INNOVATIVE BROAD-SPECTRUM TESTING AND MONITORING OF BELT TRANSMISSIONS

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The aim of this paper is to present the possibilities of testing and monitoring of belt conveyances, as well as the possibility of determining the limit states by extreme loads. The newly wrapped strap allows for extreme stresses to determine the deformation point of the belt itself. The design of the wall was based on the basic technological and constructional knowledge gained from the professional literature and practice councils. On the device, you can measure, for example, by means of mounted sensors, the actual rev counter, which is compared with the speeds set on the frequency inverters that control the electric motors. One of the wall options is to determine the slip of the belt drive by sensing the necessary parameters by means of sensors located at predetermined locations from which data is processed by a PC. By simply modifying the design of the device, it is possible to vary the different types, shapes, dimensions and conditions of aligning and setting the straps and straps. Measurement results could contribute to research into the development of new types of belt transfers.

KEYWORDS

belt gear, tension, motor, diagnostics, stand

1 INTRODUCTION

Scientific, technical and technological advancement in the sphere of production and use of the belts gave rise to a number of kinds and types of belts. Contrary to other gear types the driving belts are characterized by a few advantages such as low weight, lower price or an alternative to be used as a slip clutch. In case of device damage frequent is destruction of belts and usually more expensive device remains intact. Constantly increasing demands regarding the V-belts require continuous quality improvement of the offered belts.

The present paper deals with the alternative option of determining the status of new types of belts for belt drive designed equipment using energy from the electric motor output recovery. On the device, it is possible to diagnose where the drive belt drives the electric motor and loaded member of the output of the transmission is also electric. The two electric motors are controlled by frequency converter, and an output electric motor is as loaded brake conversion, which electromotive force interaction of electromagnetic fields motor generating power and supplying it back to the input (driving) motor. Plant design was realized 3D model in the program Autodesk Inventor. Monitoring and diagnostics of endpoints is through the incorporation of sensors in the lineup with a connection to a PC.

The entire device consists of three parts – the measuring, the control, and the monitoring ones. The newly designed stand serves for the research in the sphere of testing of the existing as well as of the new types of belts and of belt pulleys.

The paper is presented for the purpose of addressing the need to apply new technologies in the ever-increasing quality requirements.

2 CURRENT STATE OF THE ART OF BELT GEARS

The belt gears transfer mechanical energy for longer distance between shafts, the gear possesses good damping effect, and however, in case of the conventional belts its disadvantage rests in considerable slip, therefore the application of the precise transference number is excluded. The belt is stressed by tensile force in the belt and by centrifugal force and by bending during coiling onto the belt pulley. To allow the belts transferring of the peripheral force between the discs, they must be sufficiently pushed against the discs. Pushing is achieved by pre-stress of a tensile element [Gaspar 2013, Krenicky 2010 and 2011]. In the practice, frequent is the occurrence of incorrectly adjusted belt gear causing high vibrations which negatively influences the bearings, the shafts, and the entire machine structure. In case of the gears in questions, the most commonly occurring faults are, for instance, the following: the driving belt pulleys are not on the level with the driven ones, the belts are extremely or insufficiently tight, occurring resonance effects of the belts, wearing of the belts, the belt pulleys are not balanced or are fixed in eccentric position.

The designed device allows determination of the belt slip expressed by the coefficient of elastic creep and specific slip along with other parameters. The device disposes of the installed sensors to record the monitored parameters which can influence the fault rate of the belt gear. Parameter monitoring is performed by the PC technique and by the suitable software.

In case of belt gears, the terms of creep and slip of the belt must be defined. *Creep of the belt* is a phenomenon occurring if the belt is loose, i.e. insufficiently tight [Balazikova 2017]. By means of required tightening the creep can be excluded. *Slip of the belt* (specific slip) is a phenomenon occurring even if the belt is correctly tightened and with the increasing tightening of the belt the slip becomes more extensive. The slip cannot be prevented due to operation conditions of the belt drives. The belt slip represents the subject of our measurement.

