Controlling of Stands for Testing Industrial Devices and Their Parts

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Abstrakt

Článek se zabývá řízením zkoušek a prací s naměřenými daty, které probíhají na Ústavu konstruování a částí strojů. První zkouškou je měření pitingu přímých ozubených kol, které má za cíl zjistit odolnost jednotlivých typů povrchových úprav proti vzniku pitingu. Druhou zkouškou je zjišťování statické a dynamické tuhosti pružných spojek. Třetí zkouškou je zjišťování účinností jednotlivých částí pásového dopravníku a jejich testování.

Klíčová slova

piting, statická tuhost, dynamická tuhost, pružná spojka, účinnost, pásový dopravník, napjatost.

Abstract

The article describes measurement control and measured data processing of tests running at Department of Designing and Machine components. First is pitting measurement of straight gears that has goal to find out which coating is best for tooth flank in term of the pitting. Second is measurement of static and dynamic torsion stiffness of elastic coupling. Third is testing of the parts of a belt conveyor and finding ways to reduce power loss of the belt conveyor as a whole.

Keywords

Pitting, static stiffness, dynamic stiffness, elastic coupling, efficiency, belt conveyor, state of stress.

1. Introduction

In the laboratory of Department of Designing and Machine Components have been running or just finished following three measurements. First of them is a pitting growth measurement that has a goal to find out which coating is best for a tooth flank in term of pitting. Second measurement that recently finished is measurement of static and dynamic torsion stiffness of elastic couplings. The last measurement is testing of the parts of a belt conveyor and finding ways to reduce power loss of the belt conveyor as a whole.

2. Pitting growth Measurement

On the test stand for the pitting measurement (Fig. 1) is used a mechanically closed loop (Fig. 2) which is less energy demanding than open loop. Testing circuit consists of a measuring (MG) and additional (TG) gearbox, driving electromotor (EM), loading device (LD) and sensors of torque (Tq1, Tq2), rotational speed and temperature.

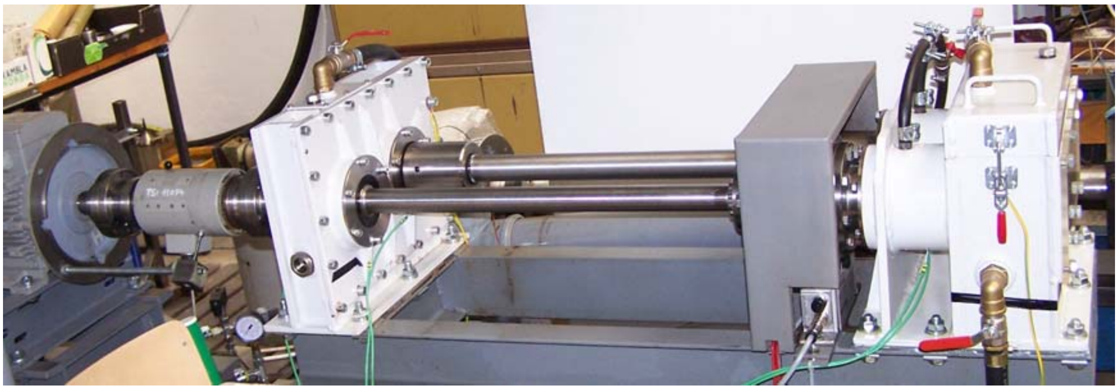

Fig. 1. View on test stand.

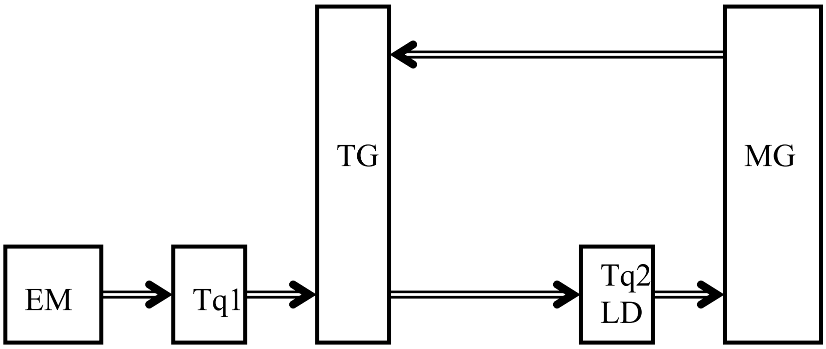

Fig. 2. Scheme of mechanically closed loop.

Testing conditions of gears and their assembly should be similar to actual operational conditions. By reason of test time shortening it is necessary to select larger torque in closed loop circuit than during regular operation. In our case we are limited by a torque sensor in circuit which can be loaded up to 800 Nm. The measurement mostly runs on one load level because of better possibility of result comparison. Power loss and virtual power in the circuit during run are recorded by one rotational speed sensor and three torque sensors. There is no attendance during the operation and so overload safety is needed. Torque sensors are over dimensioned so they can't be overloaded by crash. Tooth root break can arise during testing of tooth bending fatigue and the inertia moment can exceed the magnitude of torque set for measurement during unexpected gear block. Maxima overload which don't damage sensor is 150% of nominal torque. Process of gear load is characterized by torque and rotation speed in time. To control these magnitudes the automation is needed.

For controlling of measurement is used software LabVIEW from National Instruments and it runs on common personal computer equipped with laboratory cards also from National Instruments. Scheme of signal wiring is on (Fig 3).

