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METHOD TO DETERMINE THE MINIMAL KINEMATIC STRUCTURES OF THE MACHINING CENTERS

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Abstract: Development from the last years of types of machine tools allows fabrication of more complex parts with lower costs. Identification of a kinematic structure of the required machine tool to realise a certain part constitute one of the stages which must be road when is realised the fabrication technology. There are many variants of kinematic structures which can satisfy the manufacturing necessities of a part, but also are situations where the complexity of the operations imposed a laborious study of the movements which must execute the machine tool and/or the piece. Therefore, the present paper presents software which role is that to select the adequate machine tool to manufacture a certain type of the piece.

Keywords: machining centres, minimal kinematic structure, kinematics

1. INTRODUCTION

The main purpose of the actual technology is that to fabricate parts with a very good quality, in a shorter time and lower manufacturing costs.

Since the complexity of the parts (fig. 1) is in a continuous growing and the fabrication cycles are dropping down, the realization of that supposed to use machine tools or machining centers with numerical command, equipments which are in a continuous expansion.

Therefore, the manufacturing of a certain part is not involve only that to find a machining center, but is that to find an optimal solution to lead at: very good quality, manufacturing costs and times smallest.



Fig. 1. Complex parts realised on machining centres

Depending on the complexity of the piece, overall sizes of that, quality and the shape of processed surfaces can be obtained various types of kinematic structures. Choosing the best variant can leads to reducing of manufacturing times as the costs.

To accomplish these goals and taking account by the piece complexity it was realise software which determine the minimal kinematic structure into the industrial processes.

2. PRESENTATION OF THE SOFTWARE WHICH DETERMINE THE MINIMAL KINEMATIC STRUCTURE

Further development of the machine tools allowed developing some kinematic structures which allow realising complex processes in a smallest number of operations. To realise a process the relative motion between piece and tool can be accomplish by the tool, by the piece or both. Thus, kinematic structure designing begin from the idea that all six degrees of freedom that is having the tool and the piece, some of these degree of freedom will be suppress even at the tool even at the piece.

The suppress of certain degrees of freedom can be imposed by the type of the process, overall sizes of the piece, the way of fixing of the part on machine tool, by the use or not of auxiliary devices.

The software to determine the minimal kinematic structure it was designed on Microsoft Visual Studio 6.0 programming environment. The application interface contain elements specifics to Windows applications, thus the use of this application is very easy.

The SCM software is structured on four modules, each of them accomplish a certain role, such as:

- a module to importing the file which contain the three-dimensional model of the analysed part;
- the analyse of the part from technological point of view, meaning that, all processes of the piece are detailed;
- determination of the kinematic structures possible which can be used to realise the processes defined at the precedent stage;
- identification and selection of the gear (machine tool or machining center) from the database, which correspond to the kinematic structure determinate on precedent step.

2.1. Defining piece module

This module is use to import three-dimensional part for which is determined the required kinematic structure necessary to realise the processes (fig. 2).

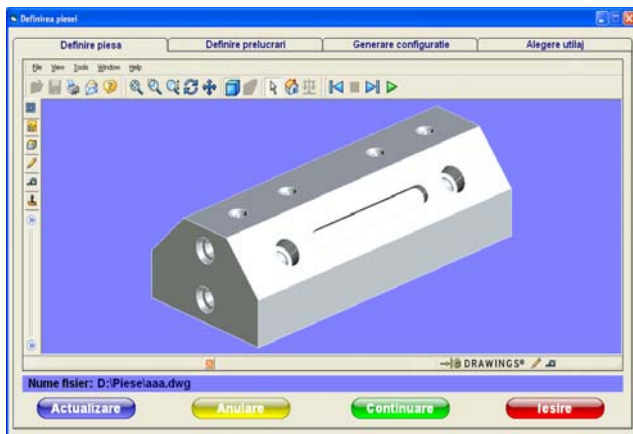


Fig.2. The three dimensional model of the part, visualised on application

The three dimensional model of the piece can be realised in any type of 3D modelling software; the importing is made through intermediary formats (igs, sat) or a format specific AutoCAD application (dwg).

The 3D model is use on the next stage to obtain some information concerning the points which define the processes on which are the piece is supposed.

2.2. Processes defining module

The processes defining module (fig.3) allow insertion of the processes on which is supposed the piece.

