ASPECTS REGARDING PRODUCT LIFECYCLE MANAGEMENT OF MODELING FUNCTIONS OF AN INTELLIGENT DRILL TOOL

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Abstract: This paper presents the main stages of a product lifecycle management concept applied for an intelligent cutting tool, more precisely a drill tool. We propose a new approach for finding optimal and efficient solutions to implement the most required functions of drilling tools and also choose the optimal variant for modeling functions of intelligent cutting tools.
Keywords: PLM, lifecycle, drill tool, function, requirement, models, optimal solution, TRIZ, creative design.

1 INTRODUCTION

Product Lifecycle Management (PLM) is the process of managing the whole life cycle of a product starting from generating an idea, concept description, business analyzes, product design and solution architecture and technical implementation and fabrication, to the successful entrance to the market, service, maintenance and product improvement. In the same time, we the concept stands as a set of optimal solutions that support making, managing, disseminating and using the information of products. This approach helps us to integrate all the available product related information into a bigger system which also includes processes and resources necessary for designing and creating the desired product.

The integration of information, such as data and process models, through an adequate database is the main basis of the PLM concept.

The main reason for which the PLM concept is largely applied in the field of cutting tools is the need for reducing the time between determining the need for the product and its release on the market. Also, after applying the PLM concept we obtain improved flow of information, reduced costs for production, and detailed records of the impact of the product not only on the market but also on the environment.

Also a good goal for using this concept in cutting tools area is the need of choosing the optimal solution from various points of view such as superior functioning, agile fabrication, reliability and recyclability.

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PLM is a general concept first appeared in the aircraft and automotive industry. Due to the positive effects that it had, it was implemented in all other industries.

Cutting tools have an important role due to their worldwide spread in material processing and thus they need to be improved regularly, which requires a detailed analysis of their whole life cycle.

One of the most important and widely used operations for material processing of the cutting process is drilling. The increasing needs for better productivity and reduced costs implies designing and creation of customable tools. This leads us to using new and modern concepts for designing innovative and customable tools.

In this paper we use new concepts, such as PLM, and with the help of creative methods for analyzing functions and needs we exemplify the analysis on drilling tools and validate the results. We also aim to find the best solution to implement the most required functions for an intelligent drilling tool by modeling the most important functions with help from creative methods and techniques.

2 PRESENTING THE LIFE CYCLE OF CUTTING TOOLS

2.1 Steps in PLM

PLM requires a sequence of steps which are presented in figure 1.

Figure 1. Product lifecycle management

Although at first glance this concept seems relatively simple, it is in reality much more complex. Integrated Engineering is based on the support of the organization and it is very much facilitated by each member who must be aware of the role it has in the entire process. PLM can be applied in all three stages of manufacturing process as we can see in figure 2.

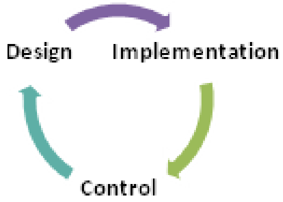

Figure 2. Manufacturing process stages

To illustrate this system better, we present the life cycle model of helical drills, emphasizing the stage of functional analysis of the product. As we stated as the aim of this paper we conceived the schematic PLM of an intelligent drill tool.