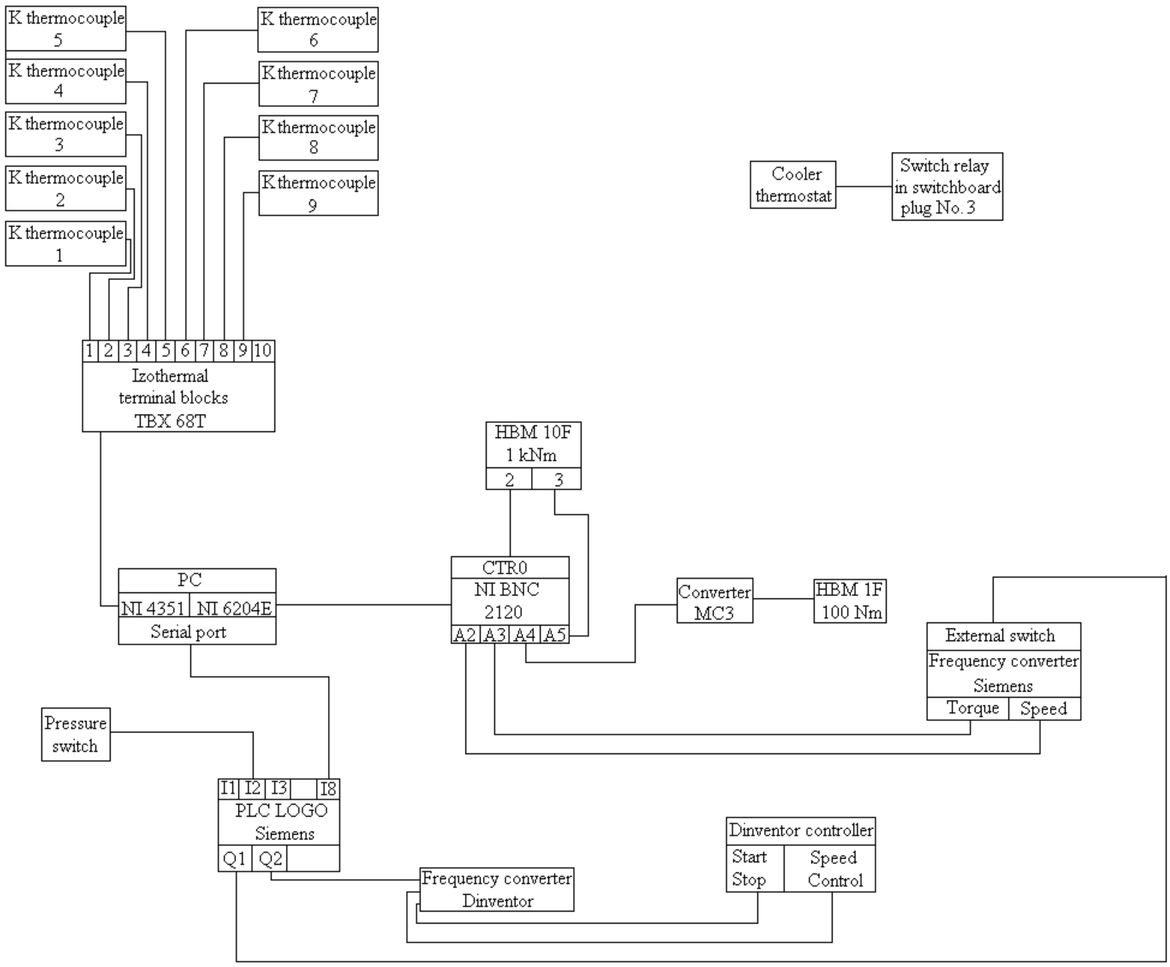

Fig. 3. Scheme of signal wiring.

Measuring software has three tasks.

First is to control measurement stand devices, so test runs according to set up conditions. In this task, program controls time of running eventually it can change rotation speed.

Second task is to write measured data to file. In this task program writes values from thermocouples, torque sensors and frequency converter. First six thermocouples measure temperature of bearings, seventh and eighth thermocouple measure temperature of oil leaving the gearboxes and ninth thermocouple measures temperature of oil entering to the gearboxes. Next signal comes from frequency converter, which shows actual speed and torque of driving electromotor. Next signal is from torque sensor HBM 1F (Tq1 in Fig. 2) which shows same value as signal from frequency converter shifted by offset and serves as safety element. This torque multiplied by speed represents power loss of the stand originated in gear assembly, bearings, coupling, etc. Next signal is from torque sensor HBM 10F (Tq2 in Fig. 2) which shows adjusted torque in closed loop. This torque multiplied by speed represents power in closed loop. Last signal is ambient temperature which serves to correction of measured signal if temperature is too different from 20°C on which is most of devices calibrated. Measured signal are recorded in volts so the further correction is possible. On the display is everything shown in converted units.

Third task is to stop run in case of crash and prevent operator from setting wrong run conditions. Program don't allow to run measurement until oil is coming into gearboxes and stops run if there is any oil pressure drop. Then it watches if temperature or torque doesn't passed by limit. As a next safety element is used PLC LOGO, which watches failure of computer. If computer doesn't response, PLC shuts down whole stand. For economical

and steady running of stand the constant temperature of oil is needed. This is provided by cooler thermostat which keeps temperature of oil within limits.
Recorded data are then converted from values measured in volts to their real units via correction constants gained during calibration of measuring devices. These corrected data are plotted into two diagrams. In one diagram is plotted behavior of torque and speed (Fig. 4). This diagram is important for the evaluation of a tooth flank load. In the second diagram are behaviors of temperatures (Fig. 5). Oscillation of temperatures is caused by switching of the oil cooler on and off.