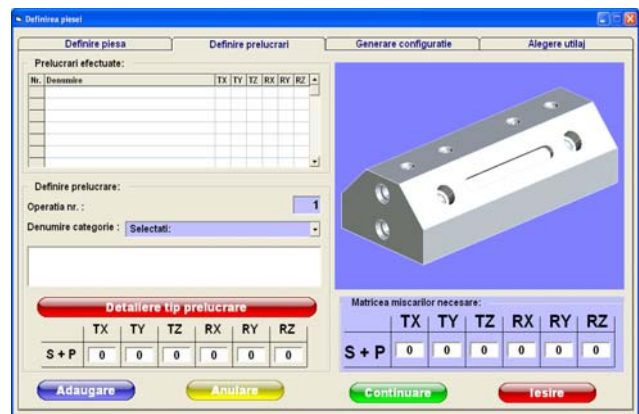


Fig.3. The window of the processes defining module

The page is contains the next graphic elements:

- a window through which is visualised the 3D model of the piece;
- the list of the defined processes;
- a hidden list with which choose the type of the process;
- a field to define the manufacturing processes;
- representation of a required movements matrix to accomplish every type of operation;
- representation of a movements matrix necessary to realise all type of operations;

The hidden list „Category name” allow to select one of the next variants: positioning, rotation, linear interpolation, circular interpolation, axial processing – 2 points, channels processing – 3 points, 3D surface processing.

After selection of one variant from all of hidden list, is activated „Detailing process type” button. On the screen is opened a specific window in accord with the chosen variant. After, the dates are introduced and return at the afferent window of step 2 is activated „Add” button. Information’s regarding the required movements it will be transferred on the defined processes list and on the necessary movement’s matrix. Forward are presented some of the processes which can be defined.

In figure 4 is presented the window afferent processes manufacturing through linear interpolation.

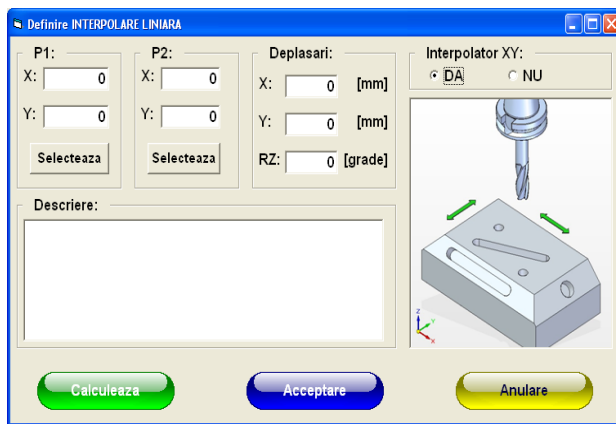


Fig.4. Window for defining of linear interpolation

The coordinates of the points P1, respectively P2 which are defining the linear interpolation are obtained from the three-dimensional model by marking with the aid of the mouse.

Based on these points are obtained the afferent values of the displacements on the two axis (OX, respectively OY) and also the rotation around the OZ axis.

Based on these values are obtained the relative motions tool – piece necessary to realise the process. The motions are added on the necessary motions list and also are added afferent information on the necessary processes matrix.

In case of a more complex process, such as a linear interpolation with the axis working define through two points which are not placed in one of the orthogonal planes (fig. 5), first of all the piece it will be suppose to a orientation

operation and then it will be realised the relative displacement between tool and piece.

The resulting motions in this case can be rotations around the OX, OY, OZ axis and translation after OZ axis.

An example of this type of manufacturing is realising of one hole on which axis is oblique.

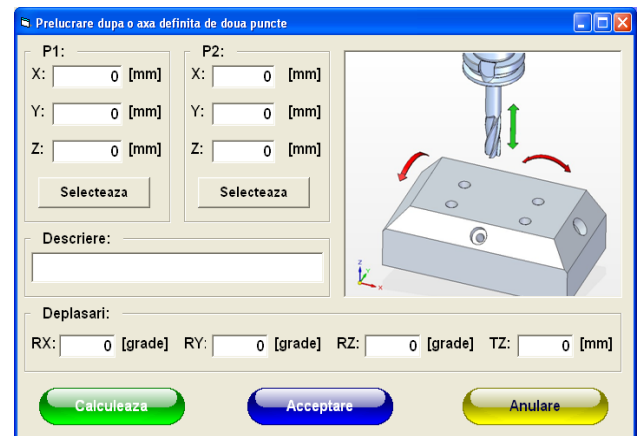


Fig.5. „Processing after an axis define by two point” window

Similarly in the case of channels manufacturing must be define by three points (fig. 6), thus the points P1 and P2 are define the entrance hole axis and the points P1 and P3 are defining the length and the spatial disposition of the channel.

