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APPLICATION OF MONITORING SYSTEM IN DRYING SECTION OF PRINTING MACHINES

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Abstract: *The paper dealt with problems of collision state monitoring in mass production process with potential environmental impact. The printing machines for plastic packaging foil production are the objects of monitoring, mainly the drying technological part. The paper is focused to usage of vibration diagnostics of rotational equipment, i.e. ventilators in drier. The selection of appropriate on-line system control by way of intelligent components implementation is a critical problem of mass production with dangerous operation. The project of applied monitoring system is described. The newly system of automatic monitoring regime with use of artificial intelligence elements was projected and tested.*

Key words: *printing machine, vibration analysis, ventilator, bearing, failure.*

1. INTRODUCTION

Slovak chemical industry has long period tradition. The producers are investing a lot in upgrading and acquiring new machines and technologies, in particular in the field of film converting, which allows to be flexible and to produce top-quality products competitive. The printing machines operate the latest rotogravure and flexoprinting technologies that meet demands of customers and also stringent legislative requirements for environmental protection.

The production of plastic flexible films is comprised in field of mass continuous production with use of high-efficiency printing machines. The production of flexible plastic films involves the eventual dangerous negative effects for environment. It is a reason to pay considerable attention to the periodic modernisation of machine-technological units and to use on-line control.

The one of important printing machine technological section is drying section that uses the high-performance ventilators. The process monitoring is needful for operating of these equipments. The vibration automatic diagnostics of ventilators can minimize the unwanted impact to environment.

2. ANALYSIS OF PRINTING MACHINE

The production machine, i.e. 8-colour (10-colour) printing machine shown in Fig. 1 consists of 8 (10) printing groups.

The foil is winded off and traversed through several printing sections between printing cylinders. The printing

Fig. 1. Printing machine – Rotomec RS 4004.

foil is winded off and traversed through several printing sections between printing cylinders. The printing cylinder has engraved printing decor. Each section contains on color. The combination of color and decor forms final printed graphic figure. The printing speed is from 250 to 300 m/min depending on difficulty of figure. Decorating the foil by one color, it has to be dried in drying section before entering to next section. To dry the foil, the ventilators are used in drying section. The aim of ventilators is to blast air and quickly steam off the diluents from printing color (acetone type etc.).

2.1. The drying section

The drying section comprises the groups of ventilators. Some printing machines have two drying sections (at the beginning and end) to achieve higher performance of drying. The ventilator scheme is in Fig. 2. The rotating ventilator wheel is fixed directly on output shaft of electromotor. Each ventilator in drying system of printing machines is installed by such concept. The engine speed is regulated in dependence on demand of drying air.

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Fig. 2. Drying section.

The sensors in each section measure the diluents concentration in air. In case of concentration increasing, the revolutions of electromotor (ventilator) are increased, up to maximum value, i.e. 5 000 min^{-1}. The diameter of ventilator wheel is 500 mm, the electromotor power is up to 10kW. The operating environment of ventilators is explosive regarding to high concentration of diluents.

The air is sent to combustion section where the diluents are burned. The whole drying section is closed by covering and the entrance to ventilators in process is impossible. To repair the ventilators in case of fail or damage, the total shut down or decreasing of machining of printing machine is necessary to do. The mentioned fact is not economical for production company. The running of ventilators is suitable for regime of automatic control.

3. REASONS OF FAILURES

The most of specialists have opinion that more than 50% of all failures is caused by the un-axial alignment. The machine parts (shafts, clutches, bearings) can be assembled without axial alignment. There are two types of axial alignment: axial and parallel (shown in Fig. 3) or their combination.

The un-axial alignment causes higher loading of bearings than permissible values resulting in fatigue of bearings. The material fatigue is visible through the appearance of pitting.

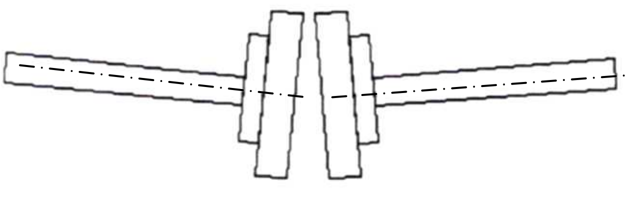

Fig. 3. Un-axial shafts alignment.

