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PREDICTIVE MAINTENANCE TECHNOLOGIES ASPECTS

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Abstract. *The evolution of the maintenance concept is determined by the technical and economical organization evolution of factories and manufacturing. Predictive maintenance is an evaluation activity of a status of a mechanism, assembly or system before its breakdown. The purpose is to avoid longer interruption of the mechanism, assembly or system working. This could affect productivity or customer satisfaction. In this paper, some methods and technologies applied in monitoring/diagnostics activities are presented in order to determine deterioration, the main causes (vibrations, noise, loading, exploitation) and their effects. Monitoring/diagnostic capability of the system has been developed including computer usage.*
Keywords*: monitoring/diagnostic, maintenance, defects, component/equipment/machine.*

1. INTRODUCTION

The exploitation manner of equipment/machine and the level of use in operation and maintenance activities must assure increasing operation period and degradation prevention. The management of the maintenance activities has specific functions that can be achieved at a given moment or at a given period of time.

The competitivity on a continuously expanded market with globalization tend is sustained by products performance, manufacturing flexibility and productivity, technological systems reliability, company management and marketing. The increasing of productivity is formed by many elements like increasing machines and equipment availability for different production necessities. These necessities require different types and strategies of maintenance. [1, 5]

The proper operation of a mechanical system, of its assemblies or components, can be evaluated by assessing the measurable systems' parameters during operation or during the operation simulation tests [3, 9].

The predictive maintenance of the machines, components or systems is applied with the goal of detect degradations' causes and to evaluate the consequences in order to correct and reduce degradation before serious failure occur [5, 12, 13].

There are many examples when mechanical systems account for the majority of plant equipment, fabrication and technological systems. For these mechanical systems, different maintenance technologies were developed and applied for predictive maintenance programs. It is known that vibration monitoring is a key component in predictive maintenance programs [7].

Every production system is build using production systems, equipments or machines interconnected, created to successively transform raw materials in final products. Its structure is determined by component subsystems (technologic, logistic, control, auxiliary). Every subsystem is built using from easy to complex mechanisms with variate components and command devices.

For these subsystems, different maintenance technologies were developed and applied for predictive maintenance programs. Therefore, a comprehensive predictive maintenance program must include other monitoring and diagnostic techniques such as termography, oil analysis, ultrasonic analysis, the maintaining process parameters, visual analysis, etc [7, 13].

Maintenance methods (corrective, predictive, preventive) are selected depending the moment of action against machines/equipments. The main characteristics of predictive maintenance are shown in tab. 1.

Table 1. The charcteristics of predictive maintenance

Technologies/activities	**Strength points**(+)**, weak points** (-)
• inspecting, adjusting, setting-up and/or replacing components; • preventing equipment/machinery failure during operation; • applying termography, vibration analysis, oil analysis, strain analysis as well to prevent hazard disturbance.	• (+) identifying component breakdown causes and preventing its reappearance; • (+) earlier warning against breakdowns; • (+) maintaining equipment/machinery at designed parameters; • (+) maintenance is performed when convenient; • (+) machines life is extended; •(+) unexpected machinery breakdowns are reduced; • (-) high investments costs –high tech technology; •(-) additional skills required- high qualified operators (skill operation operators); • (-) there are still unscheduled breakdowns.

However, vibration monitoring cannot provide all of the information that will be required for a successful predictive maintenance program. This technique is limited to monitoring the mechanical condition and not other critical parameters required for maintaining reliability and effectiveness of machinery [12].

2. MAINTENANCE TECHNOLOGIES FOR MECHANICAL SYSTEMS

Vibration analysis is the dominant technique used for predictive maintenance management. This technique uses the noise or vibration created by mechanical equipment and in some cases by plant systems to determine their actual condition. The dynamic behavior monitor of the machine can provide direct correlation between the mechanical condition (degradation) and recorded vibration data. Vibration analysis [4, 10] can identify specific degrading machine components (mechanical, hydraulics, pneumatics, electrics), its causes and predict a major failure of the machine before its occurrence.

Sensors are used to quantify the magnitude of vibration or how rough or smooth the machine is running. [14, 15, 16].

Vibrations are oscillation motion executed by a mechanical system against its reference status caused by disturbance forces with time variable magnitudes, directions or starting points.

