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ACCELEROMETER PARAMETERS DECOMPOSITION MODEL FOR TECHNOLOGICAL PROCESS DESIGN AUTOMATION

Запропоновано нову узагальнену модель акселерометра та графа ідентифікації вихідних параметрів для виконання завдання з автоматизації проектування технологічних процесів.

Ключові слова: автоматизація, технологічний процес, акселерометр, мікроелектромеханічні системи

The paper proposes a new generalized accelerometer model and input parameters identification graph for solving technological processes design automation problem.

Key words: automation, technological process, accelerometer, microelectromechanical systems

Introduction

Microelectromechanical systems (MEMS) production analysis showed that over 90% of the market are occupied accelerometers. They are used both in the automotive, aviation, military and domestic demands. The largest manufacturers of accelerometers are PCB Piezotronics, Analog Devices and STMicroelectronics.s. After existing accelerometers and computer-aided design (CAD) analysis showed that these systems cover only some stages of technological processes (TP), and the existing models do not allow to automate the design from the beginning to the end of the TP because they do not take into account all steps in including phase separation of crystals, sealing, insulation, electrical connectors packaging stage, which are an integral part of the TP. As a result, the task of accelerometers new models developing of that will describe all the physical, geometric and design parameters required to develop new and improve existing accelerometers is urgent.

Generalized accelerometer model for solving technological processes design automation problem

After existing different manufacturers' accelerometers were analyzed, we found accelerometer parameters that impact directly on the technological process design, and contain the initial characteristics that affect the use of accelerometers in various fields.

In this research, an accelerometer is presented in the form of a generalized model in next way::

$$M'_a = \left\{ P_e, \varepsilon_n, E_p, P_{hx}, T_C, A_p \right\}, \tag{1}$$

where P_e – operating characteristics; to device operating characteristics assign next: sensitivity (S_{x_i}) [2], measurement range (R_m) [3], frequency range (R_{y_i}), broadband resolution (f_R), resonant frequency (R_{eb}), non-linearity (nL), transverse sensitivity (S_t), damping ratio (D_R); ε_n – control parameters; accelerometer control parameters: overload limit (shock) (L_{sh}), temperature range (T_R), temperature coefficient of sensitivity (T_{kf}), zero offset temperature coefficient (T_Z), base strain sensitivity (S_s), magnetic sensitivity (S_m) and electrical parameters (E_p); P_{hx} – physical parameters, such as frame parameters (H_χ), sealing (S_I), electrical connector type (C_T), mounting (M_{Th}) and environment climatic factors (F_c) [4]; S_{EL} – sensing element material; based on an analysis of various manufacturers technical documents, sensing element material parameter has the following components: ceramics (Ce), quartz (Qu), silica (Sl); S_G – load sensor method [5]; describes the nature of the influence of physical effects on the accelerometer sensor. There are three load crystal method, that allow to generate an electrical signal: shear (Sh), compression (Com), flexura (Fl); ST – sensor design depending on physical impact; sensor parameters has 3 components: piezoelectric accelerometer (ω), piezoresistive accelerometer (θ), capacitive accelerometer (φ); S_Z – dimensions, mm; dimensions frame for accelerometers that are part of the device are described by standards, dimensions accelerometer, which are separate devices, depend on the size of the sensor, the frame size, isolation area and the area occupied by mounting and are described by their relationship; W – weight, g; accelerometers' weight may be different and depends on many factors, such as frame material and mounting method that depend on operating conditions; the presence or absence of isolation; sensor, depending on the type and purpose of obtaining required performance; parameter is a system; T_C – mechanism design type, that share depending on the measurement of acceleration along the axes: single axis (α_{o}), biaxial axis (α_{t}), triaxial axis (α_{th}); A_p – accelerometer value type: widespread use (W_a) and special purpose (P_S).

Input parameters identification graph for solving technological processes design automation problem

Based on the proposed accelerometer generalized model, let's develop graphs that will simplify the process of identifying accelerometers for building TP. These graphs will clearly display the relationship between the parameters of the model and facilitate the processing of information at each stage of TP design automation.