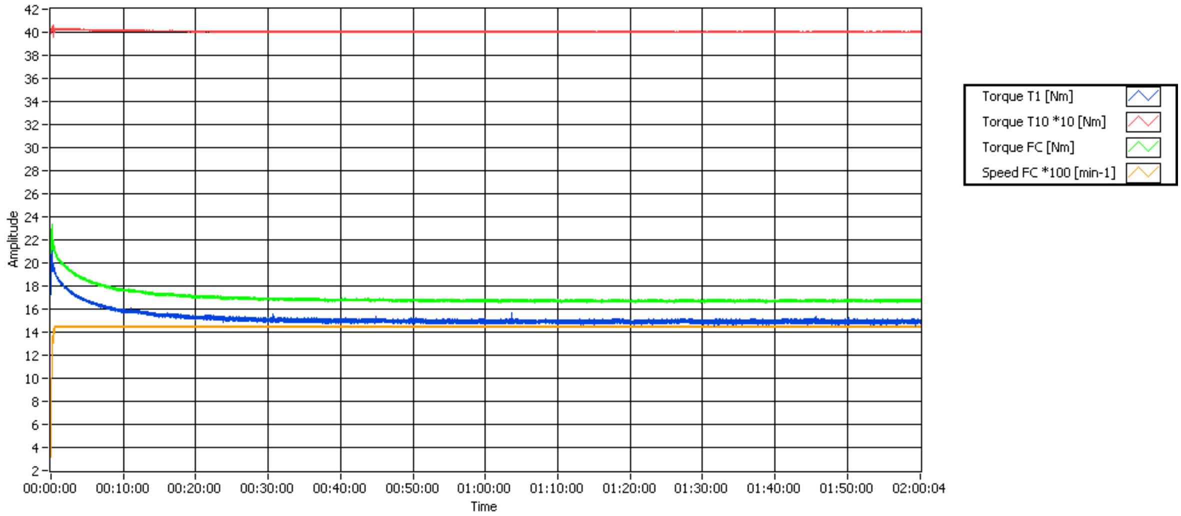

Fig. 4. Behavior of the torque and speed.

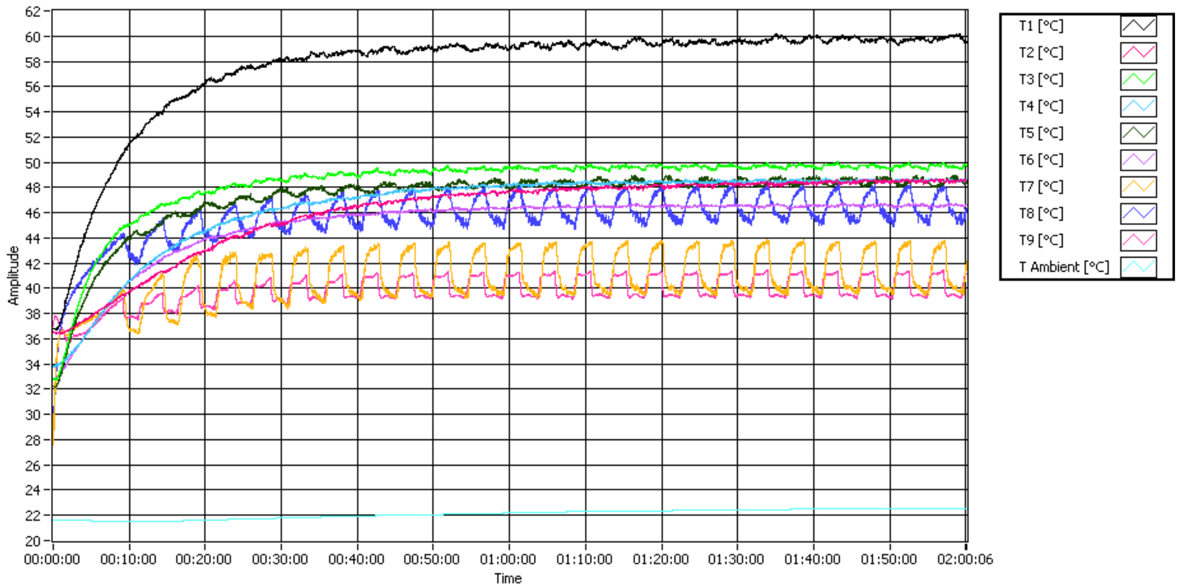

Fig. 5. Behavior of the temperatures.

Test run is stopped after certain elapsed time. The tooth flanks are cleared and degreased and then are taken photographs of tooth flanks on pinion gear. Then test run continues again.
Taken photographs are imported into program NI Vision Assistant and in it found, marked and measured pitting area. The program takes these steps. First step is import of the image. In second step is cropped area of tooth flank which is in gear mesh. In third step is color image converted into grayscale. Fourth step is finding pixels which are high on grayscale and are matching to borders of the pitting area. In fifth step are areas inside borders filled and designated as pitting area. In sixth step are deleted areas which are too small and areas

touching borders of cropped image. In seventh step are measured areas that left and written as area of pitting in pixels. Then is area in pixels converted into area in mm^2 and it is calculated percentage of pitting area on the area of one tooth and percentage of all pitting areas on the area of whole pinion gear. Program is designed to make these steps at all tooth flanks in sequence and writes gained data in file.

The test run is terminated if percentage of pitting area on one tooth flank is larger than 4% or pitting area on all tooth flanks larger than 1%. After end of test run are files from individual stops joined and values of pitting area plotted in diagram. From this diagram is evident pitting growth on certain tooth flanks. Tooth flanks without pitting are not plotted. Diagram (Fig. 6) shows pitting growth of case-hardened pinion gear.