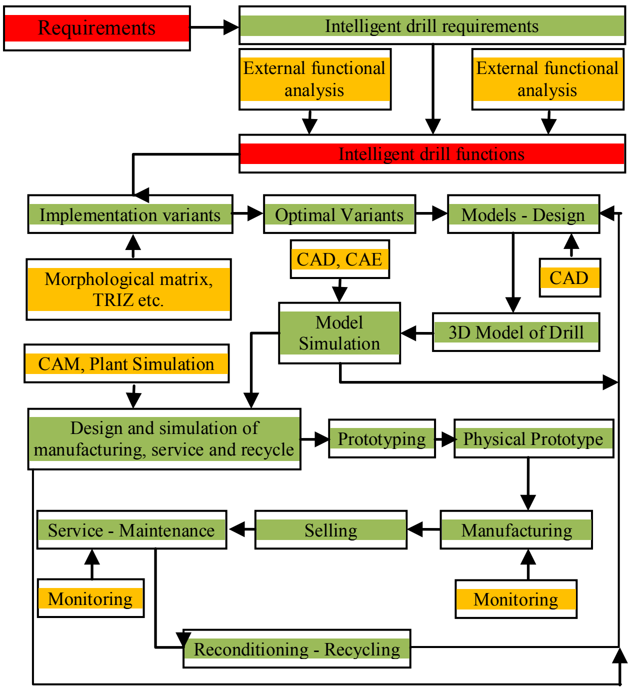

Figure 3. Product Lifecycle Management of a Drill

2.2 Defining needs

We consider two types of orders: generalized drilling tools and intelligent drilling tools so we made a detailed analysis of how implementation of functions can be realized with general use drilling tools. In the other case the client specify its needs and the function analysis is completely based on its requirements and not on a detailed study of the market. A market study identifies all the needs for the generalized drilling tool and it is done based on surveys so that the design team can try to find the appropriate solution to satisfy all the needs if possible. An efficient and objective way to run a survey is to identify the target of the intended research so they can generate output data of the survey and the input data for our research.

Following this aim we conducted a survey on the target sources which we identified and exemplified in figure 4.

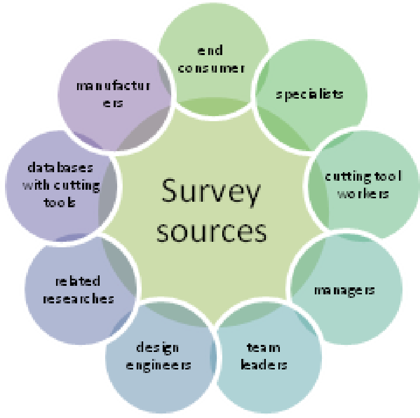

Figure 4. Sources for applying survey to identify needs

The survey consisted in a set of questions based on the 9 questions used to define the research problem and most important our goal was to interpret the answers from the most appropriate questions for our research aim.

In this case we tried to find out what the target persons need from the tool they are working with, why do they need it, where and when they need it and how much does it cost to get it.

Based on these basic questions we tried to find out from various sources their point of view on how the tool should work to have better durability, faster reconditioning, how to obtain more quality for the resulted surfaces, time and cost related savings for machining and real time communication not only with the tool but also with the whole system.

After finishing the survey and all the answer were collected.

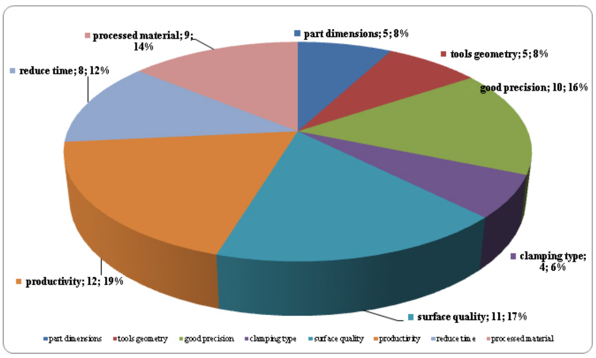

Figure 5. Needs percentage based on collected answers

The collected answers were interpreted to match the aim of the survey so we acknowledge the input data for our research and identify the real needs on the continuous and dynamic market of intelligent cutting tools. Based on the interpretation of the answers of the survey we have to rank them in order of their importance for the targeted groups.

In conclusion Ni needs arise.

$$N_1 i = (█(N_1 1@N_1 2)¦█(\ldots@\ldots@N_1 n)), i = \overline{(1,n)} =>$$
$$N_i 1\{(part\ dimensions@tools\ geometry@good\ precisions$$
$$@clamping\ type@surface\ quality@productivity@reduce\ time$$

After establishing the needs we have to validate the most important of them by interpreting the result of the survey.

2.3 Determining drilling tool functions

These needs must be satisfied by functions that the product must fulfill. These functions are Fj.

$$F_j = \begin{pmatrix} F_1 \\ F_2 \\ \ldots \\ \ldots \\ F_m \end{pmatrix}, j = \overline{(1,m)} => F_i = \begin{cases} to\ cut \\ to\ remove\ chips \\ appropriate\ holding \\ durability \\ controlability \\ \ldots\ldots\ldots \end{cases}$$

Because these functions can be implemented in a certain way by different technical features, teams must find these options and determine the importance that they have in the function. These features are Ck.

$$C_1 k = (█(C_1 1@C_1 2)¦█(\ldots@\ldots@C_1 p)), k = \overline{(1,p)} =>$$
$$c_1 k\{(tool\ geometry@tool\ dimensions@covering$$
$$@thermal\ treatment@surface\ quality@$$
$$cutting\ precision@spigots\ to\ re$$

For a better understanding of this analysis we use the case of helical drills.