Vibrations are classified as:

- free vibrations – come without disturbance forces, as components in transitory process (regime) of machinery/equipment and they have short life. eg: entrance/exit of tool cutting in/from cutting layer, acceleration/deceleration of some mobile elements, reversing motion way;
- forced vibrations – come as a result of cinematic and/or dynamics factors and they are permanent during machinery/equipment operation with major consequences against their performance, against machinery, technological process and component machined quality.

The internal or external process forced vibrations simultaneously come and deploy, that lead to a complex vibration process and their consequences must be evaluated in every machinery/ equipments operation phases.

Moreover, self vibrations are important and they are caused by excitation factors generated by its own vibrations. For instance, these machine tools' factors are: interrelation between cutting force magnitude and relative displacement between cutting tool and material; relationship between sliding speed and friction force of cinematic couples (joints) and others. A self vibration particularly aspect is the possibility of increasing its magnitude with lead to jarring, so failure occurrence possibility.

It is used transducers, accelerometers, exciters and vibration pickoff depending on its apllication [3, 4]. Regardless of the approach, any vibration measure the existing vibration and translate this information into some electronic signal. Transducers can be permanently mounted or affixed to the monitoring location periodically. In addition, instruments are used to perform signal analysis as well. Some equipment is designed to perform this analysis in the field while other equipment designs may require the use of an external PC [11].

The vibration monitoring and analysis are used to discover and diagnose a wide variety of rotating mechanisms, assemblies and equipments.

The main accepted abnormal equipment conditions/faults where the predictive maintenance technology can be apllied are: unbalance, misalignement, eccentric problems, sleeve-bearing problems, gear or belt drive problems, mechanical free play, etc.

Thermography (SR 13340-1996) is a predictive maintenance technique that can be used to monitor the condition of plant machinery, structures and systems. Thermography is part of non-destructive examination thermal methods [6] and use instrumentation designed to monitor the emission of infrared energy (measurements, visualization). Thermography assures thermal abnormal detection, for instance, colder and hotter surfaces than normal, or various elements in motion such as centering guides, wedge slide, etc.

There are instruments used in thermography such as: Spot radiometer (Infrared thermometer) Infrared imager (IR camera), IR cameras. IR cameras have the capability to detect infrared emissions from an object and translate this information into a visible format. The image is analyzed and there are provided values for the tested surfaces.

These complex instruments have the capability to analyze the image and provide temperature value for the area of interest. This capability is useful in applications where a temperature value is important in defining a problem or condition.

Oil analysis also becomes an important predictive technology. The machinery technical documentation or users manual recommend that samples of machine lubricant to be taken at scheduled intervals of time to determine the condition of the lubricating film that is critical to machine operation (friction reduction, wearing, heating, or corrosive agents action decreasing).

The oil analysis tests are used to determine the condition of the lubricant, excessive wearing of oil-wetted parts, and the presence of contamination. Oil condition is most easily determined by measuring some of its properties [8] such as: mass, surfaces, rheology, thermal or chemical (viscosity, acid number, base number and color). Component wear can be determined by identifying the amount of wear metals such as iron, copper, chromium, aluminum, lead, tin, and nickel. Increases in specific wear metals can mean a particular part is wearing, or wear is taking place in a particular part (couple) of the machine. Particles in the oil can provide significant information about the condition of the rotation or translation couples. There are studied shape, composition, size and quantity of particles. The wearing particles can be identified by two methods: monitoring and trending of the solids content of machine lubricant (composition and size of the particle less than 10 μm), identifying wearing types according to the classification of the particles by analyzing lubricating oil sample: rubbing wear, cutting wear, rolling fatigue wear, combined rolling and sliding wear, fatigue wear, corrosion, etc.

Often, changes in specific gravity of oil lubricant mean that the fluid or lubricant has been contaminated with another type of oil or fuel.

There are used variety types of test equipment to evaluate the characteristics of lubricants such as: viscometers, spectrometers, oil analyzers, particle counters, and microscopes.