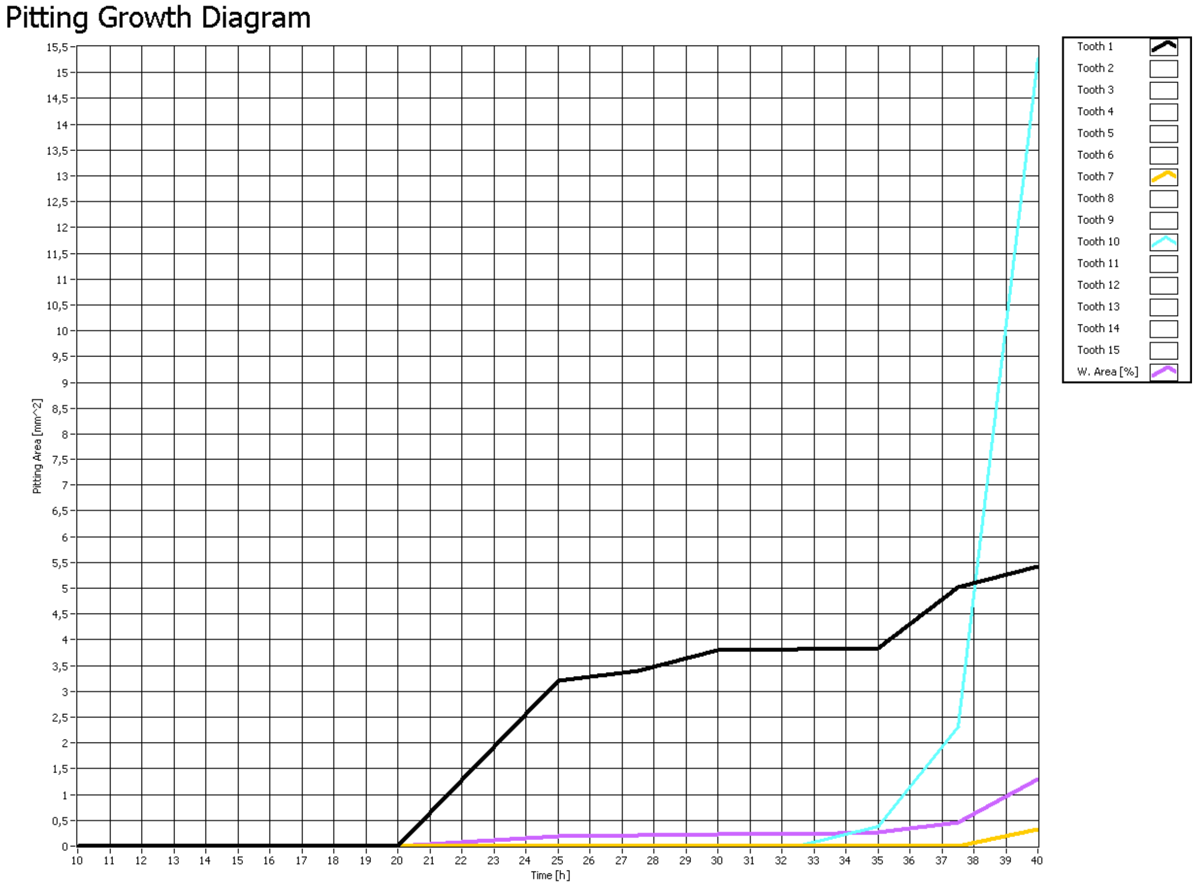

Fig. 6. Pitting growth diagram.

3.Elastic Coupling Measurement

On test stand for finding static and dynamic torsion stiffness was tested parameters of elastic coupling 70 - 4/8 - 3450 for firm Kocián.

During finding static torsion stiffness, software controls force of hydraulic motor with proportional hydraulic distributor. Hydraulic motor force is increased (decreased) by step change and then follows holding on this level for certain time before next step change. During measurement of a coupling 70 - 4/8 - 3450 was used step change by 200 N (200 Nm) in range from 0 to 3600 N by one-way loading (Fig. 7) and from -2000 N to 2000 N by both-way loading, holding before next step change was 30 seconds. The elastic couple was loaded this way four times from minimum to maximum and back. Force of hydraulic motor is scanned by force sensor HBM S9 10kN. Angular displacement of a coupling was measured by IRC sensor. Measured force was equal to torque on coupling because it was acting on one meter long lever. For static torsion stiffness are used measured data from third and fourth cycle, which are similar and average value is computed for each load level. Data gained by this method are plotted in graph (Fig. 8) and then is found waveform describing position of points and it describes torque characteristic of coupling. Static torsion stiffness can be computed by derivation of this waveform (Fig. 9).

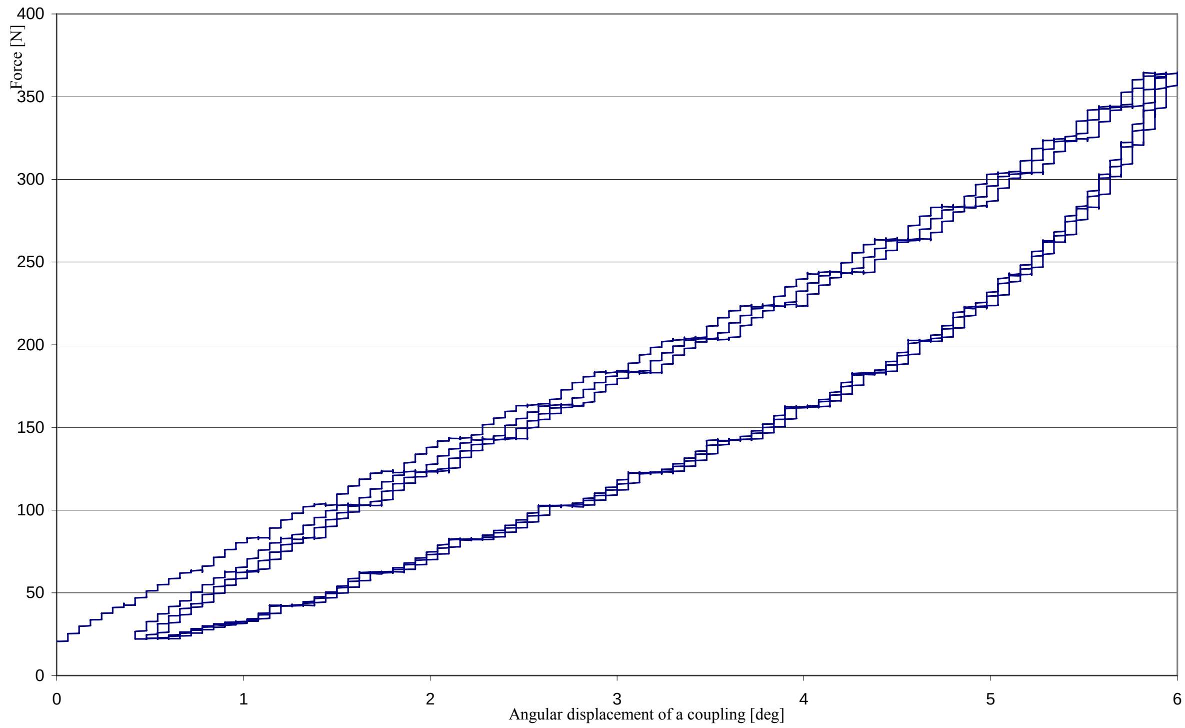

Fig. 7. Relation between torque and angular displacement during static torsion stiffness measurement.