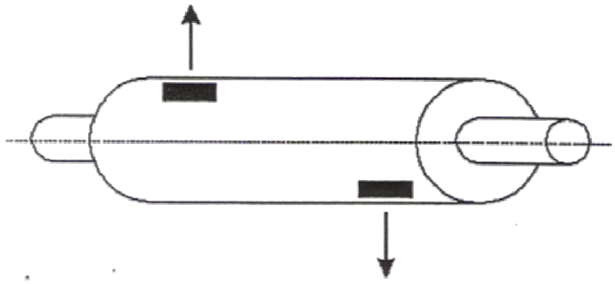

Fig. 4. Moment unbalance.

The next reason of failures can be the unbalance. The unbalance is appears if the shaft central axis of inertia is not the same as shaft geometric axis. There are three types of the unbalance: static, moment and dynamic unbalance. The dynamic unbalance is combination of the first two types.

The only one force is acting in case of static unbalance. The word “static” means that such type of unbalance is visible in not operating position.

The moment unbalance (Fig. 4) is measurable only in operating phase. When the rotor is not working, it seems as balanced. During operating phase the two same forces (masses) are acting against each other. The described state causes rotor vibration and the values of measured phase on the two shaft ends are shift at 180° [3, 7].

The dynamic unbalance as combination of static and moment unbalance is the most occurring unbalance. The static unbalance is dominant for simple machines compared to complex machines (more than one clutch) with dominant moment unbalance.

To diagnose problems related to unbalance, the measurement of vibration, FFT spectrum and phase were done. The vibration caused just by unbalanced have sinusoidal distribution with one wave per one revolution. The amplitudes for frequency of revolutions of FFT spectrum are higher. In ordinary, if the signal has harmonic multiple over base frequency of revolutions, then the problem is not caused by unbalance.

The other reasons of failures generated by the unwanted vibration are for example:

- mechanical unfastening,
- bended shaft,
- wrong assembled bearing on the shaft.

4. DESIGN OF CONTROL SYSTEM

In order to design method and system of control, the measuring of vibration was assigned as main criterion for determining of machine state. Furthermore, the knowledge of world companies in vibration diagnostics was used to measure dynamic parameters of active rotating members.

Fig. 5 shows the electromotor position and also the closed skeleton of ventilator. The mentioned facts were implemented to design of ventilator – electromotor joint.

Fig. 6 illustrates the position of sensors in mentioned joint of acting member - ventilator.

Each electromotor (ventilator) has one sensor of vibrations (accelerometer) situated according to Fig. 6.

Fig. 5. Electromotor position.

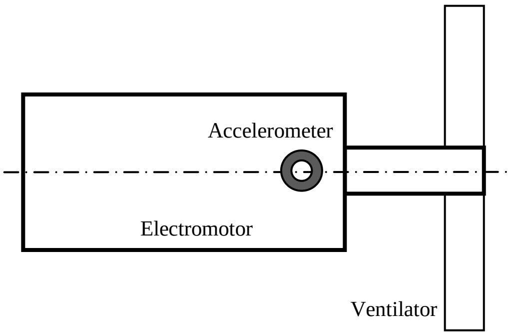

Fig. 6. Position of sensor on the acting member.

4.1. Monitoring system

The main aim of monitoring the vibrations of rotating parts of machines is provided the information about working and technical state of equipment in order to provide strategic planning and maintenance management. The vibration diagnostic is used as diagnostic parameter of vibrations which are caused by dynamic machine stress. This diagnostic parameter gives information of objective technical state estimation for rotating machines.

- 1st measuring method: acceleration – the method of measuring the acceleration of vibrations. The method can estimate: cutting tool state, bearing spindle state, cutting process, etc.

- 2nd measuring method: velocity – method of measuring the velocity of vibrations; the measured values are viewed through the norm STN ISO 108 16-3 in which the velocities of vibrations are determined. The Fig.7 shows the scheme of mentioned norm [1, 2].

