WEB ORIENTED SEQUENCE OPERATIONS

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Abstract
The intention of this paper is to give some methodical approach in process planning. Within this it covers the problem of defining the sequence of operations. Quality of the product, production time and production cost determine sequence of operations. The purpose is to analyze their influences and how to apply them in making decisions. Our developed web application can give within closed interval of tolerance, surface roughness and geometric tolerances, fast and precise, sequence operations for observed dimensions. Next steps of develoment web application would be use additional criterions (influence of the primary process, miminal change of machine tools, chucking, connections between dimensions, etc) to make intersection of the solutions..

Keywords:
sequence operations, shape, surface roughness, conversion tolerance-surface roughness

1 INTRODUCTION

The experienced process planner usually makes decisions based on comprehensive data without breaking it down to individual parameters. There is no time to analyze the problem. Understanding and a methodical thinking flow will improve the performance of the process planner. Good interpretation of the part drawing includes mainly dimensions and tolerances, geometric tolerances, surface roughness, material type, blank size, number of parts in a batch, etc.

Process planning could be presented like a balance between producing a part meets functional requirements, minimal production time and minimal production cost. Relation between part manufacturing, production time and cost certainly exists but is not always very clear.

The operations defined in process planning have to be put in certain order according to precedence relationships based on technical or economical constraints. Operations sequencing depends on many influences like:

a) nature of the material,
b) general shape of the part,
c) required level of accuracy,
d) size of the raw material,
e) number of parts in the batch,
f) possible choice of machine tools, etc.

Forming material removal is a most comprehensive process. There is an infinite number of combinations of machines and tools that will produce the part as specified by the drawing. The recommended process is not only a result of the process planner's experience, but also an outcome of the sequence of decisions made. A wrong sequence of decisions may result in artificial constraints, because if the sequence of decisions were different, the constraints might not have existed.

To achieve the nominated goal for definition of sequencing the operations is very complicated, multi-level, particular problem. Therefore, the expected difficulties in the process of solving this problem can be: pattern recognition, selection of datum, connection between machining surfaces and type of operations, machining tools, tools and positioning and work holding, etc.

Few approaches in sequence operations would be considered in the next chapters. First approach named *Matrix method* [1] can be described as operations defined by putting in certain order according to precedence relationship based on technical or economical constraints. Second approach named *Basic technological operations* [2] can be explain as development of the originall knowledge base of fundamental, the most frequently operations. Third approach named *Sequence operation* [3] can be explain as development of original web application by Microsoft .net technology and Flash. The goal was to define simple procedure for definition operations sequencing for every surface of the part. The main criteria was satisfaction of the requested geometrical and dimensional tolerance, roughness, etc.

2 MATHRIX METHOD – BOLT EXAMPLE

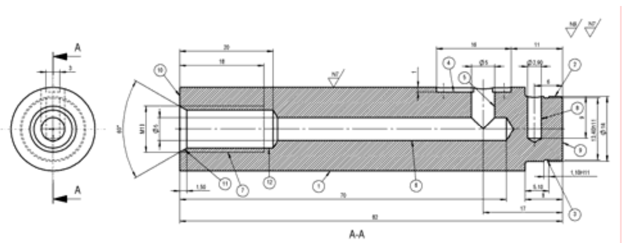

Figure 1: Bolt drawing

Quantity: 14 000 pcs.

Material: St60-2

Taking into account geometry of the product the primary shape would be a bar Φ20.

One of the possible approaches is to classify different categories in the following way:

a) dimensional precedence – dimensions with a datum as anteriority
b) geometric precedence – geometric tolerances with data references as anteriorities,
c) datum precedence – case to the choice of a datum,
d) technological precedence – case of a technological constraint,
e) economic precedence – economic constraints that reduce production costs and wear or breakage of costly tools.

So, as the first step in process sequencing is selection of the simplified approach. It includes definition of:

a) codes for machining surfaces,
b) number of passes,
c) type of fine (F) / rough (R) machining,
d) definition the relevant anteriorities different types (dimensional, geometric, technological, economic).

As it is obviously, this approach expects the experienced process planner. One of the well-known methods of finding the order of precedence of the operations is based on the use of a matrix.

Having defined all the anteriorities, it is now possible to find the right sequence of operations for machining. The consistency of the anteriorities depends heavily on the experience of the process planner. Solution is result of weighted category of anteriorities, minimal number of precedence operations and finishing of precedence operations**.** The chosen order of anteriorities implementation is result of higher priority associated to dimensional and geometrical features then economical aspects.