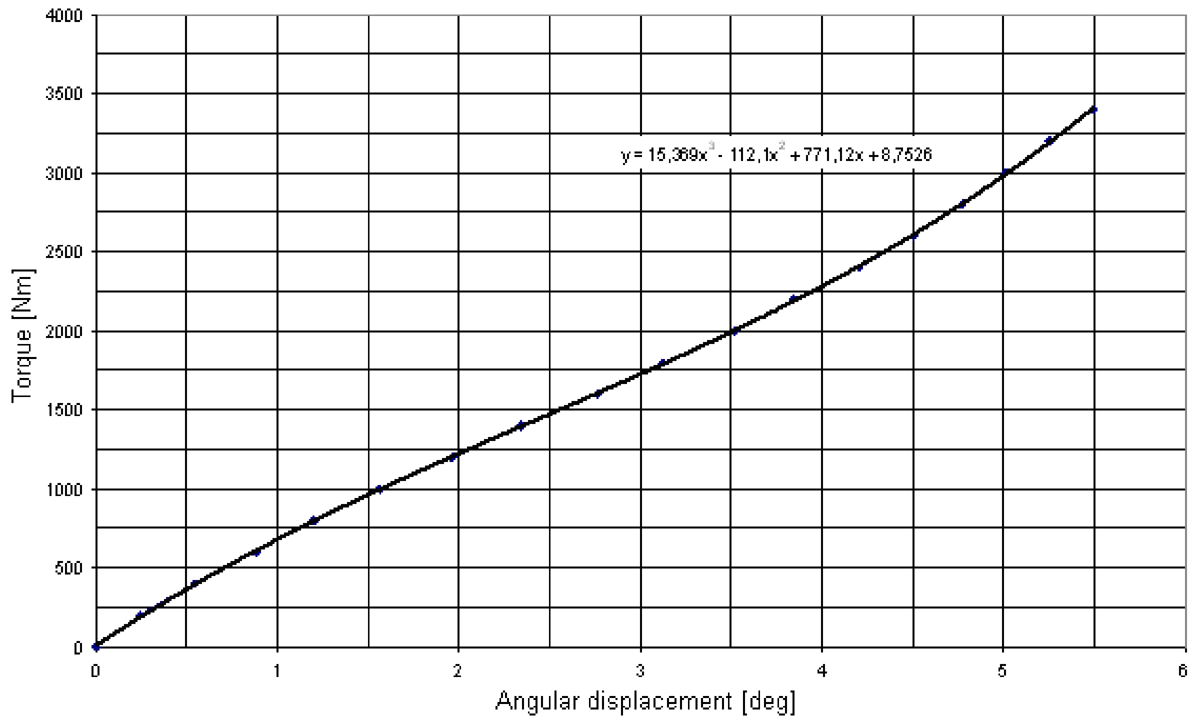

Fig. 8. Relation between torque and angular displacement.

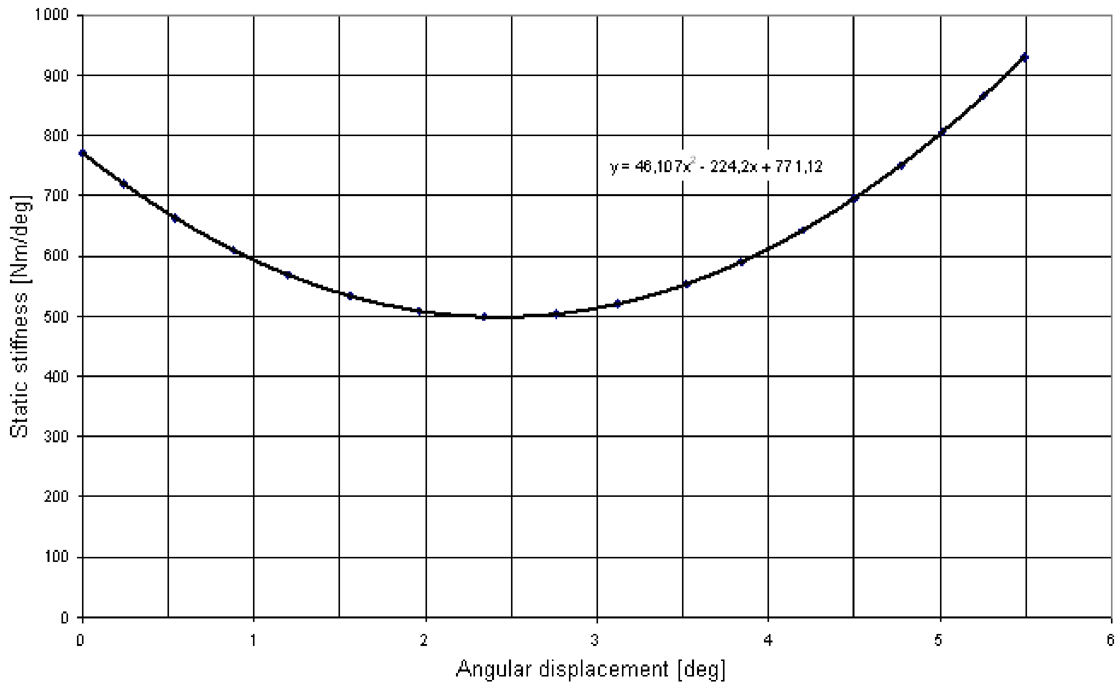

Fig. 9. Relation between static stiffness and angular displacement.