The measuring system Oktalon was selected and implemented into designed measuring chain. The Oktalon system is modular multi-parameter measuring system for permanent monitoring of mechanical vibrations and diagnostics of roller bearings. The system is constructed on the base of neuron nets of LonWorks type with opened architecture. The measuring, evaluating and saving of measured values are realized in automatic regime. The measured values are compared with the set alarm level [5].

The communication and data transfer into PC and visualization software are allowed by double data line with protocol LonTalk (up to 2 500 m), by interface RS 232 or by modem (in un-switched telecommunication network or mobile GSM network). The measuring system Oktalon is made of standard “intelligent” modules of LonWorks type based on Echelon processor.

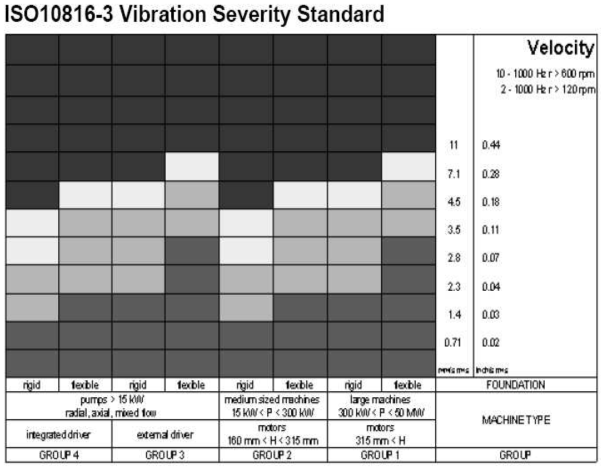

Fig. 7. Norm STN ISO 108 16-3.

Each of used components is developed for functioning in heavy industrial environment. It is characterized by high reliability and resistance of interference.

The measuring of vibrations was realized by system PXI (PCI eXtensions for Instrumentation – NI LabVIEW Order Analysis Toolkit, NI LabVIEW Sound and Vibration Toolkit). System is shown in Fig. 8. The vibration scanner MTN/1135C is accelerometer of small dimensions widely applied in industry, mainly for measuring of vibrations of action members with rotation motion.

The following types of failure can be identified by measuring of vibration velocity according to ISO 2372 for estimation the mechanical vibration in low-frequency range: dynamic unbalance, un-axial shafts alignment by clutches, bended shaft, low stiffness of base or mechanical unfastening, resonance effects of supporting frames, housing, boxes, bases, etc. [7].

4.2. Project of measurement scheme

The previous way of measuring (off-line control) was replaced by automated measuring system that significantly shortening time for elimination of defects. The aim is possible to achieve by early prediction of occurring problem. Further, the human factor in operating control is necessary to minimize regarding to explosive work conditions and high importance of drying section. Involving the mentioned facts, the project was proposed. It

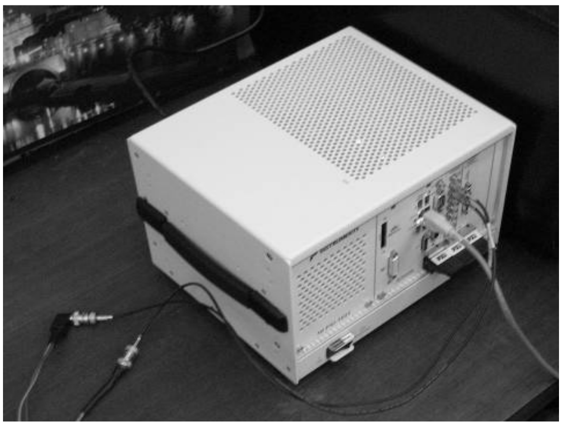

Fig. 8. Modul of PXI system.

