



Application of TRIZ approach to machine vibration condition monitoring problems

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ABSTRACT

Up to now machine condition monitoring has not been seriously approached by TRIZ¹ users, and the knowledge of TRIZ methodology has not been applied there intensively. However, there are some introductory papers of present author posted on Diagnostic Congress in Cracow (Cempel, in press [11]), and Diagnostyka Journal as well. But it seems to be further need to make such approach from different sides in order to see, if some new knowledge and technology will emerge. In doing this we need at first to define the ideal final result (IFR) of our innovation problem. As a next we need a set of parameters to describe the problems of system condition monitoring (CM) in terms of TRIZ language and set of inventive principles possible to apply, on the way to IFR. This means we should present the machine CM problem by means of contradiction and contradiction matrix. When specifying the problem parameters and inventive principles, one should use analogy and metaphorical thinking, which by definition is not exact but fuzzy, and leads sometimes to unexpected results and outcomes. The paper undertakes this important problem again and brings some new insight into system and machine CM problems. This may mean for example the minimal dimensionality of TRIZ engineering parameter set for the description of machine CM problems, and the set of most useful inventive principles applied to given engineering parameter and contradictions of TRIZ.

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1. Introduction

During the machine operation (*life*) its condition deteriorates, what can be observed as evolving faults typical to a given machine type. Condition monitoring of machines (*systems*) is the science and technology for the assessment of condition by means of observation of machine phenomenal field – mostly vibration, where symptom of condition can be captured and measured (*see for example* [1]). This means that we are trying to determine the fault space of the machine, its dimensionality and fault advancement, by some observed symptoms of condition, creating in this way our observation space. The fault space of a system (*machine*) can be assumed by some prior knowledge taken from the experience with the other running machines, and the same concerns with symptom observation space.

Fault space of every machine is multidimensional, for example we have unbalance, misalignment, bearing faults. The similar multidimensionality is needed in our observation space, and as usually it needs some redundancy too. This is because the symptoms which we measure are usually interdependent, and by means of some symptom processing procedures we can determine the dimensionality of observation space and so-called generalized fault symptoms (*see for example* [5,12]). These results enable us to infer on the machine fault space and intensity (*advancement*) of the main faults which evolve during the machine operation in its lifetime θ .

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¹ TRIZ = Russian acronym for Inventive Problem Solving System, created by G. Altshuller ca 50 years ago.

Condition monitoring is mostly applied to critical machinery, where by special monitoring system we can observe thermo and vibroacoustical phenomena carrying needed information on system condition. This means that by some measurements of these phenomena and respective signal processing we can create symptom of condition, like for example the velocity vibration amplitude measured at the bearing pedestal, or some other location of machine casing. What is important here that by means of special signal and symptom processing procedures, one can determine the type of fault, and its advancement. We can calculate also the symptom limit value S_l and symptom reliability $R(S)$, which is analogous to lifetime reliability $R(t)$ of the machine [2].

In summary one can say, that having some experience on machine life and running, and a prior knowledge concerning processing of received signals and measured symptoms of condition, we can assess the current machine condition and make forecasting of future condition with relevant probability of success. This concerns also the fault type and a date of stopping machine for the renewal, etc. But up to now machine condition monitoring has not been approached seriously by TRIZ practitioners, and the knowledge of TRIZ methodology has not been applied there frequently. Some introductory thinking to connect TRIZ with VCM problems has been already made [9,11,14]. And this paper as a prolongation of previous deals mainly with a set of contradictions and extended contradiction matrix. Such is the main purpose of the paper.

2. A brief characteristics of TRIZ

As it was already mentioned in a footnote, the idea of TRIZ was elaborated by Russian Navy officer G. Altshuller at the end of World War II, expanded later on by his coworkers. Its English functional name is Theory of Inventive Problem Solving – TIPS. This is the first algorithmic inventive system which allows defining the ideal final result – IFR of a problem, and to find in the inventive space a real workable – solution, which is close to IFR. In essence TRIZ is a philosophy, and a complete method with a collection of tools. A Chinese proverb says that ‘one picture is more than a thousand of words’, so below one can find a mindmap [16] of TRIZ structure and the graph outline of its approach. This particular mindmap was published first in *Diagnostyka Journal* [7] and extended later on in my last book *Creativity Engineering* (Cempel, [15]).

One can see from the bottom part of Fig. 1 that the important activity of TRIZ is discovering contradictions, which are immanent in every innovative problem, and a gradual solution of them. This is why the main problem of this paper concerns with contradictions and contradiction matrix what one can find solving the problems of vibration condition monitoring of machines.

3. The ideal final result in diagnostics of machinery

This type of thinking, looking explicit for ideal final result (IFR) coming from TRIZ philosophy and methodology is new in machine condition monitoring (MCM). Hence let us imagine, what we really need here? Self repairing machine, like in military aircrafts, it seems to be too early. But if we integrate advanced symptom CM system with the machine and with proper signal and symptom processing, our resultant IFR can be as follows.

The machine itself is signaling approaching breakdown, a type of fault, and the time, when it should be stopped for renewal

In order to get this one can imagine that integrated CM system should contain: thermal, acoustic, and vibration transducers with signal preprocessing, to form several symptoms of condition $S_i(t)$, $n=1,2,\dots,n$. In this way multidimensional machine observation space is created, which is monitored continuously, and symptom readings are taken with the proper lifetime distance Δt_j , depending on the machine type and the wearing intensity [2]. These successive symptom readings by VCM system, are forming so-called symptom observation matrix (SOM); with columns presenting different types of monitored symptoms² and rows giving the values of discrete symptoms readings at t_j , $j=1,\dots,m$. This rectangular matrix, with the growing number of rows during the machine life, is the only source of information concerning the overall condition of the machine. One can extract this information by applying singular value decomposition (SVD) [4], or principal component analysis (PCA) [3]. The special processing of SOM can give also symptom limit value S_l which may control the stopping of the machine, and also symptom reliability $R(S)$ which assesses the potency of residual running or functional ability of the machine [2].

Knowing this one can say that by proper SOM processing method, SVD for example, we are projecting the observation space in a fault space of the machine. In this way we are gathering wanted information concerning fault evolution, their types and the advancement.

As many symptoms of condition depend on the current machine load and speed controlled by production process, special processing of SOM should be elaborated and taken into account [6,12], which gives the results being almost immune against the load variability and other disturbances as well.

When these precaution and preparations are successfully applied into the processing of signals, processing of symptom readings in SOM, the defined above IFR of TRIZ seems to be under the reach of contemporary technology of MCM and signal/

² From one broadband vibration signal, received at some location of the machine body, several symptoms of condition can be created and measured during machine life.

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