During finding dynamic torsion stiffness, software changes force of hydraulic motor continuously between two limits. Oscillation of torque is usually around rated torque and there are measured several torque amplitude sizes and several frequencies. For dynamic torsion stiffness was used measured data from twenty-first to twenty-fifth cycle, which were similar and average value is computed for each load level. Data gained by this method are plotted in graph (Fig. 10) and then is found waveform describing position of points and it describes torque characteristic of coupling. Static torsion stiffness can be computed by derivation of this waveform.

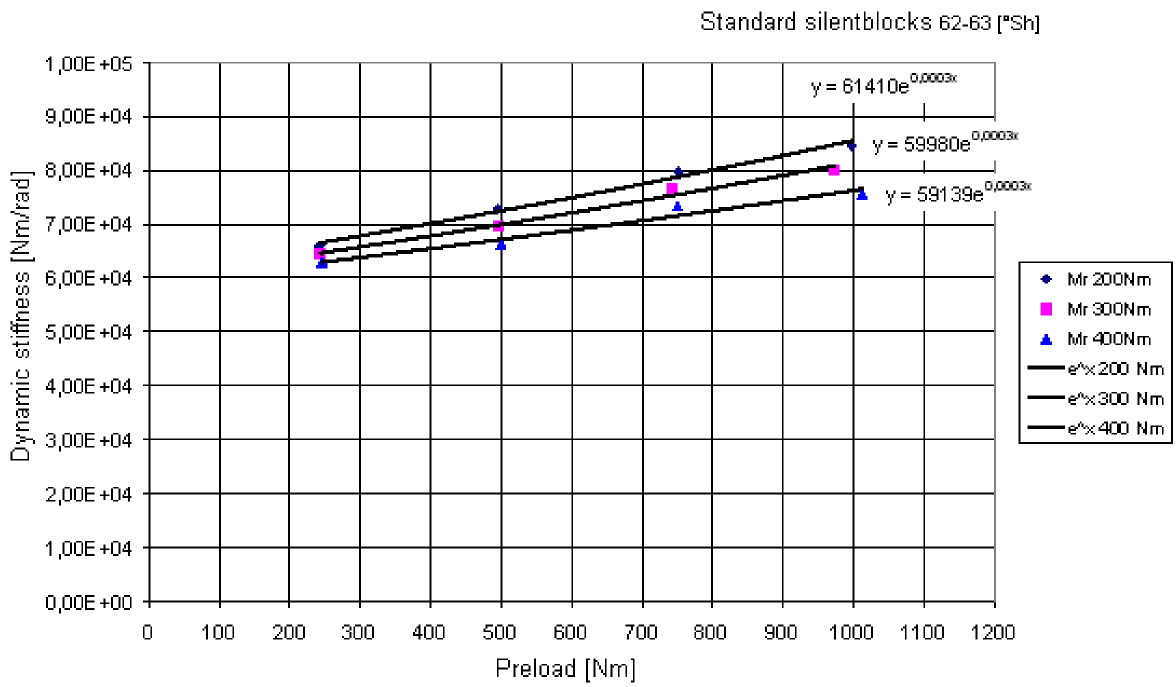

Fig. 10. Relation between dynamic stiffness and angular displacement.

4. Belt Conveyor Measurement

There is a laboratory sectional station developed for measurement, which provides mapping of influence and behavior of each individual component in mechanism of belt conveyor, thanks to its structure (Fig. 11). Resistance is simulated by a brake motor, which is of a same type as a propel motor. The laboratory station uses pair of identical drives and it is designed as electrically closed loop. So it has propel and brake electromotor, where the brake motor works at generation mode and it is electrically connected to the propel motor. Energy is taken from the network to compensate power loss. The whole circuit is regulated by moment feedback. First we measured real load on conveyor belt and then we used these load diagrams to simulate real conditions (Fig. 12) in the laboratory in modular station. Thanks to this simulation we are also able to measure precisely all individual components of mechanism in the way we couldn't do in real conditions. This partial division is necessary for the quality of description of behavior of the mechanism as a whole. Further on it provides good comparison of new construction solutions, which are also examined.