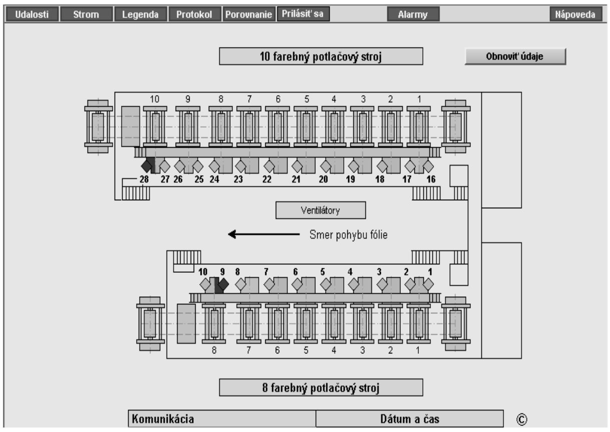

Fig. 9. Measurement scheme in hall.

utilizes software: Lab View Professional Development System. The choice of hardware measuring components was influenced by present trends in field of artificial intelligence components development intended for explosive conditions.

The project of measurement scheme integrates knowledge in the field of artificial intelligence namely application the hardware and software for monitoring the process state and its evaluating. This new automatic system fully substitutes previous patrol system. The measurement scheme was projected with consulting of experts of diagnostics and technicians for printing machines.

Fig. 9 shows complex measurement scheme with help of Oktalon system. The status warning and danger are showed in color according the norm in Fig. 7. The output of measurement is on the LED panel through the software that is part of Oktalon system. The ventilators status can be checked by visual control of operating staff in central monitoring display.

5. MEASURED VALUES AND CONDITIONS OF MEASUREMENT

The review of ventilators working conditions was done by measuring and evaluating their frequency vibration spectrums.

The 12 exhausting ventilators are operating for 10 color printing machine ROTOMEC 3.

According to ISO 10816-3 the recommended levels of mechanical measured frequencies are determinate.

The methods mentioned in Table 1 mean:

MFV – mechanical vibration (dynamic unbalance, un-axial shafts alignment, bended shaft, unfastened base, mechanical unfastening, etc.)

EN3 (Enveloping) – the measuring of envelope of vibration acceleration; the enveloping filters out low-frequency vibration signal noise and makes high-frequency signals of bearings more intensive.

The potential statuses:

1. In case that measured values are higher as the Alarm 1 level, it is necessary to watch device (joint) or make the correcting operation.
2. In case that measured values are higher as the Alarm 2 level, the quality working is impossible to expect for a long period. The repair is needful in time of shut down of manufacturing [4, 6].

Table 1

Measured values, Rotomec 3

Measuring method	**ALARM 1 (warning)**	**ALARM 2 (danger)**
MFV (mm/s)	4.5	7.1
EN3 (gE)	2.8	4.5

Table 2

10 color printing machine ROTOMEC 3 – ventilators

Ventilator number	**Operating condition - evaluation**	**Note**
1.1	good	after repair, improvement, stabilized
1	-	without measuring
2	-	without measuring
3	good	
4	good	
5	good	
6	good	
7	good	
8	convenient	mechanical vibration (alarm A1), stabilized, motor bearings OK
9.1	good	
9	good	
10.1	INconvenient	high mechanical vibration of motor on the tail (alarm A2), correction of motor, vibration decreasing (20% compared with last measuring)
10	INconvenient	high mechanical vibration of motor on the tail (alarm A2), correction of motor, vibration decreasing (25% compared with last measuring)
Main	good	low revolutions and measured values

Figs. 10 and 11 provide summary of measured values of mechanical bearing vibration and evaluated statuses of each ventilator.

The following Table 2 involves complete evaluation of operating conditions of measured ventilators gears, mainly mechanical vibration (unbalance, mechanical unfastening, un-axial alignment, etc.) and operating conditions of bearing mounting. The column “Note” mentions the reason of inconvenient or damage state. The inconvenient or damage state is not mean that the bearing is failed.

Figs. 12 and 13 describe frequency spectrums of mechanical vibrations of MFV parameter measured on the electromotor of ventilator denoted as 10.1 (Fig. 12) and 10 in Table 2.

Despite the correction of motors and decreasing of vibration (20–25 %), the values are over the recommended values of Alarm 2.

The dominant amplitudes with frequency 50 Hz respond to frequency of motor revolutions.