To avoid the creep on the small belt pulley during the run, the adequate tightening after fitting the belt on the pulley should be assured. The extent of prestress in case of the V-belts should be as follows:

$$F_p = \frac{F_1 + F_2}{2}$$

To avoid the creep of the belt the actual prestress is selected

$$F_{ps} = (1.2 \div 1.6).F_p$$

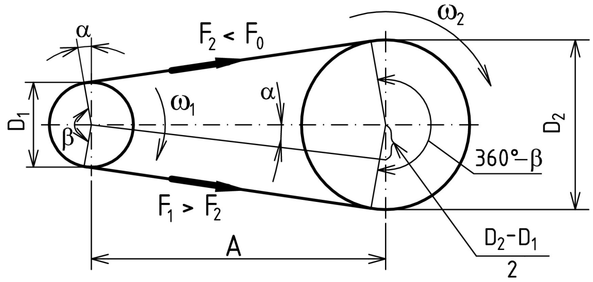

Figure 1. Distribution of forces in case of the belt gear

The prestress, especially of the new belts is substantially more extensive in case of which the elongation during the period of the running-in must be taken into consideration. With regard to actual prestress of the belt, in the individual strands during the run, the action of forces F_1, F_2 is observed, which are bonded in reference to the following relation:

$$F_1 = F_2.e^{f\alpha_1},$$

with

F_1 - force (tension) in converging strand,
F_2 - force (tension) in diverging strand,
f - coefficient of friction in the key seat,
α_1 - angle of wrap of small pulley.

Their difference determines maximal driving force F_{max} which with the respective force relation can be transferred by the belt without the creep on the small belt pulley.

$$F_{o1} = F_1 - F_2 = F_2(e^{f\alpha_1} - 1).$$

In a similar way maximal driving force of the big belt pulley can be determined.

$$F_{o2} = F_2.e^{f\alpha_2}.$$

As $\alpha_2 > \alpha_1$, so $F_{o1} > F_{o2}$. Driving force F_{o1} is given by the transferred torque as follows

$$F_{o1} = \frac{2M_{k1}}{D_1}$$ [Gaspar 2017]

In the case of higher peripheral velocities the effect of centrifugal force can also be observed

$$F_{cv} = \rho.S.v^2 = q.v^2,$$

with

S - cross-sectional area of the belt [m^2]
q - weight of 1m of the belt length [kg.m^{-1}]
v - peripheral velocity of the belt [m.s^{-1}]
ρ - specific weight [kg.m^{-3}].

Gradual decrease of force (tension) F_1 in the belt from the *A* point to force F_2 in the *B* point of the driving belt pulley (see fig. 1) causes shortening of the belt by corresponding value of Δl.

The proportional shortening expressed by the relation

$$\varepsilon = \frac{\Delta l}{l},$$

is referred to as specific slip of the belt. The belt is elongated (it creeps) on the driven belt pulley by the same length with the increase of force (tension) in the *C* point to the value of F_1 in the *D* point (fig.1). Coefficient ψ defined as $\psi = (1 - \varepsilon)$ is referred to as the coefficient of elastic creep. [Fabian 2014]

Peripheral velocity of the small belt pulley is as follows:

$$v_\eta = \frac{\pi.D_1.n_1}{60} = \frac{D_1}{2}\omega_1.$$

Elastic deformation of the belt causes lower peripheral velocity of the driven belt pulley contrary to peripheral velocity of the driving pulley.

According to the aforementioned facts the following can be proved:

$$v_2 = v_1(1 - \varepsilon) = v_1.\psi.$$

The gear ratio of the belt gear is given by the following relation:

$$i = \frac{n_1}{n_2} = \frac{\omega_1}{\omega_2} = \frac{D_2}{D_1.\psi}.$$

The value ψ ranges usually from 0.98 to 0.99. The slip becomes extensive with the gear ratio, with velocity, and with the belt tension.

3 NEWLY DESIGNED DEVICE FOR BELT GEAR TESTING

The developing and structural-design stage during which a test stand design was realized is followed by a production technology design. The production process proposal being recorded into a technological documentation is realized within the frame of technological preparation of production. This part of pre-production stages is referred to as the most arduous and the most time-consuming one in the course of preparation phase of the production process [Smeringaiova 2016].

Primary task of technological preparation of production is especially:

- processing of structural and technological analyses,
- selection of adequate semi-finished products,
- determination of number and order of production, check, and assembling operations,
- selection of adequate machines, tools, appliances, instruments, measuring devices,
- calculation of basic technical and economic data on consumption of time, material, energy,
- processing of programs for NC machines, robots, and control device.

