USE OF THE THERMOVISION TO INCREASE SAFETY IN OPERATING OF THE MECHANICAL SYSTEMS

Assoc. Prof. Dr. Marin **NEACSA**, University POLITEHNICA of Bucharest,
neacsam@gmail.com,
Assoc. Prof. Dr. George **ADÎR,** University POLITEHNICA of Bucharest,
georgeadir@yahoo.com
Assoc. Prof. Dr. Victor **ADÎR,** University POLITEHNICA of Bucharest,
victoradir@yahoo.com
Eng. Ancuta **ADÎR,** Grigore Cerchez Technological College, Bucharest
adirancuta@yahoo.com

Abstract: *In this paper is presented the way we can use the thermovision in detecting of the degradation processes of the mobile mechanical systems. It is also presented a method for establishing of the profitableness in using thermovision to identify priority applications of this technology.*

Keywords: thermovision, temperature monitoring, reliability

1.ALTERATION OF THE THERMAL REGIME AND MALFUNCTIONS OF THE MECHANICAL SYSTEMS

In mechanical systems the energy is stocked as plastic deforming energy or heat. The motion of the mechanical systems with more degrees of mobility, can be studied by using Lagrange equations. It's written the Lagrange equation for each degree of mobility:

$$\frac{d}{dt}\left(\frac{\partial E}{\partial \dot{q}_k}\right)-\frac{\partial E}{\partial q_k}+\frac{\partial D}{\partial \dot{q}_k}+\frac{\partial V}{\partial q_k}=Q_k; \qquad (1)$$

where:

E - kinetic energy;

$k \in [1,n]$ - where n is the number of degrees of mobility (number of driving elements);

q_k - generalized coordinate k;

D - dissipation function of the system's energy, through friction to heat, wear or through plastic deformation or breaking etc.;

V - total potential energy (includes also the energy given by the forces of plastic deformation and of weight);

Q_k -generalized force applied to coordinate k

It results a system with n differential equations of order 2.

Transformation of the input mechanical energy in the mechanical system to kinetic or potential energy is reversible, but the dissipation of the system's energy through friction to heat, wear or through plastic deformation or breaking, is irreversible.

In case of the real loads, the effect of overloads interacts with the current loads; malfunction, degradation D, can be express by the following relation [2,5]:

$$D = \sum D_{supr} + \sum D_a + \sum D_{int} = 1 \qquad (2)$$

where:

D_{supr} – degradation caused by overloads;

D_s – degradation caused by loads with lower amplitude;

D_{supr} – degradation caused by the effect of the order of loads application, those with lower amplitude follow after the overloads.

Relative to the transformation of the input energy in the mechanical system to deformation energy, through oligocyclic fatigue, the breaking energy W_f, can be established [1, 5] with the relation:

$$W_f = \sum n_i \cdot \Delta W_i \,, \qquad (3)$$

where:

n_i – application cycles;

W_i – deformation energy, that represents the hysteresis loop of the *i* cycle.

Relative to the transformation of the input energy to heat, the alteration of the thermal regime is considered as a negative effect, very important of wear. The wear processes, that cause the alteration of the thermal regime, are:

a) Grip – consists in establishing and breaking of the micro-weldings (welding bridges) between the contact micro-surfaces, therefore the mechanical energy is transforming to thermal energy and the thermal regime is quite a little modified;

b) Abrasion – consists in wear caused by the hard particles existing between the contact surfaces or by the roughnesses of one of the contact surfaces; the deforming process that appears caused the alterantion of the thermal regime;

c) Surface's fatigue - consists in wear caused by the dynamic stresses of the surfaces in contact of ball bearing with sliding; it is encouraged the appearance of the rachetting process, a onedirectional process of cumulation of the deformations due to the mechanical stresses; this process appears in case of association of materials with big friction coefficient; continuous cumulation until reaching of a critical value ε_c, then the ductile properties of the material are exhausted and the crack is initialized. Establishing of the number of cycles necessary for degradation is made based on the oligocyclic fatigue mechanism [5]. In case of lubricated contacts, the lubricant enters in the cracks obtained due to fatigue of the surfaces in contact of ball bearing with sliding, is powerful pressed there and therefore the cracks are developed and they can join together in a bigger crack. These holes cause noise, dynamic loads and worsen the lubrication, causing alteration of the thermal regime.

d) Gripping – appears when the layers of lubricant have disappeared and it is now a direct contact between the layers in relative motion, under big loads. Due to these causes, appear micro-weldings between the surfaces that are sliding, of the flanks in contact, and

increase of the temperature, and then, because of the motion of gears, the micro-weldings break and appear again micro-weldings; This repeated process leads to the damage of the active surfaces, the thermal regime is very much modified and, finally, the joint is blocked because of the weldings that cannot be broken due to motion. If there are used for gears lubrication oils with inappropriate additives, the wear is increasing because of the corrosion caused by the chemical reactions, destructives, between additives and the gears materials. The most sensitive transmissions to gripping are those where the sliding between flanks are great: transmission screw worm – worm wheel, transmission with helical gears. For the transmissions with bevel and cylindrical gears gripping appears only at high speeds and for very big loads.