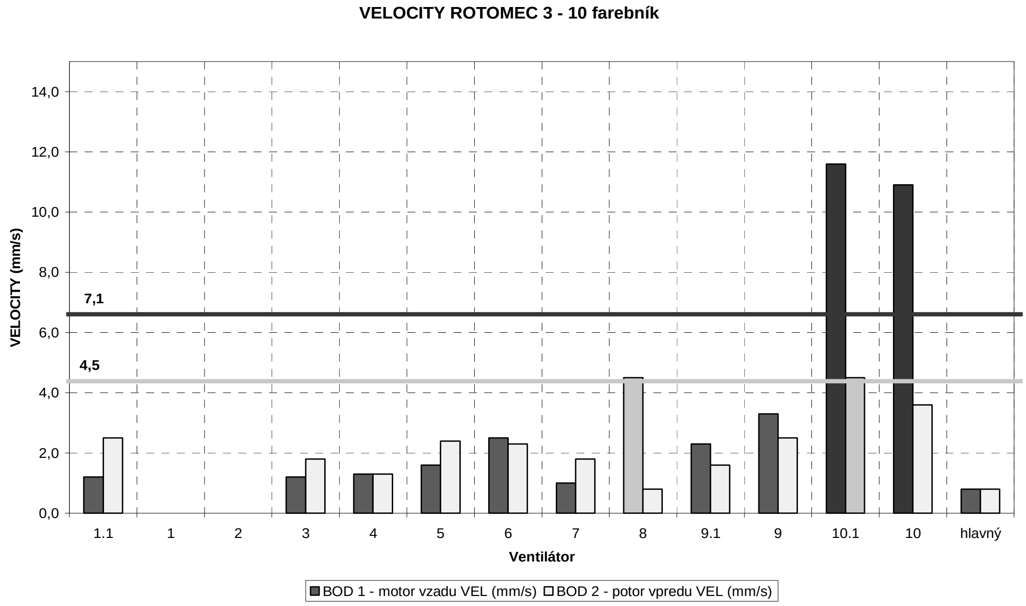

Fig. 10. Measured values: Velocity, Rotomec 3.

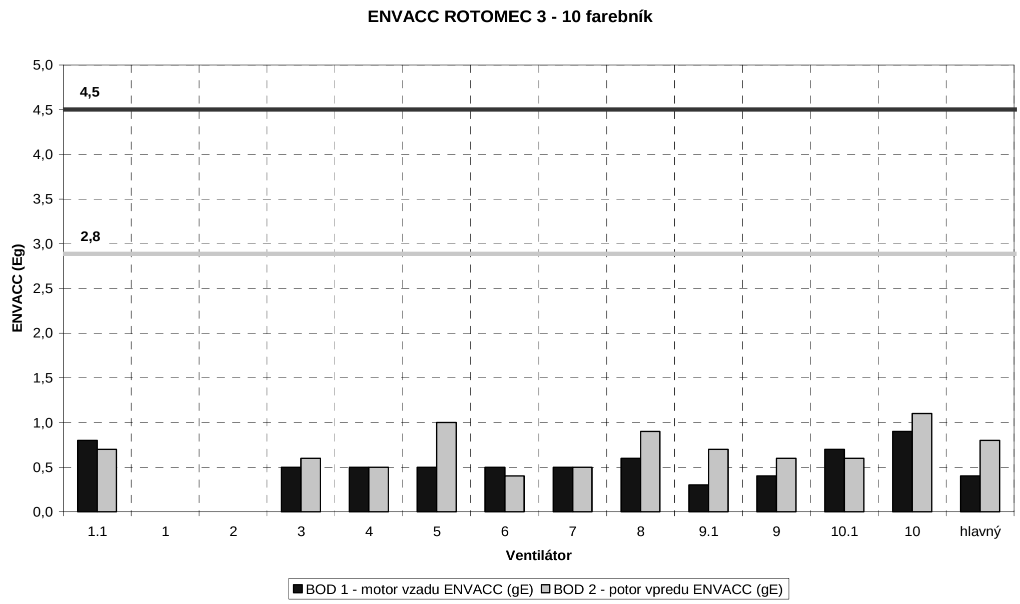

Fig. 11. Measured values: Env Acc, Rotomec 3.