The difficulty can come from the assessment of the anteriorities, which can result in contradictory conditions. In this case the process planners have to introduce additional criterion in order to solve this contradictions. At the same time process planer defines anteriorities needed to establish a matrix, he makes a table that contains possible machining processes, machines, fixture devices and tools for every feature.

To solve contradictory situation the feature that precedes according to matrix is compared with the momentarily possible features in the matrix. “Values” in the table that belong to features are compared. The feature whose “values” from table are the most similar to “values” of preceding feature has advantage. The logic in this approach is that as much as possible number operations in a sequence should be done by same process on the same machine in the same fixture and using same tool.

The first step is to analyze the part drawing and “divide” the part into features. Features are made by different machining operations. According to geometric shape, tolerances, surface quality and other information a drawing contains we can select possible machines and tools by which a specific feature could be produced. For the example in Figure 1 a selection was made and is presented below in Figure 2.

The problem that appears next is which feature should be machined first and *more important in which order should features be done*. Certainly there are restrictions regarding technology, geometric and dimensional tolerances, datum, economy (reduce production costs and wear or breakage of costly tools). Taking into account all this restrictions another table (Figure 2) is made in which it is clear which features must precede before other features.

Surface (Feature)	Description	Surface quality	Machine	Tool
1	Φ18k6 $\left(\begin{matrix}+15\mu M\\+2\mu M\end{matrix}\right)$	Ra 1.6µm	Lathe	
2	Φ14	Ra 6.3µm	Lathe	
3	Φ13,40h11	Ra 6.3µm	Lathe	
4	Counter bore 2mm	Ra 6.3µm	Mill	
5	Φ5	Ra 6.3µm	Drilling machine Mill	
6	Φ5 dpth.70	Ra 6.3µm	Drilling machine Mill	
7	M10 dpth.18	Ra 6.3µm	Drilling machine Mill	
8	Φ2.90 dpth.9	Ra 6.3µm	Drilling machine Mill	
9	82 (right side)	Ra 6.3µm	Lathe	
10	82 (left side)	Ra 6.3µm	Lathe	
11	1.5x60°	Ra 6.3µm	Mill Drilling machine	
12	Φ8.4 dpth.20	Ra 6.3µm	Drilling machine Mill	

Figure 2 Surface analysis

If Figure 2 is presented in matrix (Figure 3), advantages from this approach are now clear. It is easy to see that the first feature to be machined is 10R. When 10R is removed from table it sets free other features that were “blocked” by it. [1]

	Execute these operations												
Before these operations	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	11R	12R	Seq. oper.
1R										X			1
2R	X									X			2
3R		X											1
4R	X												1
5R	X			X		X							3
6R	X	X	X							X			4
7R						X				X	X	X	4
8R		X											1
9R	X	X	X										3
10R													0
11R						X				X		X	3
12R	X					X				X			3

Figure 3: Matrix of anteriorites

That is not analyzing all the steps in the determination of operation sequence. It would be interesting to look at the situation when two or more features are not preceded by any other feature that needs to be done before. This means that all of them can be done at the same time. But this is not possible because only one feature can be machined in time. One of them must go first and then the other. In this example this situation occurs in the third step.

This situation is shown in Figure 4. The feature that was done before is 1R (Figure 4). In this step we have to decide which feature is going to be machined first 2R or

4R (Figure 5). To make this decision we need more data. Therefore another table was made, shown in Figure 6.

Before these operations / Execute these operations	1R	2R	3R	4R	5R	6R	7R	8R	9R	11R	12R
1R											
2R	X										
3R		X									
4R	X										
5R	X			X		X					
6R	X	X	X								
7R						X				X	X
8R		X									
9R	X	X	X								
11R						X					X
12R	X					X					

Figure 4: Matrix of antteriorites for second step

Before these operations	2R	3R	4R	5R	6R	7R	8R	9R	11R	12R
2R										
3R	X									
4R										
5R			X		X					
6R	X	X								
7R					X				X	X
8R	X									
9R	X	X								
11R					X					X
12R					X					

Figure 5: Matrix of antteriorites for third step

In the Figure 6. a few additional criteria were brought out. In order of significance they are:

- same machine (if we change the machine we change all other factors: process, fixture and tool)
- same process (if we change the process we change fixture type, tool and sometimes machine)
- same fixture (changing fixture needs more time than changing tool and it is recommended to do as much operations as possible in one fixture because it is more precise)
- same tool (the least significant factor in this list)

If we look at the Figure 6 we can see that feature 1R that proceeded was done by turning process on lathe. Since feature 2R is also done by turning on lathe which means by the same machining process as feature 1R it has advantage before feature 4R. Feature 4R requires milling and therefore different tool and fixture.