Many accelerometer output parameters affect the technological process. Let's divide graphs in terms of accelerometers purpose (A_p). There are tree type subgraphs for each accelerometer values type for wide application ($A_p = \{W_a\}$) and special purpose ($A_p = \{P_S\}$).These graphs show the parameters relationship such as sensitivity (S_{x_i}), measurement range (R_m), frequency range (R_{y_i}), resonant frequency (R_{eb}), non-linearity (nL), transverse sensitivity (S_t), damping ratio (D_R), overload limit (shock) (L_{sh}), temperature range (T_R), sensing element material (S_{EL}), load sensor method (S_G),sensor design depending on physical impact (ST),mechanism design type (T_C).

Depending on the output parameters let's represent the graph since accelerometer appointment and parameters names.

Figure 1 shows a fragment of graph for widespread use accelerometers of general purpose subgroups – $W_a = \{UT\}$.

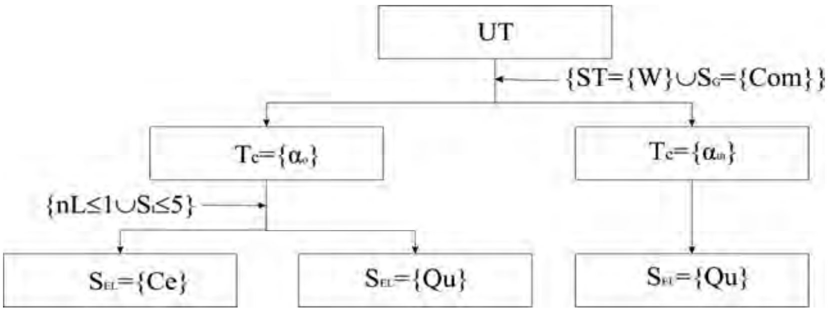

Fig. 1. Fragment of graph for widespread use accelerometers of general purpose subgroups

Let's isolate the general parameters for the accelerometers group on the following criteria: design sensor depending on the physical influence (piezoelectric accelerometers) and load sensing element method (compression) – $\{\text{ST}=\{\text{W}\} \cup \text{SG}=\{\text{Sh}\}\}$.

Parameters generalization allows you to split the graph of the accelerometer mechanism the design for the group, which is represented in the form of single-component and three-component accelerometers, respectively – $\text{T}_\text{C}=\{\alpha_0\}$ i $\text{T}_\text{C}=\{\alpha_{th}\}$.

One-component and three-component accelerometers have different materials of sensor: ceramics ($\text{S}_\text{EL}=\{Ce\}$) and quartz ($\text{S}_\text{EL}=\{\text{Qu}\}$) for a one-component group and only quartz for three-component group. Let's select general parameters for one-component accelerometers, such as non-linearity ($\text{n}L \le 1$) and transverse sensitivity ($S_t \le 5$).

Each group of sensing element materials is divided into elements such as sensitivity (S_{x_i}), measurement range (R_m), frequency range (R_{y_i}), overload limit (shock) ($|L_{sh}|$) and temperature range (T_R). Figures 2–4 show relevant graphs.

