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PIEZOELECTRIC TRANSDUCERS IN SYSTEM OF TOOLS

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ABSTRACT
During machine tools operating (MT), the vibration represents destructive secondary results of the forces which are generated by the wear and the injury of the machine elements or of the chipping tools (CT).
If these latter MT components are supervised, the elimination of the useless tools changing, the accuracy providing when operating, the recognition of some undesirable short time chipping working runs and the elimination of dead intervals can be performed.
Generally, the transducers used in (CT) supervising are of piezoelectric type, one for each axis of three-dimensional system in the audio range and a fourth one installed on axis Z for measuring the "acoustic emission" (AE) in range 20…150 KHz, caused by the shear and plastic deformation of the material; the friction between the tool and the piece, respectively the variable contact surface. The resulting acoustic emission can be permanent or intermittent.
Keywords: Transducer, acoustic emissions, shocks, amplifier, piezoelectric.

1. MATHEMATICAL MODEL OF THE ACOUSTIC AMISSION

If the signal a(t) coming from the transducers (AE) has a variation depending on time, the ΔE energy variation corresponding to a time interval Δt results as follows:

$$\Delta E = kA^2 \Delta T \tag{1}$$

where k is proportionality constant and A is the effective value of the signal a(t). The signal E power corresponding to the time interval Δt is considered the main indicator of the wear level of the tool, expressed by the relationship:

$$E = \frac{\Delta E}{\Delta T} = kA^2 \tag{2}$$

This relationship emphasizes that the power is proportional to the square of the EA signal effective value. Its value is depending on the tool geometrical parameters and on chipping speeds, which are also depending on the tool wear, as follows:

$$A = C\left[\tau b_1 U\left(\frac{\cos\alpha}{\sin\Phi\cos(\Phi-\alpha)}t_1 + \frac{1}{3}(l+2l_1)\frac{\sin\Phi}{\cos(\Phi-\alpha)}\right)\right]^{1/2} \tag{3}$$

where c is proportionality constant, τ - shearing tension; l, l_1, b_1, the tool relative length, respectively the knife width, the other parameters being defined in Fig. no.1.

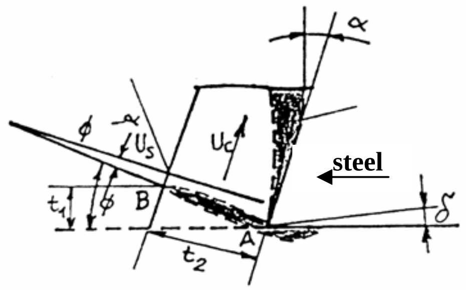

Figure 1.
α – assemble angle; δ – chipping angle; Ø – shearing angle; U – cutting speed; U_c *– chipping speed;* U_s *– shearing speed;* t_1 *– height of the knife;* t_2 *– thick of the knife.*

2. TRANSDUCERS FOR MEASURING ACOUSTIC EMISSION

Taking account of the EA signal frequency range, it results that the increasing and decreasing time have very little durations; at the same time the microscopic breaking from the tool, structure, determine acceleration impulses of high value and big lope. Consequently, the transducers used in this application are framed in the category of those which are used in shocks monitoring.
The acceleration impulses may be approximated, according to the I.E.C. recommendations [2] with the situations presented in Fig. 2.

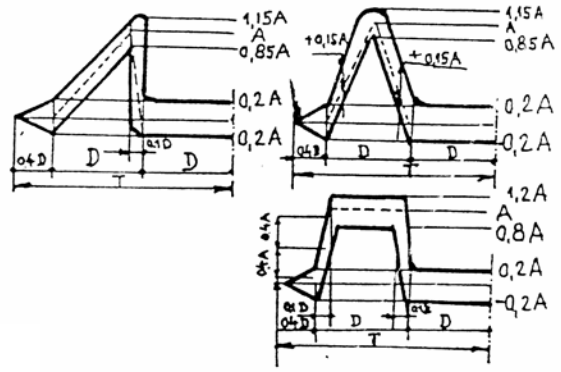

Figure 2.
T – impulse monitoring minimum time; D – nominal period; A – pick acceleration
- - - - nominal pulse; --- - range of allowance.

A measuring system of the shocks acceleration includes acceleration transducers, a voltage or load amplifier and an element (a device) for memorizing and post of the measured variable.
From the types analysis of the transducers used in the shocks acceleration measuring it comes out that the piezoelectric transducer of special construction in order to cove the extended measuring range (constructively, the seismic mass has low value), represents the optimum variant. The characteristics of the piezoelectric transducers for shocks, produced by the firms: EN DEVCO, BRUEL&KJAER and BOSCH, are presented in the next table no.1.
The use of piezoelectric transducers for shocks measuring creates problems because important errors may appear: for example, the "zero displacement" error and the ringing error [2]. The zero displacement error appears owning to the unliniarities generated by the low frequency components of the real signal in the amplifier.
These distortions influence the pick value of the signal. The working frequency of the amplifier must be lower then 0.08/T in order to maintain the errors in acceptable limits, T being the shock period.
The errors become significant if the acceleration impulse is integrated in order to obtain the displacement or the speed. The zero displacement can be produced by the transducer too when

applying some shocks of very high level, owning to the fact that not all the load stored on the crystal is sent for measuring.
The "ringing" error appears in the proximity of the mechanical resonance of the transducer. The mechanical resonance frequency "f" is imposed to be lower than 10/T, where T represents the period of the measured signal. At the same time, a preamplifier with low-pass filter at the input can be used [2].