To exemplify some of the above aspects, there are presented a machine-tool (fig. 1) an an industrial robot (fig. 2). For them there are highlighted some possible perturbatory sources: vibrations, forces and variable speeds, temperature variations, functioning in transitory regime, usage of joints, lacks of balance. All of these sources may reduce the functional performances of mechanical, operating and command systems within the machines/equipments' structure. For the purpose of reducing the influence of the perturbatory sources and maintaining the prescribed exploitation period there are imposed the monitorisation/diagnosis of the dynamical and thermical behaviour.

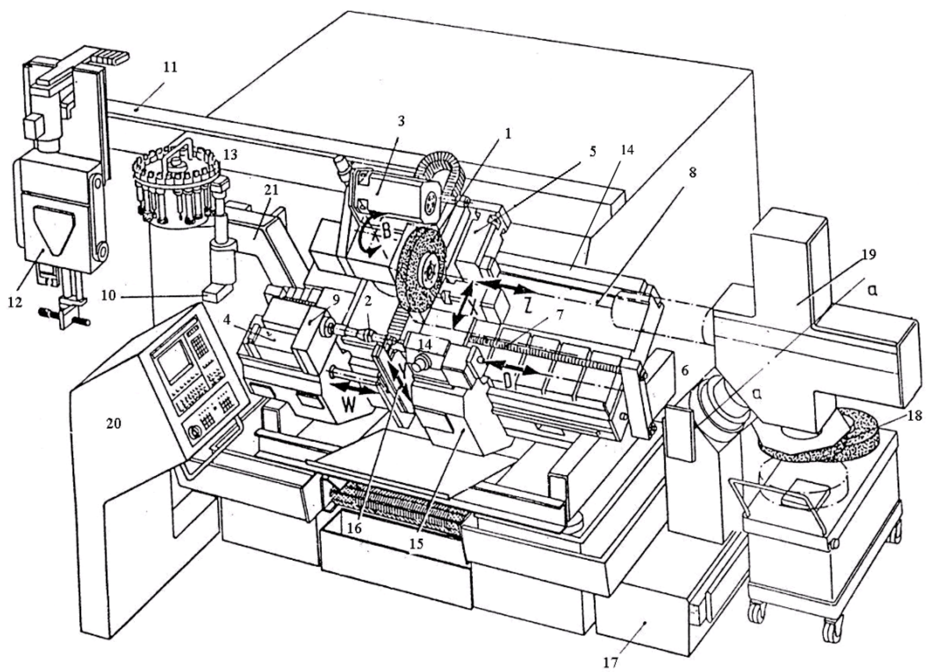

Fig. 1 Grinding machining centre:

1-*grinding wheel*, 2-*workpiece*, 3-*spindle motor*, 4-*work headstock*, 5-*servo drive*, 6-*servo drive*, 7-*ball screw*, 8-*main bed*, 9-*servo drive*, 10-*automatic tool changer*, 11-*fixed transversal guideway*, 12-*industrial robot*, 13-*tools magazine*, 14-*longitudinal guideways*, 15-*sledge*, 16-*measuring support*, 17-*support bed*, 18-*grinding wheel*, 19-*support for feeding arms*, 20-*CNC control equipment*, 21-*tools magazine support*.

The monitoring of lubricants is required for machine-tools and robots as a preventive method for rotation and translations joints (main drive shaft, guideways, hydrostatics or hydrodynamics guideways) that work at high speed and variable load.