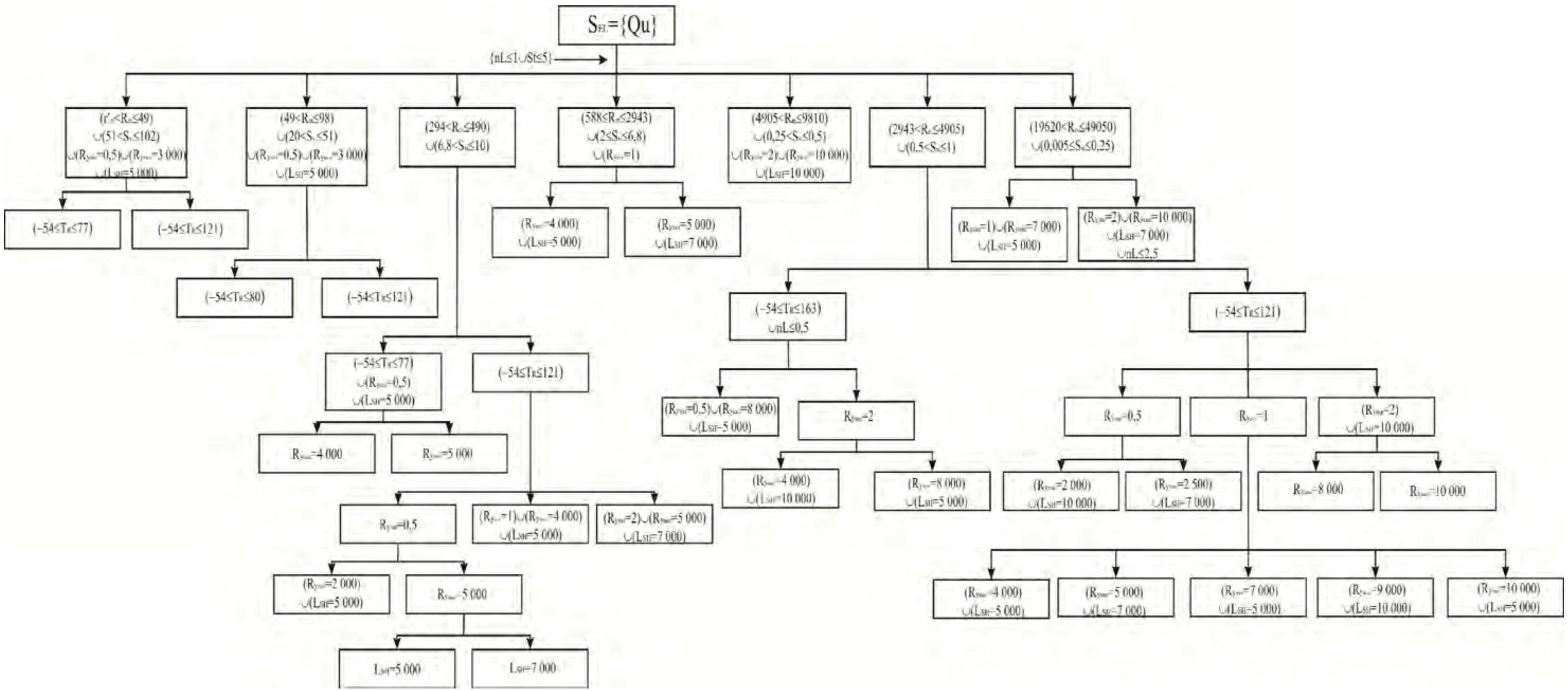

Fig. 2. Accelerometers graph fragment, general purpose subgroup, 3-axis accelerometer sensor with the material – quartz

With the help of the same principle 16 another graphs are constructed for widespread use and special purpose accelerometers groups in terms of initial parameters.

However, these graphs do not include packaging but it's very important and costly TP stage. As a result, it is necessary to develop separate graphs for packaging stage that will display the type of relationship between the type, the material, the electrical connector location, form factor and mounting type.

Fragment graph subgroups of general purpose accelerometers, tryosovyy accelerometer sensor with the material – quartz.

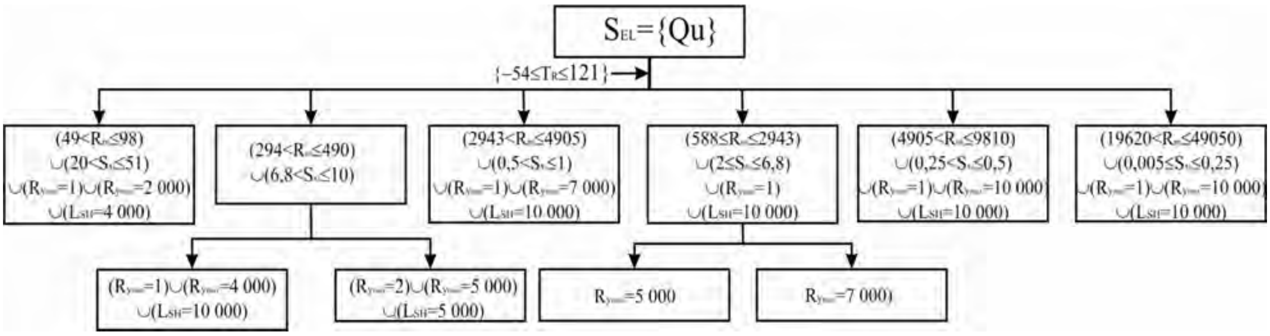

Fig. 3. Accelerometers graph fragment, general purpose subgroup, with uniaxial accelerometer sensor with the material – quartz