Table 1.

Firm	Model	Sensibility [pF/g]	Capacity [pF]	Frequency range [Hz]	Resonant range [Hz]	Measurement range [g]
ENDEVCO	225	0.7	800	5…15.000	80.000	0…20.000
ENDEVCO	2291	0.0035	11.5	20…50.000	250.000	0…100.000
ENDEVCO	2292	0.14	80	20…20.000	125.000	0…20.000
B&K	8309	0.04	90	1…54.000	180.000	1…60.000
BOSCH	0261231	0.15	800	1000…2000	130.000	0.1…400

3. THE SYSTEM OF THE SIGNAL PROCESSING
The output of the piezoelectric transducers is processed according to Fig. 3.

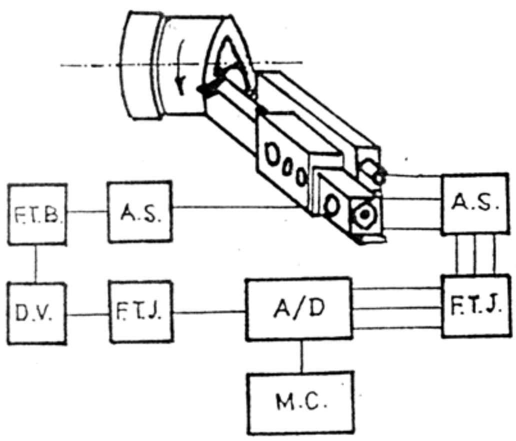

Figure 3.
L.A. – load amplifier; L.P.F. – low pass filter; B.P.F. – band pass filter; P.D. – pick detector; A/D – converter A/D; M.C. – microcomputer.

The corresponding transducer EA is preceded by the load, a band pass filter in range 20 – 150 KHz, a pick detector and a low pass filter. The subsequent processing on a computer, after the A/D conversion, takes into account the mathematical model presented and the using strategy of the tool. The output signals of the vibration transducer, placed on 3 axis, are processed through the load amplifiers, modeled as in Fig. 4 by means of the voltage supply V_i series with the capacitor C_o [3].

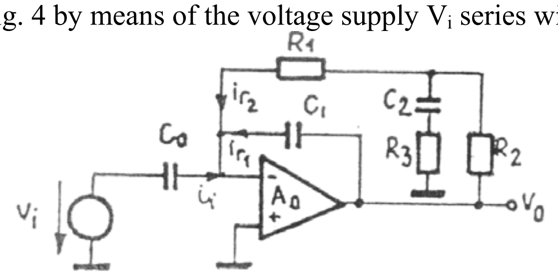

Figure 4.

The current at the reversing input of the operational amplifier AO is:

$$i_i = \frac{dq_i}{dt} = \frac{dv_i}{dt} C_o \tag{4}$$

The modeling provides the treatment of the load amplifier as a voltage amplifier, making easier the amplification calculus. The reversing input of the amplifier being virtually ground connected, results:

$$i_i + i_{r1} + i_{r2} = 0 \tag{5}$$

and

$$i_{r1}(s) = v_0(s) s C_1 \tag{6}$$

respectively

$$i_{r2} = v_0(s) \frac{1}{R_1 + R_2} \cdot \frac{1 + sC_2R_3}{1 + sC_2\left(\frac{R_1R_2}{R_1 + R_2} + R_3\right)} \tag{7}$$

If we consider $i_{r2} << i_{r1}$, the amplification on voltage is:

$$A = \frac{v_0}{v_i} = \frac{C_0}{C_1} \tag{8}$$

The limitation of the answer for high frequency appears owning to the amplification decrease and for low frequency owning to the second feed-back path (i_{r2}) for the closing of the i_B D.C. current circuit.
The use of A.O. with input on FET and polarization current of 10^{-11} A provides the achievement of the proposed objectives. The obtaining of an answer without overgrowth requires the complete transfer function study.
The signals resulted at the load amplifiers output are processed by means of a low pass filter following then by the A/D conversion and the processing on the computer. From the EA point of view, these are used as discrimination elements between the tool wear and the injuring of the machine tool.

4. CONCLUSIONS

From all above presented and carry on experiments according to the paper, is resulting the importance that must be given to the frequency answer of the transducer-amplifier system. Consequently, the use of a voltage amplifier is inadequate according to the piezoelectric transducer at low frequency, the measurement being affected by capacitance of the connection cable between the transducer and the amplifier.

5. REFERENCES

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