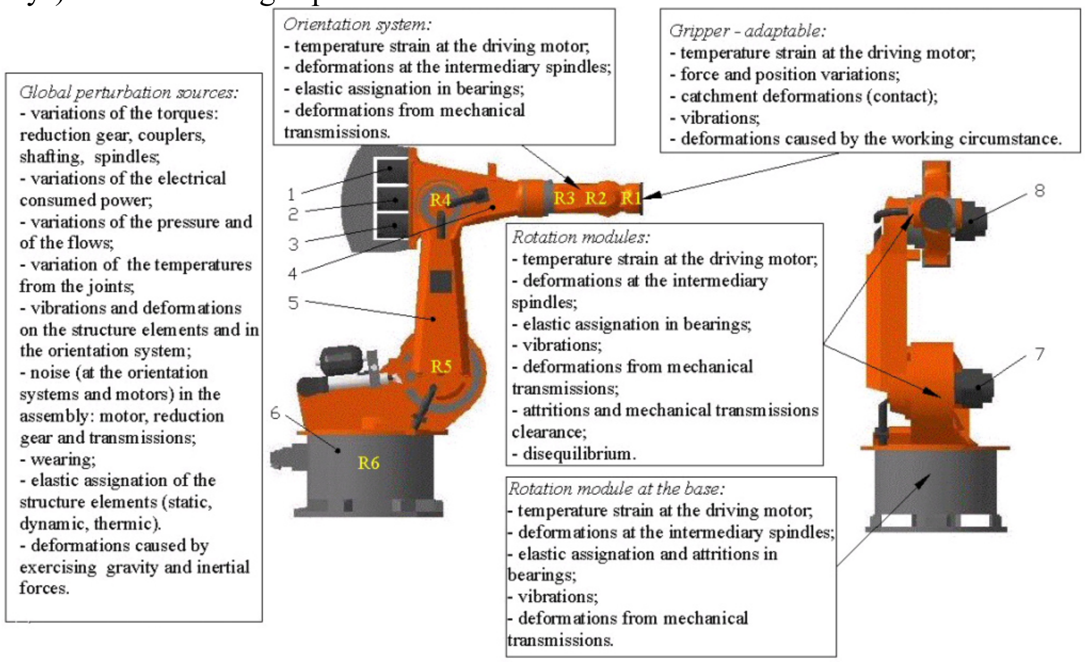

Fig. 2 Industrial Robot (*Kuka*)

1, 2, 3, 7, 8 - *driving motor*; 4, 5 - *robot's arm*; 6 - *robot's base*, R1, R2, R3 - *rotations modules for the orientation system*; R4 - *rotation for the arm 1*; R5 - *rotation for the arm 2*; R6 - *rotation module at the base.*

Ultrasonic analysis is applied as a predictive maintenance modern technology as well. It uses principles similar to vibration analysis. The noise generated by the machines, equipment or installation is analyzed to determine their condition. This technique monitors high frequencies (between 20000 Hz şi 100 kHz) generated by pressure/vacuum leak, mechanical machines and equipment (gearboxes), electrical installation. Ultrasonic analysis is one of the less complex and less expensive predictive maintenance technologies. The cost of the equipment is moderate and the amount of training is minimal when compared to other predictive maintenance technologies.

Many plants do not consider machine or systems efficiency as part of the maintenance responsibility. Machinery that is not operating within acceptable efficiency parameters severely limits the productivity of many plants. Therefore a comprehensive predictive maintenance program should include routine **monitoring of process parameters** [13].

Process parameters monitoring should include all machinery and systems in the plant process that can affect its production capacity. The systems that can be monitorized include pumps, filtration, heat exchangers, and other hydrostatic equipments. The inclusion of process parameters in the predictive maintenance can be done in two ways: manual or microprocessor-based systems. Both methods require installing measurement instrumentation to indicate the actual operating condition of monitored systems. The inclusion of process parameters in maintenance program require initial costs to calibrate existing instruments of the machines but unutilized (temperature, pressure, sound magnitude and flow measurements). The periodically **visual inspection** of the machinery/equipments and systems can be considered a predictive maintenance technology as well. By visual inspection can be detected abnormal operating condition before a serious deterioration occur and cannot be detected with the above maintenance technologies (oil leak, rifty, fissure, optic signal etc). Supplementary notice gathered by visual inspection can enhance predictive maintenance programs regardless of primary technique used.

3. CONCLUSIONS

The maintenance application in a company must give the confidence that all production equipments will be in a proper condition. The quick answer to breakdowns (reworks, adjustments, revisory, change components, etc) must be substitute with maintenance technologies to assure optimal operating condition for all production process systems.

Predictive maintenance must be an approach that use operating condition of a equipments/machinery and production systems of a plant to optimize its global operating. A management program of predictive maintenance must use modern equipments and devices and must offer information about current exploitation condition of all fabrication systems components. The decision concerning machinery prevention or reparation and significant cost reducing must be based on date from maintenance management program. Moreover, predictive maintenance aims to improving of product quality, increasing plant productivity and profitability.

Due to the increasing of transducers and sensors performance, monitoring and diagnostics methods and software, allows companies to execute maintenance activities depending on its own needs, of fabrication complexity and customers' necessities. This lead to multitude of methods with various objectives that are hardly statistic counted and determine application of a maintenance management.

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