e) The fretting fatigue (fretting-wear) is defined as an oscilating motion of low amplitude between the surfaces in contact, in the range 2 – 50 μm, for metallic or non- metallic materials. This type of degradation is actually considered one of the most dangerous type of damage. The effect is the appearance of the surface pinches (pitting), craters, surface cracks, scratches, substrate cracks, material transfer, plastic deformations [3, 5]. Therefore, in this case also is caused the alteration of the thermal regime.

e) Tribochemical reaction – consists in achieving of some products of chemical reaction, because of the chemical interractions between the elements of a tribological system, due to a tribological action; any chemical reaction is neither endotherm nor exotherm and therefore modifies the thermal regime [7].

The environment can be a very powerful stress factor for damaging of the mechanical systems. Solar radiation and the environment temperature are between the main stress factors, that determine the importance of monitoring the environment temperature, to undertake preventive actions.

Heating of the kinematic elements involves the alteration of the resistance and thermal deformations, that generate alterations in pressure distribution in the kinematic joints, tribological, as well as plastic deformations, appearance and developing of malfunctions.

2.MEASURING SYSTEMS OF THE USEFUL TEMPERATURE IN MONITORING OF THE FAILURE PROCESSES OF THE MECHANICAL SYSTEMS

Thermovision [8] is a technique that, by using a camera / scanner, displays o map of the radiation intensity, in a field of the electromagnetic spectrum; it is used especially in the military applications or in civilian supervision. With the support of the thermographics cameras, can be detected kinematic problems of the kinematic joints, tribological (bearings, plain bearings), as well as for the active kinematic joints (thermal electrical engines, hydraulical or pneumatical).

Any body with temperature higher than 0^o Kelvin issues electromagnetic infrared radiation. The intensity of this radiation is varying depending on the object's temperature and his capacity to issue energy. For thermovision (thermography) is interesting only the field between 0,8μm and 15μm 2 – 3 subdomains The producers distinguish 2 or 3 subdomains:

- Short waves (SW - ShortWaves) or Near Infrared (NIR – NearInfrared) 0,8 ... 1,5μm
- Medium waves (MW - MidWaves) 2 ... 5μm
- Long waves (LW – LongWaves) 7 ... 15μm

Transmission depends on the distance between the scanned object and the infrared camera and the carbon dioxide and water vapors from the atmosphere , environment.

An infrared thermal camera, converts the infrared radiation, invisible for the eye, into visible image, through the detector of type sensors area (FPA), thermoelectrical cooled. The optical system have to ensure a very good transmition of the radiation, is achieved by a system of lenses, made by germanium or silicon.

The solution adopted by the „Low Cost manufacturers" is a small lens. As regards the energy captured by the infrared camera, only 20 % is from the scanned object and the rest from the internal elements of the camera or from other objects from the environment, reflections etc. A professional equipment establishes and eliminates a part from this „parasite"radiation; a variation of 1°C on the surface of the measured object is translated into a variation of 0,001°C at the detector level.

Measuring of the real temperature requires compensation of the apparent temperature through adjustment by the operator, issuing, reflected temperature, factors of atmospherical influence etc; the uncorrect adjustment can lead to errors in measuring, greater than 100%, as well as measuring of temperature by using thermometers without contact (pirometres).

3.CONCLUSIONS

Thermography allows to obtain centralized information concerning alteration of the thermal regime of the kinematic elements, kinematic joints, tribological, so it can be efficiently applied the useful error theory [6], to increase precision in estimating of the reliability parameters, in a better prediction for the safety of the mechanical systems.

REFERENCES

1) **Bui-Qouc, T.**, *Cyclic stress strain and energy variation under cumulative damage tests in low-cycle fatigue*, Journal of Testing and Evaluation, ASTM (American Society for Testing and Materials), 1(1), p. 56-64, 1973
2) **DuQuesnay, D.L.,** *Fatigue damage accumulation in metals subject t high mean stress and overland cycles*, Ph. D. Dissertation, University of Waterloo, Waterloo, ON. Canada, 1991
3) **Hoepner, D.,W.,** *Freeting Fatigue liffe Prediction: Past, Present and Future*, Keynote paper, Third Internationa Symposium on Freeting Fatigue, Nagoaka, Japan, 2001
4) *Normativ privind proiectarea clădirilor civile din punct de vedere al cerinţei de siguranţă în exploatare*, indicativ NP 06802
5) **Palaghian, L.,** *Siguranţă durabilitate şi fiabilitate la oboseală*, Editura Tehnică, Bucureşti, 2007
6) **Popper K.,** *The Logic of Scientific Discovery*, Routledge Classics, London and New York, 2002
7) **Tudor, A., Prodan, G., Muntean, C., Moţoiu, R.,** *Durabilitatea şi fiabilitatea transmisiilor mecanice*, Editura Tehnică, Bucureşti, 1988.
8) http://www.termoviziune.ro/ro/Tehnologia-IR/