Surface (Feature)		Process	Machine	Fixture	Tool
1R	Φ18k6 $\left(\begin{smallmatrix}+15\mu M\\+2\mu M\end{smallmatrix}\right)$	Turning	Lathe	▼10 ▼9	
2R	Φ14	Turning	Lathe	▼10 ▼9	
3R	Φ13,40h11	Turning	Lathe	▼10 ▼9	
4R	Counter bore 2mm	Milling	Mill	▼1	
5R	Φ5	Drilling	Drilling machine Mill	▼1	
6R	Φ5 dpth.70	Drilling	Drilling machine Lathe	▼1	
7R	M10 dpth.18	Threading	Drilling machine Mill	▼1	
8R	Φ2.90 dpth.9	Drilling	Drilling machine Mill	▼1	
9R	82 (right side)	Turning	Lathe	▼1 ▽10	
10R	82 (left side)	Turning	Lathe	▼1 ▽9	
11R	1.5x60°	Countersinking	Mill Drilling machine	▼1	
12R	Φ8.4 dpth.20	Drilling	Drilling machine Lathe	▼1	

Figure 6: Additional criterions for solving conflict situations

The shape of part is usually very complex so process planer can miss or not see some relations. Knowledge and experience are limited. That is the reason why table of anteriorities is not always set up to give unique answer. This example shows logical approach that can be used to solve conflict situations in decision making regarding sequencing of operations. This approach reduces influence of intuition and gives more methodical approach suitable for intelligent process planning.

3 BASIC TECHNOLOGICAL OPERATIONS

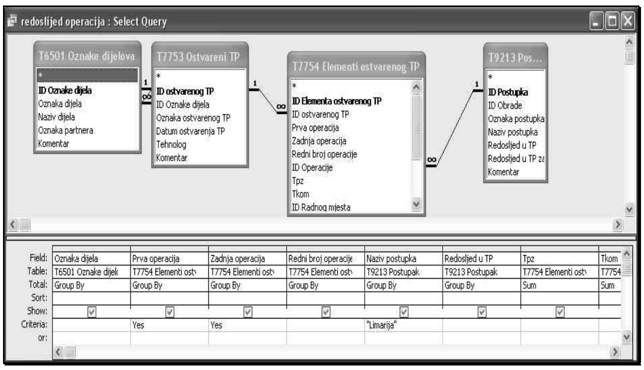

Figure 7: Relation between tables (*Marks of parts, Realized technological processes -, Elements of realized technological processes and procedure*)

Process planning is primarily based on workpiece sketch and requested tolerances (dimensional and geometrical), roughness, heat treatment, material, batch size, planner experience and skills, etc.

So, fundamental idea in fourth approach [2] of production time's estimation is investigation of existence kind of relationship between shape and date from sketch and process type, process sequencing, primary process, way of tightening, selection of tools, machine tools, etc.

The greatest challenge is to establish (or investigate) the most important factors from sketch for useful, easy, fast and very exact estimation of production times. It is necessary in process of offers definition for better estimation terms of product delivery, production times and costs, manufacturing management and last but not the least important, product price.

As one of the first step in our project research, we have defined possible shapes of raw material and 12 basic technological processes. The fundamental idea is to establish parameters of basic technological processes based on sketch features of considered product.

Parameters of basic technological processes can be:

- shape and kind of raw material (features of sketch, knowledge base),
- type of workpiece (features of sketch, shape and dimensions of raw material),
- necessary operations for treatment (features of sketch, expected production time and knowledge base).
- operations sequencing (features of sketch, , necessary operations of treatment and knowledge base),
- necessary production times (features of sketch based on equations).

So, it have to be establish features of sketch (independent variables), possible dependent variables, size and criteria for sample homogenization (principles of group technology) for analysis of variance and regression analysis.

Basic technological processes must give requested date to sales department as the most important date for defining product costs/price and date of delivery. On the other hand, basic tehnological processes can be very useful as the base for detailed process planning or optimization of process planning. We can be faced by few approachs in process planning. For example, definition very precise IF THEN procedure for creation technological knowledge database. Or, we can be faced by use of fuzzy logic and certanities of possible solutions. Or, we can try to solve restricted area of problem by heuristic approach. What can it means?