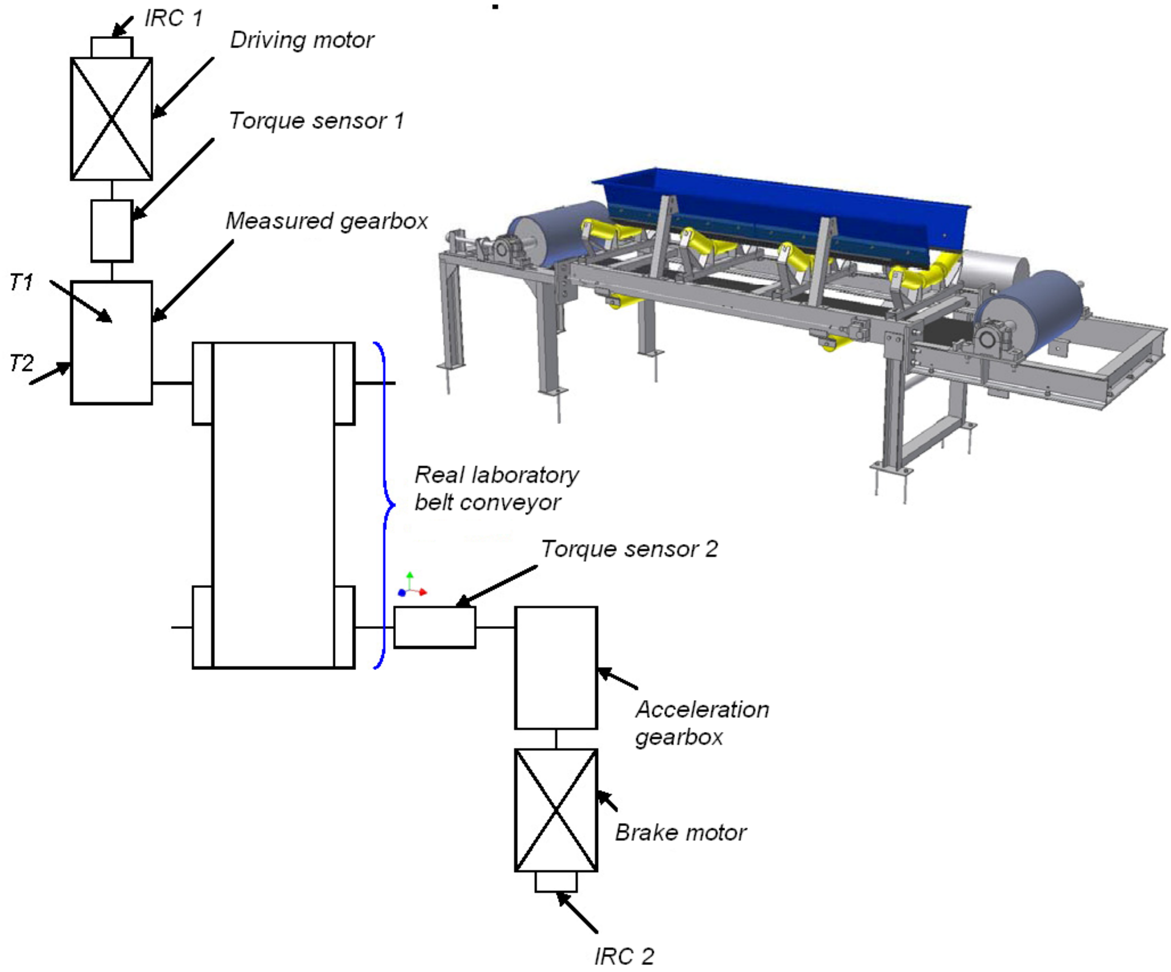

Fig. 11. Model of belt conveyor and scheme of test stand.

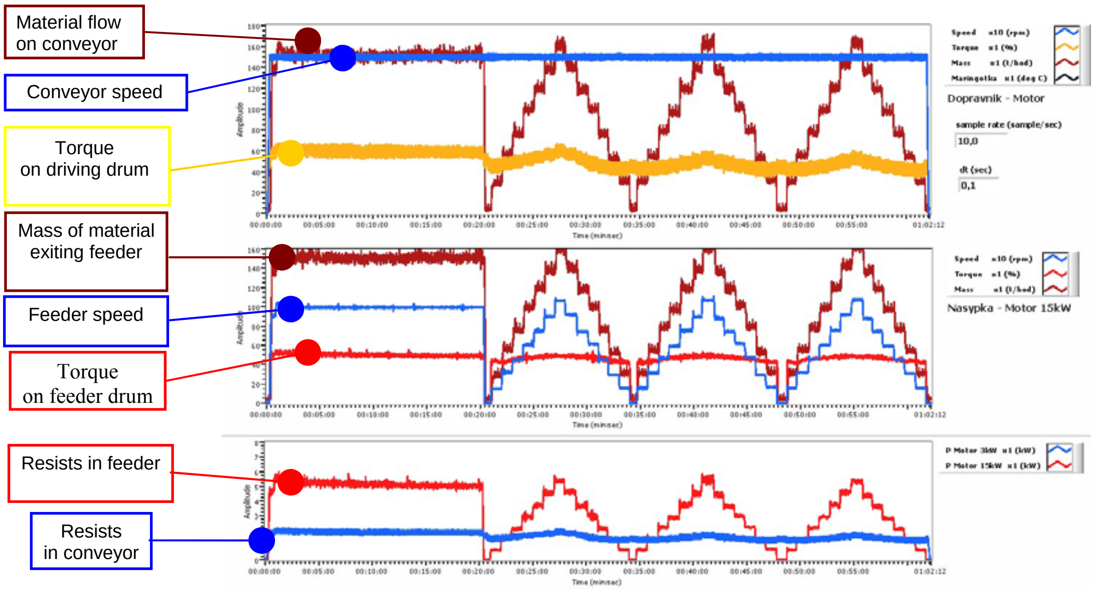

Fig. 12. Data measured during real run.

Strain gauges were placed on drum (Fig. 13) to measure relative deformation in radial and tangential direction. This problem was also simulated on FEM model (Fig. 14). Difference between measured and computed values was 5% in tangent direction and 12% in radial direction. This place was chosen because of often appearance of weld cracks. In future these deformations can be used for measuring torque and tensile force in belt.

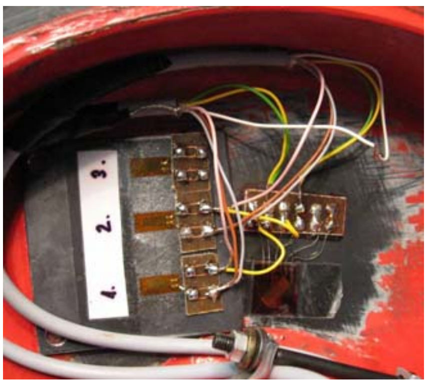

Fig. 13. Strain gauges on driving drum.