The production process as a set of independent activities in which input material is transformed to finished structural parts of a measuring device is realized on the basis of technological procedures. Technological procedures are intended for production of individual components and for final equipment assembly. Technological procedure determines inevitable production equipment, tools, appliances, measuring devices, and technological conditions to assure accordance with the respective technological procedure, economic production of components meeting qualitative and quantitative requirements prescribed by technical documentation. It is a standard of the applied machinery and auxiliary equipment employed in production as well as a standard related to technological conditions under which the machinery operates.

The newly designed device consists of the basic frame containing a drive electric motor and a driven electric motor, which is included into the assembly as a brake element. The belt pulleys mounted on the electric motor shaft and on the driven electric motor are connected by the V-belt and thus together they form the belt gear. The asynchronous electric motors Siemens (1LA7090-2AA10ZA11 1.5KW 2900/min 400V Y 50Hz IMB3 PTC thermistor) fixed on the frame are adjustable with the option of the V-belt tightening. The driven electric motor controlled by a frequency converter is set up as the brake the extent of which can be controlled proportionally and in the electric motor its brake effect induces respective forces of the belt in converging and diverging strands. Yet, the difference causes the belt pulley slip that can be measured. Tightening of the belt and the respective shift of the electric motor are performed with a tensometric sensor of thrust, with a screw rod and with a thrust bracket. The quantities inevitable for calculation and for the slip are monitored and assessed by a computer through sensors of actual revolutions of the driven and of the driving electric motors. The values of intensity of tensioning force are assessed by a PC. Following Figure 2 shows the scheme of the actual designed measuring device of the belt gear slip [Mascenik 2014, 2016a-c]

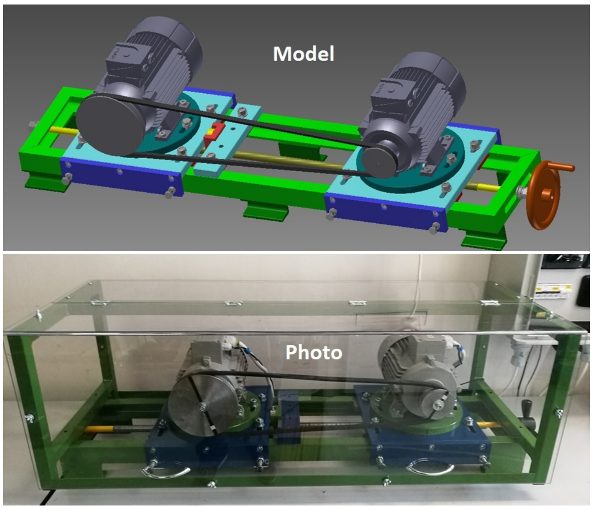

Figure 2. Newly designed stand for belt gear testing

Monitoring and adjustment of the belt tightening is directly connected via force tensometric sensor of EMSYST EMS50. A membrane sensor features bridge interconnection in case of small dimensions and measurement is carried out in direction of pressure. Force measurement ranges from 0.1 up to 10 kN. The sensor can serve for industrial as well as for laboratory purposes. The position of the sensor is shown in Fig. 3.

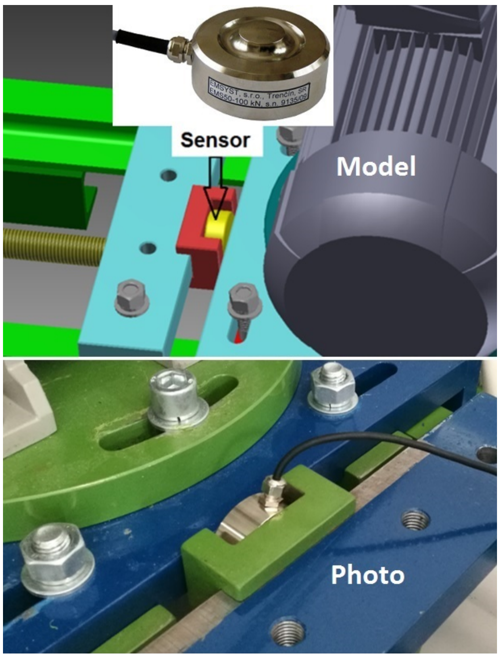

Figure 3. Monitoring of belt tightening with tensometric sensor of thrust

The design of the belt gear tightening includes a screw rod in the lower part of the device. Turning of a crank assures a shift of the respective electric motors and tightening of the belt. With a simple replacement of belt pulleys or belts the device can test also the new belt types. To test the belts under extreme conditions a correct layout of the belt pulleys can be misaligned through a simple adjustments and modifications, yet setting of specific angle and axial misalignment is required.