Technological processes are basicly based upon product sketches with adequately dimensions, tolerancing (dimensional and geometrical), surface roughness, batch size, shape and kind of material, heat treatment, requested delivery, disposable equipment, tools, etc. On the other hand, process plans is primary results of planner experience, intuition and decision support. Very often, process planners work under high level of pressure or lack of time.

Process planner can establish possible connections between sketch features and necessary machining times for products manufacturing. Defined hypopthesis says that established connections we can express, except methods of AI, with equations. Established purpose is to define basic process planning with satisfactory precision.

4 FAST PROCESS PLANNING

Material may be expressed by three basic groupes: quality, shape and dimensions. Investigation of the connection between machining time and features of product (through four group of independent variables) can give as result regression equation. All elements of the sample are records for created datebase (Figure 7).

Considered sample consists of original production documentation one metal manufacturing Croatian company. For establishing potential high quality relationship between features of sketch and production time we have to execute two actions.

One action can be explain as exploring measures for reduction number of indenpendent variables for egression analysis. Method of analysis of variance [4] (ANOVA procedure) and stepwise multiple linear regression (Excel, MatLab) are helpful in process of reduction of number of indenpendent variables.

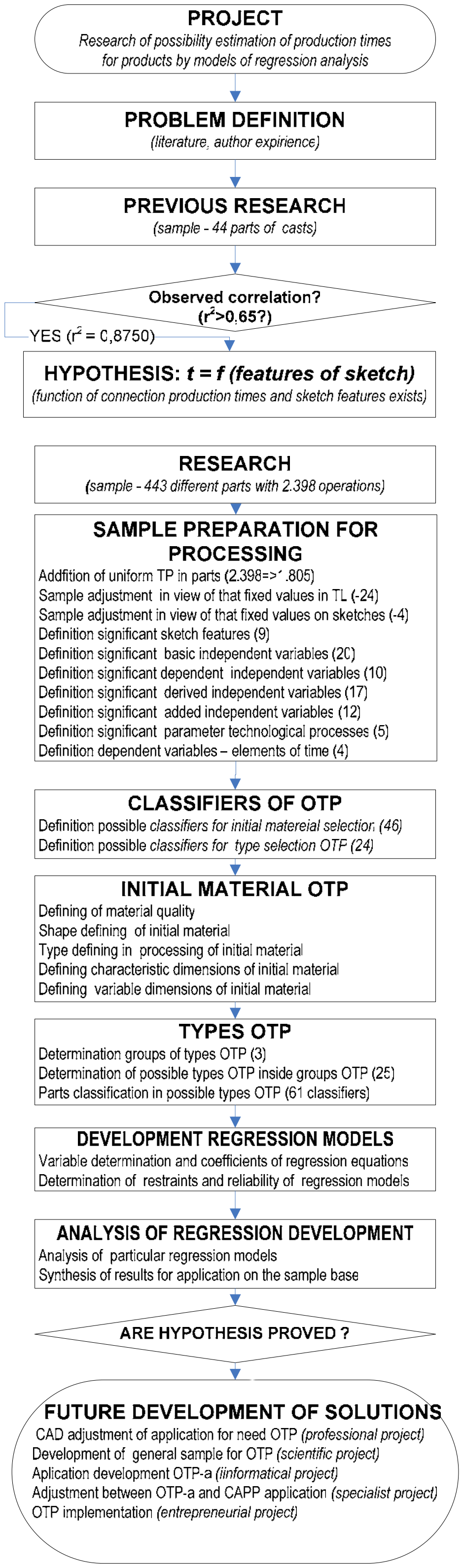

Figure 8 : Flow chart for model development for time estimation and basic technological operations [2]

The other action was process of sample homogenization (for example, elimination of too big or small value of members of sample).

Shape product dependent variable as the most important criteria were established for 5 different product types. As result of development we have developed 5 regression equations.

Size samples are results of sample homogenization and .query of logical operators (classifiers) for 12 basic technological operations (OTP).(Figure 8).

4.1 Analysis of results

As the precedence work we have to define domain borders of independent variables (less than 40), reduction number of variables by correlation/factor analysis and definition type of smoothing curve with high index of determination.

Of course, desired level of generalization in regression analysis would be important indicator for the quality of regression equation. One of the most important problem is process of homogenization of sample of products. Adequate method for this action can be one of methods of group technoogy.