F1 = to cut is influenced by: geometry and precision, tool material, covering, thermal treatment, channels for chip removal, lubrication system, tool guiding.

F2 = to remove chips is influenced by: geometry and dimensions, surface quality, channels for chip removal, lubrication system.

F3 = appropriate holding is influenced by: geometry and dimensions, tool material, surface quality, tool stiffness.

F4 = durability is influenced by: tool material, covering, thermal treatment, surface quality, geometry and precision, lubrication system, etc.

F5 = controllability is monitoring and control of real time cutting process and is influenced by: geometry and dimensions, sensors, level of intelligence

Resulting from technical features analysis we can determine the influences that concur in designing a customizable end product. These influences are presented in figure 6.

All the technical features requested are directly influencing the cost of implementing the required function. Also we realized a process flow diagram that helps us to exemplify the steps to fulfill this papers goal.

Figure 6. Influences on designed end product

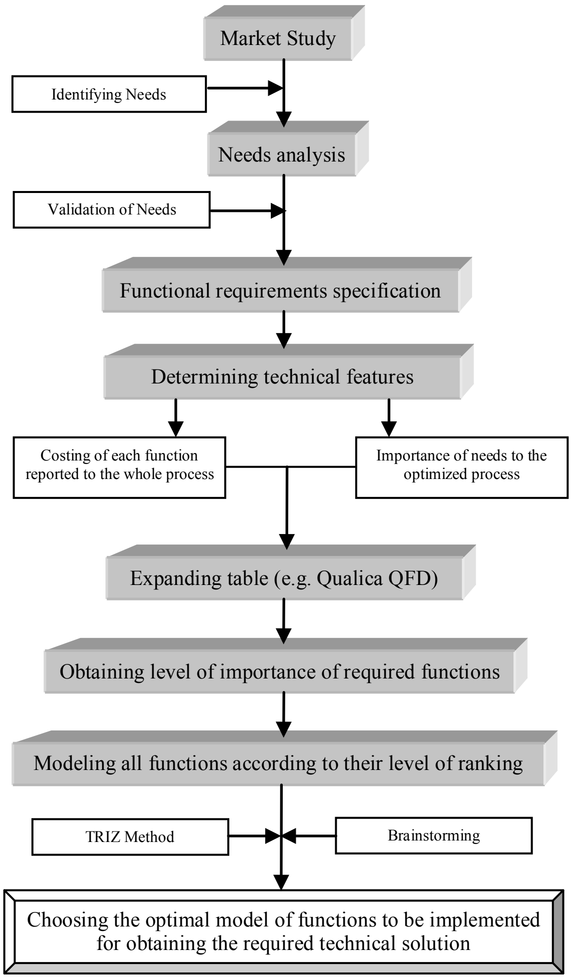

Figure 7. Process diagram of choosing the optimal model of functions to be implemented

Beside the costs of designing it has been performed a thorough analysis between needs and functions and functions and technical features of a drilling tool.

After searching in related literature the most researched technical parameters of drilling tools which are factors of influence for cutting process are presented in figure 8.

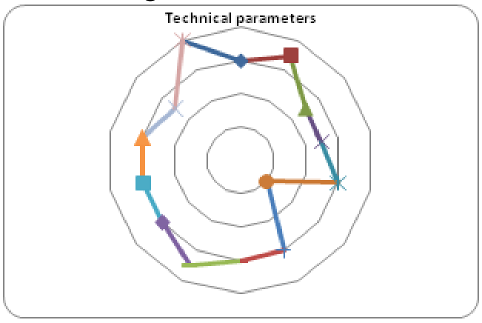

Figure 8. Technical parameters most researched in recent literature

By observing the whole process of modeling as a system of interaction between its own branches we used a holistic conception model based on four branches identified as client branch, functional branch, physical branch and process branch. This model is represented in figure 9.

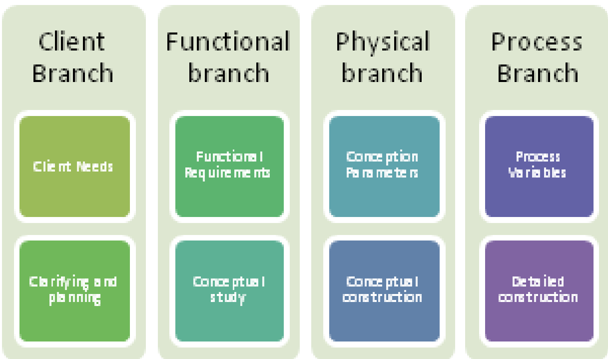

Figure 9. Simplified holistic model

All client needs (user needs) identified earlier and which represented the first branch of the holistic model, were transformed in functional characteristics after a thorough functional analysis and we obtained the description of the functional branch of the holistic conception method. After making and external functional analysis to see the influences of external environment on the functional requirements of the new model of intelligent drill, we highlighted the main functions of the cutting tool which are divided in main functions and constraint functions.

