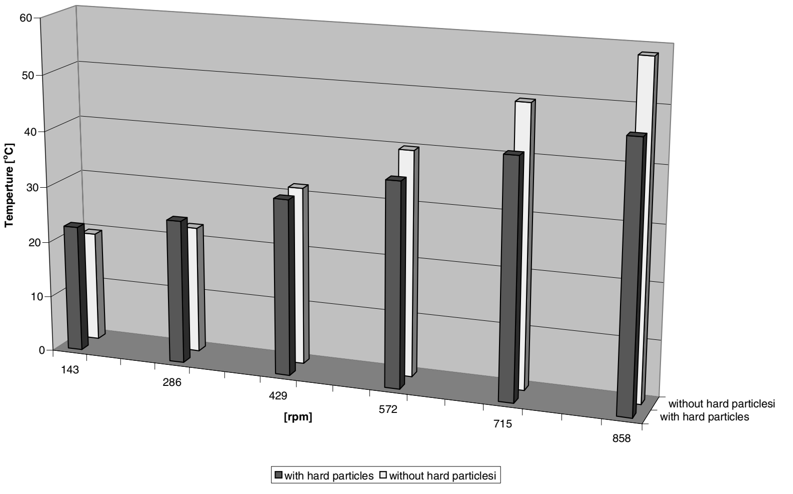

Fig. 11. Temperature comparison between the tests conducted with and without hard particles; temperature measurement – thermocouple, ambient temperature 20°C; pad material – transparent plastic

3.3. Image processing

Image processing on consecutive shots are used to obtain an example image presenting the effect of abrasive particles on the friction zone. The shaded area on Figure 12 is a scratch resulting by movement of a solid particle inside the friction zone.

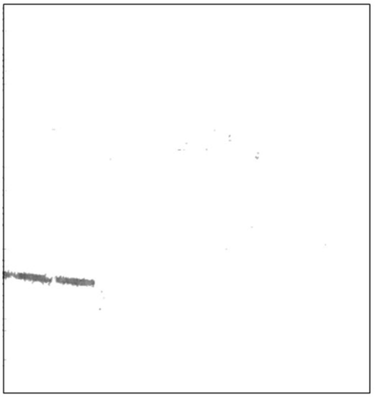

Fig. 12. Image analysis: result of hard abrasive particles movement in the friction zone; difference between two subsequent frames: before and after scratch appearance

In addition to observation of phenomenon intensity and scale, image analysis enables hard abrasive particles embedded into pad to be identified.

Image processing was also used in order to obtain information of third body formation and destruction. Individual frames were extracted from video sequence and processes. An example of those operations is presented in Fig. 13.

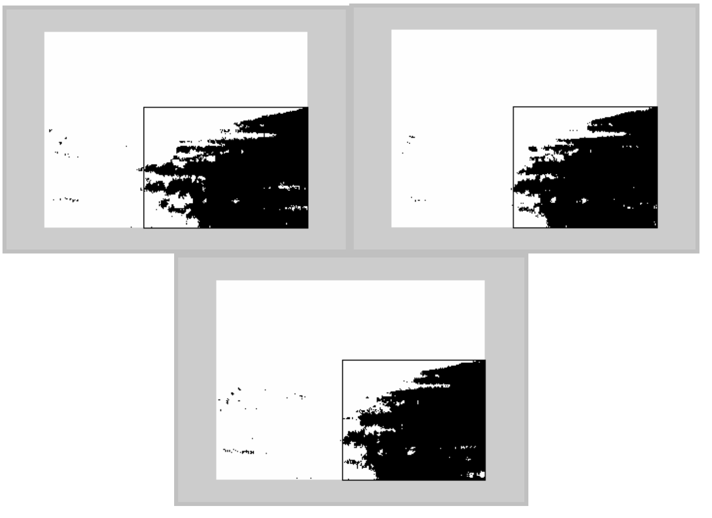

Fig. 13. Results of friction zone analysis in respect to the creation and destruction of the third body

3.4. NVH analysis

The system, after addition of an acoustic chamber, soundproofing and measurement devices allows also for NVH analysis. Figure 14 presents an example of variability of acoustic pressure in relation to brake disc rotational speed. There were conducted investigations aimed at a comparison between acoustic pressure level for operation with and without hard abrasive particles [4].

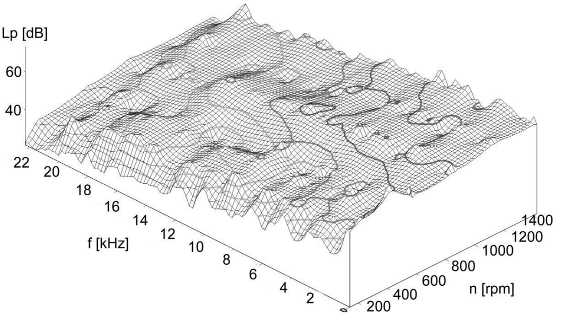

Fig. 14. Variability of acoustic level pressure in function frequency for different rotation speeds of brake disc; operation with hard particles [4]

3.5. Neural network modelling

Data obtained during test system operation were used for neural network modelling. This comprises both values of measured parameters and recorded images. An example of neural network modelling is presented in figure 15. This is the case where on NN model was used to describe friction force changes for the operation with and without hard abrasive particles [5].

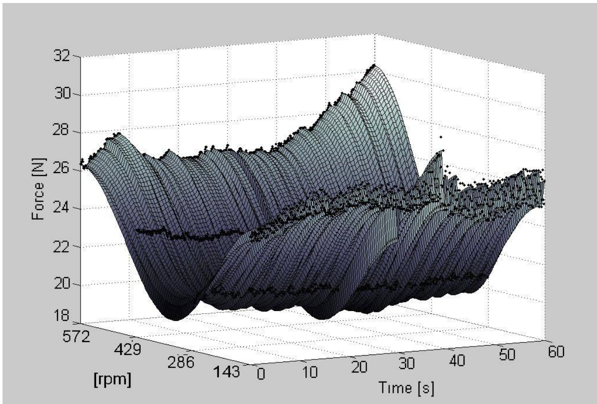

Fig. 15. The 3-dimensional surface model of the brake friction force to the brake friction disc velocity [5]

Conclusions

Presented system enables:

- Investigations in situ of friction processes taking place in the presence of hard abrasive particles.
- Investigation with transparent sample (pad) with embedded chosen friction material component. This allows for analysis of phenomena occurring in the material interface. Those phenomena are decisive for the run of friction processes.
- Determination of correlation between friction processes and values and changes of measured parameters (e.g. friction coefficient, wear rate, temperature).

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Recenzent:
Stanisław F. ŚCIESZKA

System obserwacji zjawisk tribologicznych na powierzchniach samochodowych hamulców tarczowych

Słowa kluczowe

Hamulec**,** zjawiska zużyciowe, zjawiska tarcia, cząstki ścierne.

Streszczenie

W trakcie prowadzenia eksploatacyjnych obserwacji i badań powierzchni tarczowych hamulców samochodowych występuje szereg trudności, które wymuszają konieczność budowy specjalnych stanowisk badawczych. W artykule przedstawiono stanowisko badawcze przeznaczone do obserwacji i pomiarów roboczych parametrów tarczowych hamulców pracujących w obecności twardych cząstek ściernych. Artykuł składa się z dwóch części. W pierwszej zaprezentowano cechy funkcjonalne systemu, układu pomiarowego i zastosowanego oprogramowania. W drugiej części przedstawiono przykładowe wyniki badań.