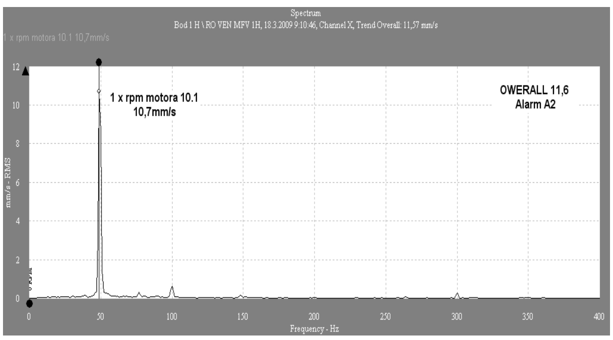

Fig. 12. FFT Spectrum – velocity 11.6 mm/s, frequency of revolutions.

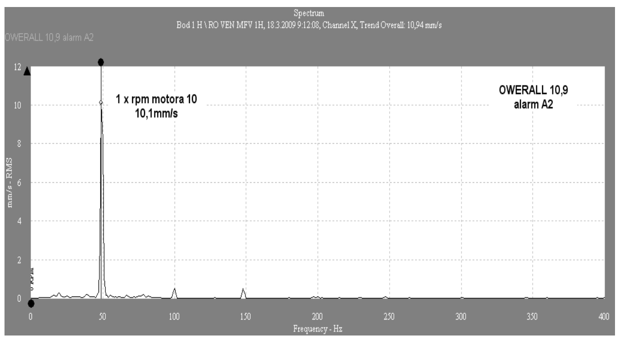

Fig. 13. FFT Spectrum – velocity 10.9 mm/s, frequency of revolutions.

Fig. 14. Damaged tail bearing.

5.1. State of measured components during implementation of monitoring system

On the base of realized diagnostic measuring, the state of exhausting ventilators in printing machine ROTOMEC 3 during implementation of monitoring system is following:

1. The motor of ventilator 1.1 provides good and stabilized state of mounting after reconditioning.
2. The motors of ventilators 10.1 and 10 provide inconvenient state of mechanical vibrations (alarm A2).
3. The decreasing of vibration (20–25 %) was achieved by correction of silenblock screws of motor frame, but the level of vibration is still high.
4. All other ventilators are in good and convenient state of mechanical and bearing vibration.

The monitoring system required harmonizing and optimizing to eliminate all mentioned undesirable operating conditions. Fig. 14 shows failed bearing of ventilator motor 10.1 and 10 before application of monitoring system. The damage bearing ring, roller bearing and retaining ring are visible.

The measured state was found by method of measuring the envelope of vibration acceleration in high-frequency range that enables identify following types of errors: fatigue bearing damage, damage of contact surfaces with "metal" contact, heavy operating conditions of bearings (due to high mechanical vibration), unwanted friction regime – lubrication [2, 4].

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6. CONCLUSIONS

The find facts obviously confirm that implementation of on-line control systems for operating machines in mass production with environmental effect is needful.

The paper work analyzes basic theoretical incomings for application of new monitoring system for technology of packaging foil manufacturing. The experiences of previous patrol system were involved in project. The mentioned previous system was un-able to detect fails and collision states in time.

The most important part for detecting the failures is the drying section with operating rotating equipments – ventilators. In case of collision in drier, the required amount of dangerous exhalation could not be flow out into combustion section. It can cause the disaster with environmental impact.

The newly system of automatic monitoring regime with use of artificial intelligence elements that was projected and tested confirms the validity of purpose. The implementation of intelligence elements into on-line control eliminates human errors and furthermore it enables quality prediction of collisions. The effects are in field of economy (minimization of shut down of production due to failures) and in field of protection of environment.

The following facts can be defined on the base of achieved results:

- The previous vibration diagnostics conditions of printing machines invite the innovation change with focus to automatic data collection, quick evaluation with required decision in case of possible failure appearance.
- The new system fulfils the request of failure-free automatic operation by reason of character of foil mass production where each unexpected production shut down is followed by large economy loss.
- The selection of monitoring components for automatic regime was built on artificial intelligence members for reason of specific technological conditions.
- The applied system allows so called 24-hours hot-line web service.

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