As stated earlier we identified five main functions and twelve constraint functions and presented them grouped with their constraint functions.

MF1 = *to cut*
C1- geometry
C2- dimensions
C3- precision
C4- surface quality

MF2 = *remove chips*
C5- spigots
C6- guiding
C7- lubrication

MF3 = appropriate holding
C8- stiffness

MF4 = *durability*
C9- thermal treatment
C10- covering

MF5 = *controllability*
C11 - monitor
C12 - control

All these are exemplified using a Pieuvre diagram such as in figure 10.

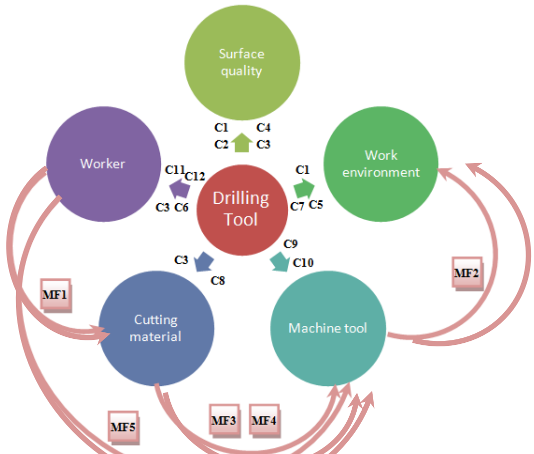

Figure 10. External functional analysis

The basic functional requirements that the tool, in our case the intelligent drilling tool, have to fulfill inside a modern and efficient cutting process are:

- ✓ Obtaining a form and dimension of surface according to specifications
- ✓ The quality of processed surface according to specifications
- ✓ High productivity
- ✓ Reduced machining cost
- ✓ Reduced auxiliary times

3 CREATIVE MODELING OF FUNCTIONS OF AN INTELLIGENT DRILLING TOOL

Creative modeling is made based on these features resulting in a number of models which are then ranked using technical and economic conditions in the manufacturing process, use and recycle (ex. Morphological matrix [4]). Following the search phase of ideas and possible variants, the team will find a number of conceptual models. Previously obtained conceptual models will be combined to create a unitary model. To achieve this it is necessary to select the optimal model of function according to their importance so the designers can focus their energy and attention on a feasible safe option for best implementation of them. Considering being a key feature for intelligent cutting tools, monitoring by using sensors and other real time communication devices, we identified the aim of monitoring and control of the cutting process and implemented a model of a system which states the capability of cutting tools, in our case a drilling tool, to be part of a reconfigurable monitoring system (figure 11).

Figure 11. Reconfigurable drill monitoring system

Drilling tool functions modeling involves the detailed modeling of its shape, dimensional design, cutting geometry determination, establishment of dimensions and types of clamping systems, choosing what and when to monitor and the adequate sensors, etc. For the intelligent drilling tool the monitoring and control process is the main feature that has to be taken into account and its aim is presented in figure 12.

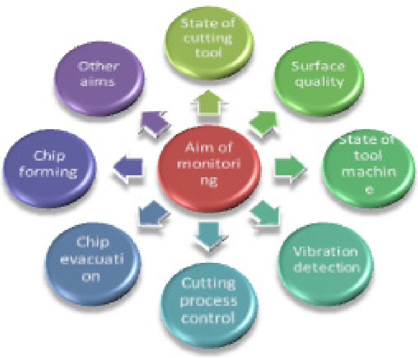

Figure 12. Aim of monitoring the cutting process

The simplified model of the intelligent product based on McFarlane physical and informational representation is presented in figure 13.

Figure 13. Intelligent product simplified representation

Starting from the base functions which each existing element of cutting system has to fulfill and thinking at the intelligent product simplified model earlier presented we can figure out the schematic of the cutting process.