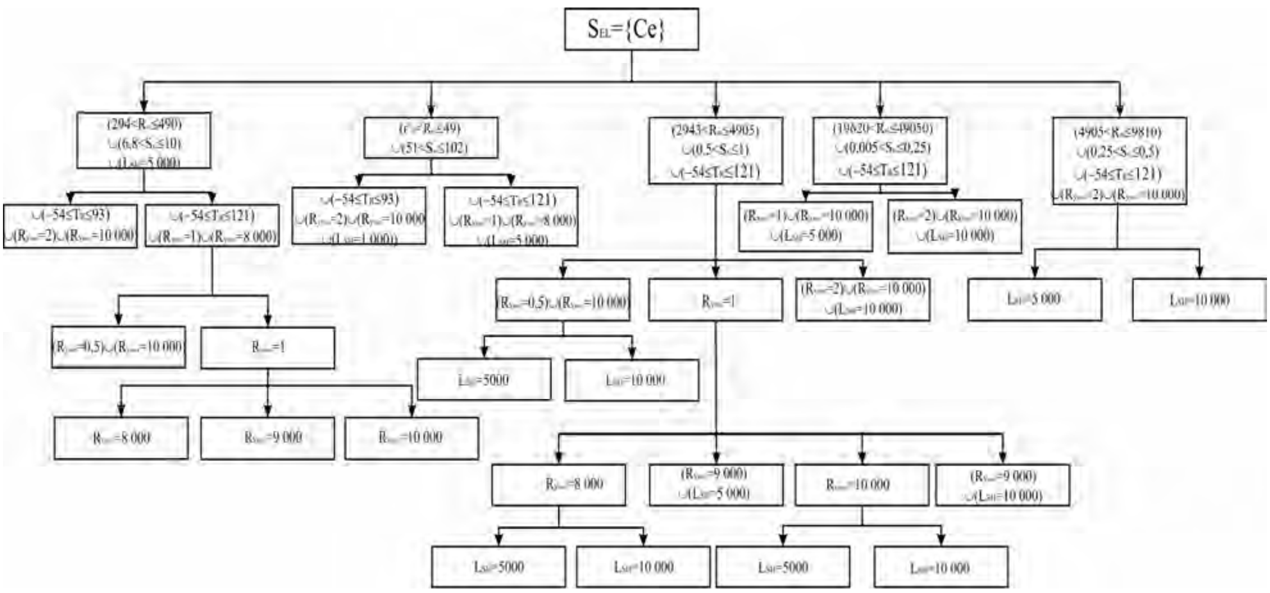

Fig. 4. Accelerometers graph fragment, general purpose subgroup, with uniaxial accelerometer sensor with the material – ceramics

In accelerometers package material research manufactured by PCB Piezotronics, Analog Devices and STMicroelectronics in an amount of 237 pieces revealed the following:

– for widespread use accelerometers: in 85,1 % cases used material is titanium, in 6,8 % cases – aluminum, in 6,8 % cases – stainless steel, in 1,9 % cases – inconel; more than 162 such accelerometers were analyzed;

– for special purpose accelerometers: in 89,4 % cases used material is stainless steel, in 5,3 % cases – improved stainless steel (316L), in 4 % cases – inconel, in 1,3 % cases – titanium; more than 75 such accelerometers were analyzed.

Conclusions

Analysis of modern MEMS computer-aided design systems showed that in most cases these systems will allow to automate only certain tasks and will not be able to be applied in terms of new accelerometers types developing. It should be noted that existing approaches to the accelerometers development allow to evaluate output parameters only after a prototype release, resulting in increased cost and do not give a complete guarantee of obtaining accelerometer with given parameters. Therefore, in this research basic parameters accelerometer decomposition model that take into account all the necessary factors is proposed to automate design processes. This model will take into account both the physical parameters and packaging settings and operating conditions. Based on the proposed model accessories graph was developed it will allow to automate the design process accelerometers production method "from bottom to top." This will allow to develop a software module, with the ability to integrate it into modern CAD and reduce the complexity of TP design that will reduce research costs by eliminating accelerometers production total TP prototyping phase.

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