Logical operators during query process in database Access were very helpfull in process of homogenization of sample of products. The other approach was critical analysis values of dependent variables and excluding the extreme values.

As example of multiple linear regression (seven variable) (1), after stepwise multiple regression was selected group of metal rod with 221 parts in a sample.

Observed multiple linear regression Y = f(X43, X40, X11, X50, X8, X33, X1) has index of determination R^2 = 0,742471 for:X43 residuals. (Figure 9).

Y = machining time

X1 = tolerance external diameter of workpiece

X8 = surface roughness

X11 = internal diameter of workpiece

X33 =ratio length/diameter of workpiece

X40 = complexity of workpiece

X43 = superficial area of raw material

X50 = difference of length workpiece and raw material

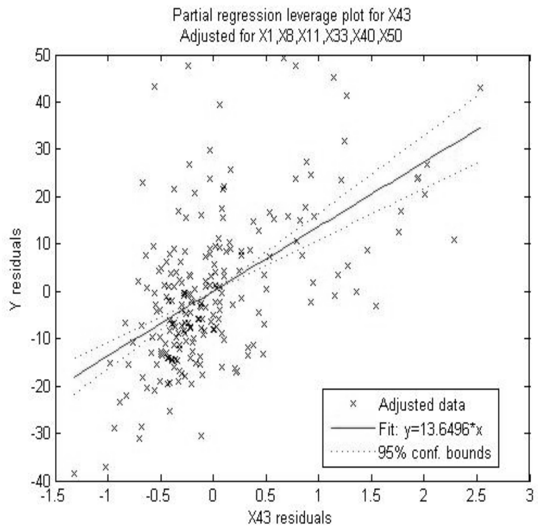

Figure 9: Partial regression leverage plot for X43

$$Y= 36.419+13.649\ X43 + 0.099\ X40 + 0.459\ X11 + 2.023\ X50 – 4.080\ X8 – 0.655X33 + 0.712\ X1. \quad (1)$$

For different group of values of parts (same group) with the significant level of homogenity were established 5 multiple linear regression equations.

The future research would be conduct in the way of automatic recognition and joining part to the adequate group of parts (logical operators – classifiers in datebase) .

Research as the second request would include more precise measurement and calculation parts of production times. As the third request would be procedure for estimation multiple linear regression with the least variables, the greatest index of determination and good coincidence calculated and predicted values of dependent variable.

Research work would be continued by looking for adequate model for optimization (minimum of machining time). Implementatioin of the genetic algorithm can be one of possible methods for solving optimization problems.

5 SEQUENCE OPERATIONS IN WEB ENVIRONMENT

Third approach can be realized in few steps. The first decision should be to select the types of materiall removal processes from among the many basic processes. To assist in making this decision, the basic material removal processes are classified according to their capability to machine a group of parts to a required shape (round symmetrical, prismatic, superimposed – holes and threads) shapes. (Figure 10).

The final selection of the basic processes depends on the accuracy of the part. Concerning selection of machining technology the most important parameter is the surface roughness required, followed by the geometrical and dimensional tolerances.

The ability of a process to produce a specific surface roughness depends on many factors. The sequence of the proposed basic processes in each section of a shape group is arranged by priority and technical constraints. In other words, if the basic process first proposed does not meet the surface roughness requirements, an additional basic process might be added, though it should not replace the first basic process. The dimensional tolerance has an effect similar to the surface roughness. (Figure 11). The final result were determination of types and sequence of operations for the all machining surfaces with requested dimensions, tolerances and flatness roughness (Figure 12).

To consider the dimensional tolerance, there is an empirical relation between the dimensional tolerance and surface roughness (finish). The geometric tolerances (parallelism, perpendicularity, concentricity, angularity) should be considered as the final criteria to be checked with regard to the capability of the process. Meeting the specified geometric tolerances involves, many other criteria, such as chucking, machine selection, etc.

Dimensions have to be changed so as to leave material to be removed by the following process, as each process must have a minimum depth of cut.

Our developed web application can give users within closed interval of tolerance, surface roughness and geometric tolerances, fast and precise, sequence operations for observed dimensions. Next steps of develoment web application would be use additional criterions (influence of the primary process, miminal change of machine tools, chucking, connections between dimensions, etc) to make intersection of the solutions.