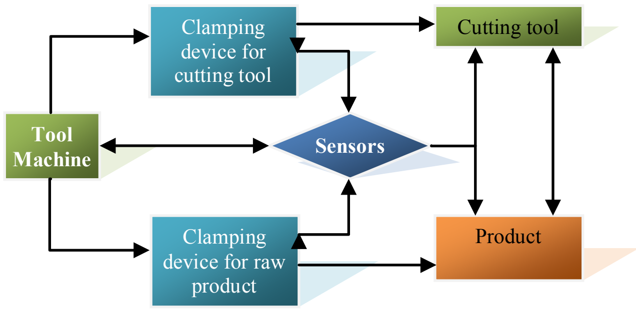

Figure 14. Cutting process schematic

For determining implementation variant we chose applying creative methods such as TRIZ. Besides brainstorming and networking models which have the disadvantage that they are unpredictable and unrepeatable, the TRIZ method offers repeatability, predictability, reliability and a very good algorithmic approach.

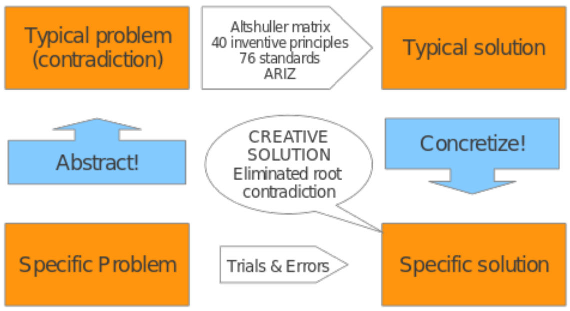

Figure 15. Schematic of TRIZ method

Based on the 39 standard characteristics which can generate contradictions and 40 inventive principles which can solve the generated contradictions, it was developed a method to correlate the conflicts with inventive principles and it was called "contradictions matrix".

One of the fundamentals concepts of TRIZ is that contradiction which has to be removed from a technical system. This is exactly the aim of the TRIZ method, to put the system into an ideal state, a state in which there are no mechanisms, just functions. Aiming to use the TRIZ method to identify all the possible variants, we considered all functional requirements of the new drill and expressed them such as existing contradictions in our level of interest, called operational area.

With help from the TriSolver Professional software, which permits expressing the contradictions according to the 40 basic principles of TRIZ method, we managed to pair them two by two; the first one has to be improved in expense of the second one. For each pair of contradictions the software generates automatically the set of principles which has to be applied and also its frequency of appearance.

After this analysis the software returned a set of 15 principles (figure 16).

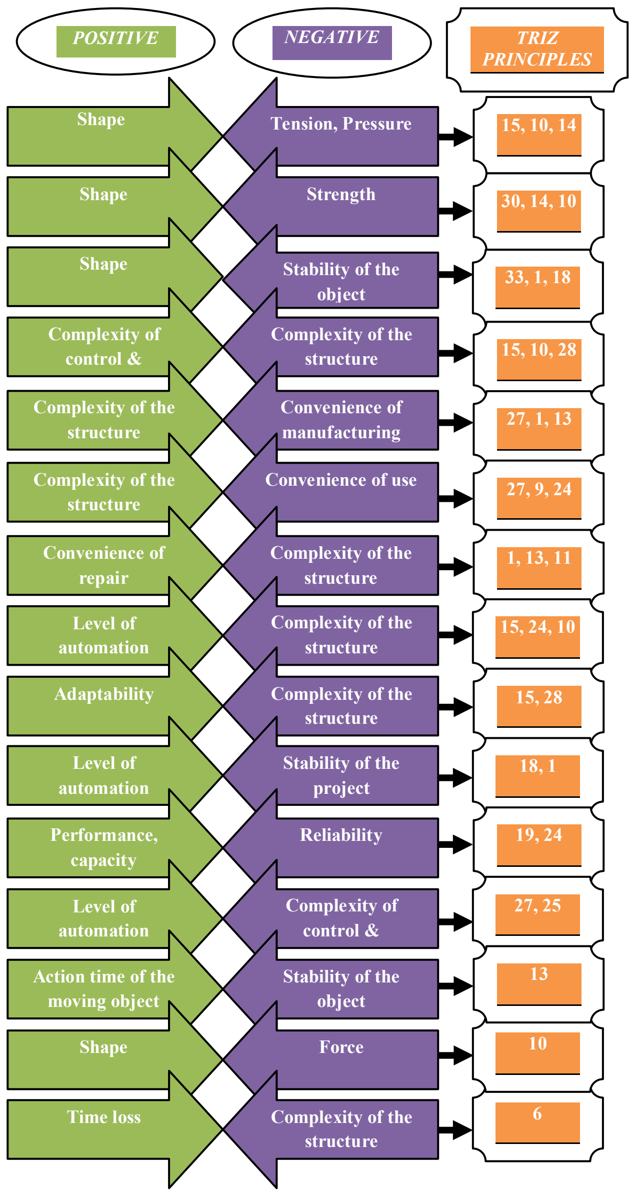

Figure 16. TRIZ Contradictions

The 15 principles generated by the software are the following table:

Generated TRIZ Principles with TriSolver Proffesional	
TRIZ Principle	Short Description
01.Segmentation	-Modules design, elements with variable position, active part design, clamping part design
06.Universality	-If an item can fulfill several functions maybe it is not necessary using other items
09.Prior counter-action	-Starting with the type o machining (regime, time, material) it is established the moment of changing the cutting tool
10.Prior action	-Prior setting of the geometry due to the type of operation (semi finishing, finishing) -Establishing level of wear and report of the remaining durability -Changing and setting the tool (before, during or after the machining) -Use of any auxiliary devices to identify and do the change of the tool at the optimal moment
11.Preventive measure	-Low reliability compensation through preventive measures
13.Inversion	-The problem of wear results to tool change -Customizable tool position -Interposed elements -Fixed tool and change of entire system
14.Spheroidality	-Use of items such as cones, spheres -Tool rotation before, during or after machining
15.Dynamism	-Adjustment of cutting tool – automated, semi-automated or manually -Modular construction -Use of interposed elements -Diverse shapes of body to permit better adjustments
18.Mechanical vibration	-Use of particular oscillations to modify own resonance frequencies
19.Periodic action	-The moment of tool adjustment can be overlapped with tool repositioning
24.Mediator	-Interposed items for action transfer such as: liquid, gaseous, viscous or elastic elements
25.Self-service	-Intelligence, continuous adaptability to working conditions
27.Disposability	-Cheap and ecological design -Recyclable materials -PLM design
28.Replacement of the mechanical system	-Wear monitoring -Optical system, RFID -Sensors
33.Homogenity	-Immediate report on the wear state of the tool and taking decision to readjust or change it.

Taking into account the research directions returned by TRIZ method, together with the aim of this paper to design an intelligent drilling tool, the principles must be combined so feasible constructive variants should be obtained which will satisfy all the requirements of an intelligent cutting process. The main variant which fulfills all the generated principles and is largely analyzed is represented by a modular construction which permits the use of auxiliary items (elements) to monitor in real-time the drilling process and to take decision regarding various factors that appear during the process.

So, this drill tool has to permit the collecting of data from several points of the machine, to identify and report the wear state of the cutting tool, to take the decision of new adjustment or to change the tool at the optimal moment.

Also it should have a modular construction based on interposed elements with variable position.

Now we can contour the general model of the intelligent drill tool which contains elements from various and complex areas such as mechanics, programming, electronics and automation.

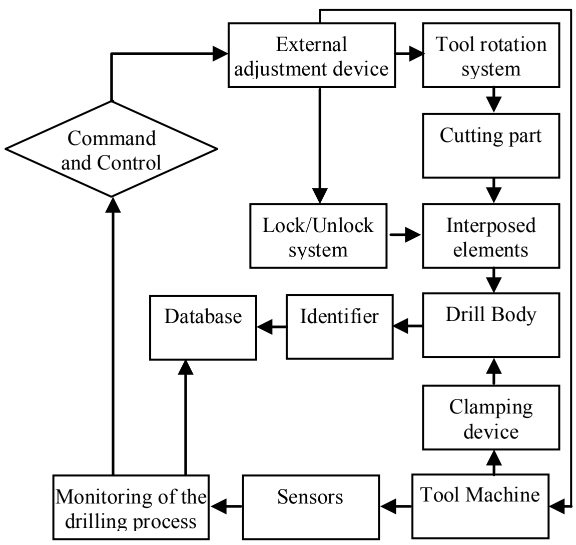

Figure 17. General model of a feasible constructive variant of an intelligent drill

4 CONCLUSIONS

The new obtained model of a intelligent drill tool which is designed according to the needs of the market and which fulfill all the modern cutting process requirements is in fact an intelligent tool that can analyze, report and improve its operation continuously. The proposed constructive variant analyzed in this paper behaves similarly with the classic one of the same dimensions and almost the same geometry and is subjected to the same process conditions.

The main advantage of the proposed model is that it consists in a lot of data collecting sensors which can help the user to know almost everything in real time during its operations. Also it can take some decisions related to its operation without any interference of the human error.

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