Following Figure 4 shows a scheme of the device designed for measuring of belt gear slip or for testing of new belt types. The device assembly consists of the following: 1 – driving electric motor, 2 – driven electric motor as the assembly brake, 3 – monitoring and assessing computer, 4 – belt, 5 – sensor of the actual revolutions of input belt pulley, 6 – sensor of the actual revolutions of output belt pulley, 7 – tensometric sensor of thrust, 8 – supporting frame, FM1 – frequency converter to control the driving electric motor, FM2 – frequency converter to control the driven electric motor.

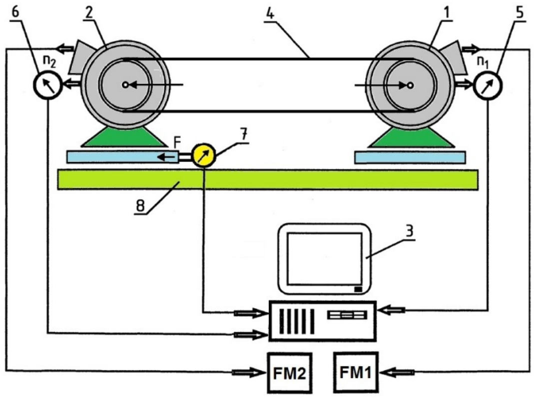

Figure 4. Scheme of device designed to test the belt gears

Frequency converters can be controlled and monitored when the entire assembly is connected to the PC through monitoring and adjusting SoMove software. SoMove software is used for configuration and adjustment of parameters of Altivar frequency converters (Fig. 5), of Lexium synchronous drives, TeSys motor starters [Puskar 2012].

Figure 5. Control panel with frequency converters

SoMove program features a unique option of off-line mode which allows access to any parameter of the adjusted device (prior to connection to a superior system). Its output is a configuration file that can be archived, printed or exported to Excel. The created configuration can be read by Multi-Loader which, apart from other, allows copying of parameters without use of personal computer. Following Figure 6 demonstrates the working environment of SoMove program [Bicejova 2013].

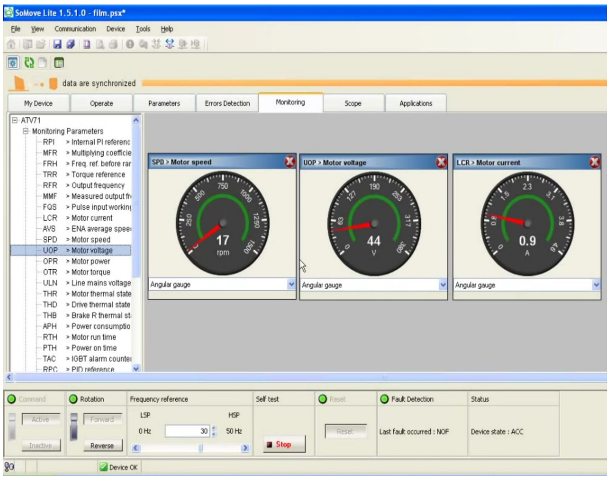

Figure 6. Working area of monitoring and adjusting software SoMove

4 CONCLUSIONS

Contemporary gears with the V-belts represent powerful drive; however, the optimal output shall not be achieved without, for instance, correct tightening and layout. High output is given by a multi-year research and development carried out by the engineers and by the technicians heading towards the refinement of materials and processes. Although the belt gear represents rather obsolete component of output transfer, the current belt gear is exceptionally powerful means of the output transfer between the driving machine and other device.

The main aim of the measuring device design is to determine limiting conditions or to define a destruction point through extreme loadings of the belt. The stand design stemmed from the essential technological and structural knowledge gained from technical literature, available materials and practical advice offered by the experienced professionals. The selection of the most suitable alternative was preceded by a proposal of several alternatives and their detailed analysis by means of virtual model. Through application of the installed sensors the device allows measuring of the actual revolutions of belt pulleys which are compared with the ones set up for frequency converters. Monitoring of the inevitable parameters to determine for example the belt gear slip is carried out by means of the sensors installed at pre-defined places the data from which are processed by the PC. When the device is placed on a damping or rubber pad the vibrations of conversion can be measured. The results and knowledge of research measurements could contribute to the sphere of development of new types of belt gears.

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