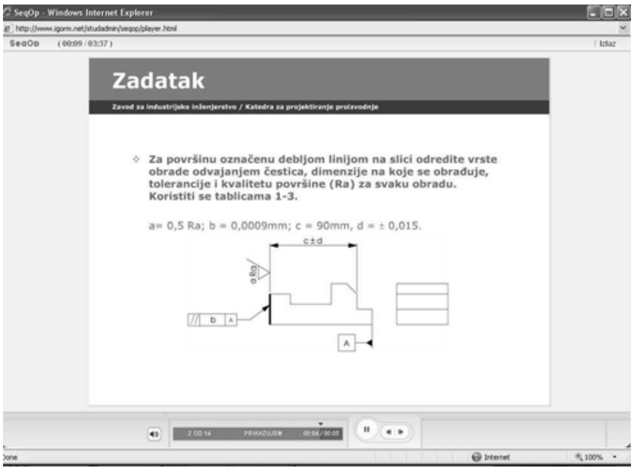

Figure 10: Example of development sequence operations – sketch of part with dimensions, tolerances, roughness

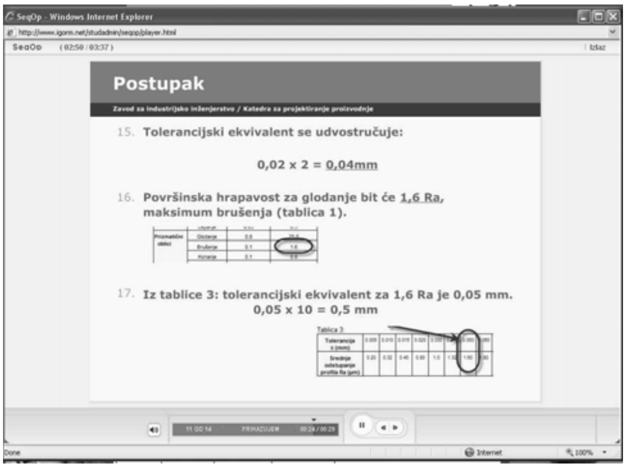

Figure 11: Minimal flatness roughness as a criteria for the type operations

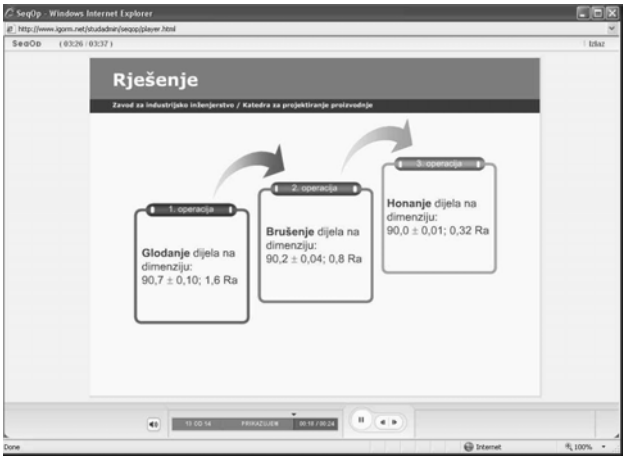

Figure 12 : Final solution of sequencing operations

6 CONCLUSION

One of problems process planning solves is setting up optimal sequence of operations. Sequence is set up following certain rules. Some operations have to precede other operations regarding requirements for dimensional and geometric tolerances, restrictions that come from technology, economical aspects and some other.

One of the methods that can help process planers in making their decision is using a matrix of precedence. But it was shown that there are situations when matrix does not give exact answer. Two or more operations appear with the same level of precedence regarding matrix. This might be caused by process planer's lack of experience and knowledge or incomplete drawing. Anyway the matrix was not set up to give unique answer. To solve these situations other criteria was set up. It says that as much as possible number operations in a sequence should be done on the same machine by same process in the same fixture and using same tool.

Hypothesis about relationship from one side between sketch features and from the other side production times and parameters of technological processes is confirmed. Result of research is fact that possible initial shape of material raw can be automatic defined on the base of the sketch features.

Process of the previous classification parts in defined types of parts based primarily on geometric features is not so important in the process planning. Solution can, indeed, find not in determination type of part but in parts joining to specific, in advance, type of defined fundamental technological processes (OTP) based on sketch features.

Our developed web application can give users within closed interval of tolerance, surface roughness and geometric tolerances, fast and precise, sequence operations for observed dimensions. Next steps of develement web application would be use additional criterions (influence of the primary process, miminal change of machine tools, chucking, connections between dimensions, etc) to make intersection of the solutions.

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