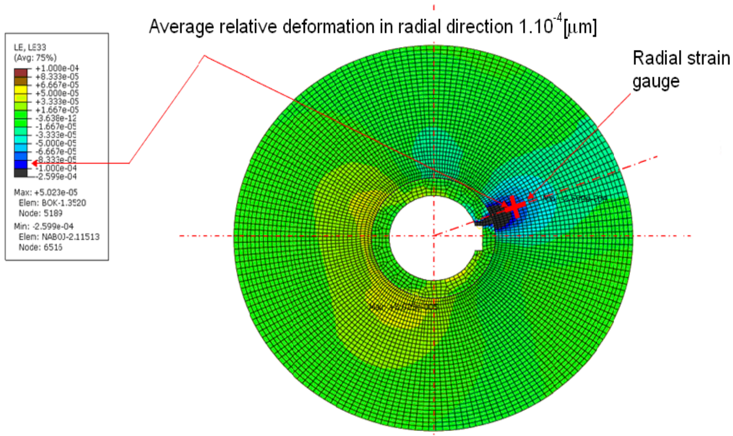

Fig. 14. Relative deformation on driving drum in FEM model.

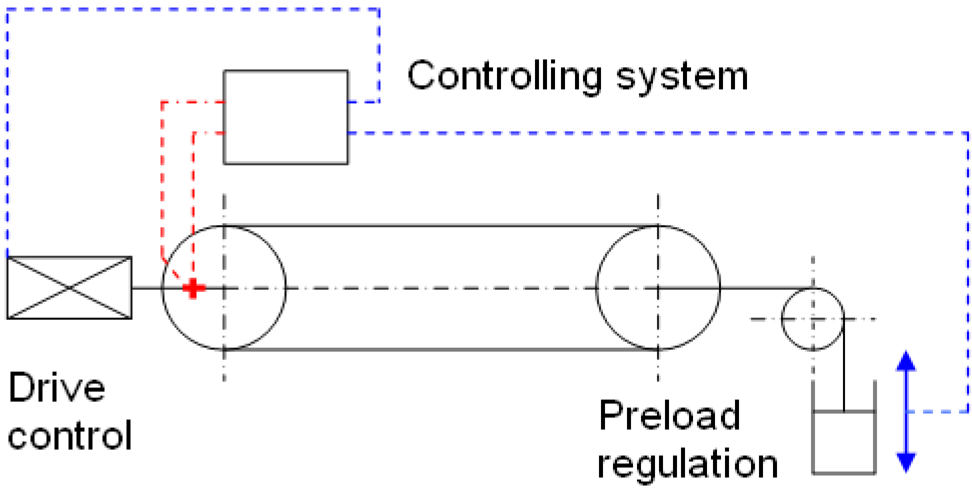

Fig. 15. Scheme of preload regulation.

5. Conclusion

Pitting measurement is not finished yet, but according to (Fig. 16) can be seen that TiN (CK1-TiN-1L) coating has longer operating life. On the other hand same coating if it is not made right (CK1-TiN-1P) has shorter lesser operating life than commonly used case-hardened gears (CK1-0). First pinion gear with CrN coating had a short operating time. But the second that is not in diagram withstand over 100 hours. Lesser operating life of coated gear is assigned to possible tempering of gears during coating process.

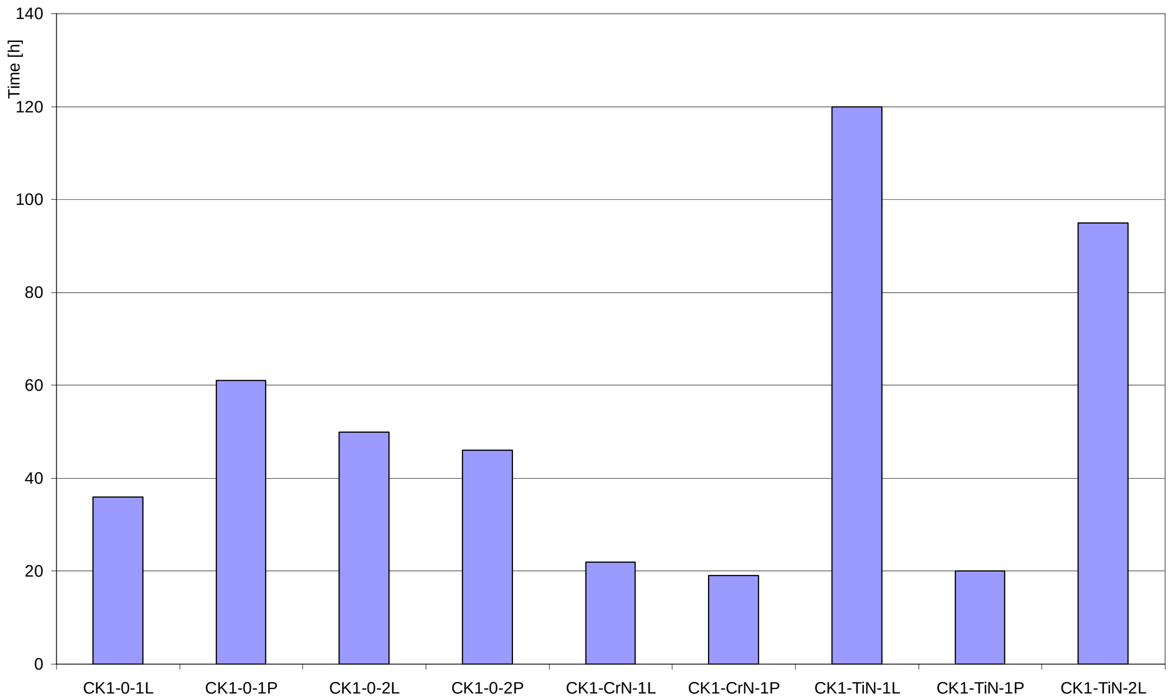

Fig. 16.Comparision of operating life of different coating types.

Results of static and dynamic torsion stiffness of elastic coupling are summarized in diagrams (Fig. 9) and (Fig. 10).

During measurement was found out that lowering of power loss could be achieved by preload regulation. Higher preload is needed only for start of run, overload or freeze of conveyor belt. During regular operation can be preload lowered.

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