In the case of this process, depending by the emplacement in space of all three points can be obtained displacements along of all three axis or rotations around of all three axis.



Fig.6. „Processing channels defined by three points” window

The most complex process can be defined into the software is that to realise 3D surfaces (fig. 7).

In this case, it was considered that the all two curves (the profile and the generator) are defined by three points each other.

The software is taking from the three-dimensional model the coordinates of all six points and depended by the dispose of them in space and the way of establish an orientation of the piece are determine which are the required motions to execute the manufacturing.

Defining by three points of every curve provides cover a multitude of possible situations. Thus, if the points which are defining all two curves are collinear then it's about a plane surface.

If only the points of one curve are collinear, then perhaps it's about a cylindrical surface etc.

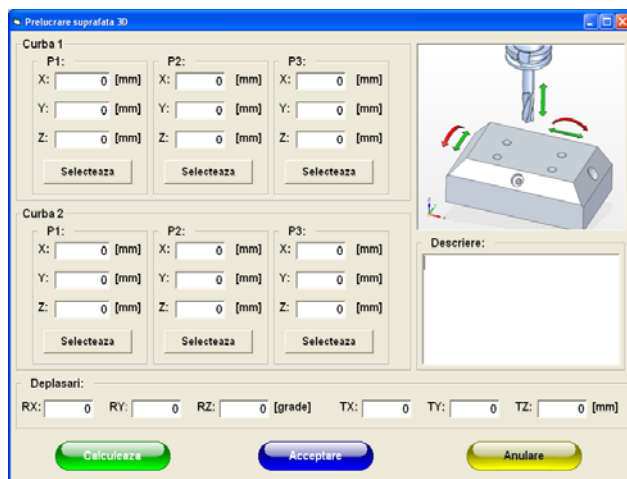


Fig.7. „Processing 3D surfaces” window

2.3. Determination of possible kinematic structures module

After defining of all processes it pass through the next step, that to determine the possible configurations (fig. 8).

Based on the required motions matrix is realised a particularization by generating of all possible configurations that to provide the relative movements tool – piece.

The window is contains the next elements:

- the necessary motions matrix, on which values was determined on the precedent stage;
- a „Filtering” button which allows to realise a primary filtering of the required motions;
- filtering matrix of the necessary motions;
- a table on which will occur all possible combinations of potential motions which can be execute by the tool, respectively by the piece;
- a matrix on which will appear the chosen configuration by user and for which it will be realise searching on the gears base date;
- two buttons which allows selecting a single configuration from the list of all possible.

The filtering operation has as purpose to reduce the number of possible configurations based of certain technological considerations (as example: if the analysed piece is very heavy, it will be suppress the piece motions, imposed motions only the tool etc.).

After generation of all possible configurations with the aid of buttons „Next”, respectively „Precedence” it will be chose one configuration from all possible.



Fig.8. „Defining of kinematic structure” window

In the field „Kinematic scheme” is put up the kinematic structure of the chosen structure, in a three-dimensional representation.

2.4. Equipment selection module

After the selection of a possible configuration, it passes out at the next step (last), respectively to select the equipment from the database. It was realised a database with

many equipments (from the simplest until equipments with a complex configuration) in order to ensure coverage of the most common processing operations.

Window (fig. 9) contains a matrix of required motions (determinate in previous step), a hidden list that will find the corresponding equipments of the kinematic structure anterior chosen, a field where will be represented the picture of the equipment and two field where will be presented the type of machine tool found and the description of that.



Fig. 9. „Equipment selection” window

Based on the matrix of required motions is realised a search on equipments database. Behind of this searching, the hidden list will show all the equipments of which configuration correspond with the chosen configuration.

By selecting of one of elements from the hidden list, the other fields will be completed with corresponding dates from the database.

3. DETERMINATION OF THE KINEMATIC STRUCTURE IN THE CASE OF A PRISMATIC PIECE

3.1. Piece description

The piece (fig. 10) is unframed into a parallelepiped with dimensions 230 X 100 X 60 „mm”, having two bevelled edge 30 x 45°.

On the frontal faces are disposed two holes for countersunk screws, located on symmetry axis of the face.

On the superior face (opposite face on which is realised the positioning of the piece) are placed four holes Ø8 mm, depth 10mm, bevelled 2 X 45°, placed symmetrically about the median plane transversal of the piece.

On one the angled faces are two holes Ø12 x 15 mm, enlarged at Ø18 x 5mm, and a channel with dimensions 12 x 90 x 5mm. The holes and the channel are symmetrical disposed about the transversal median plane of the piece.

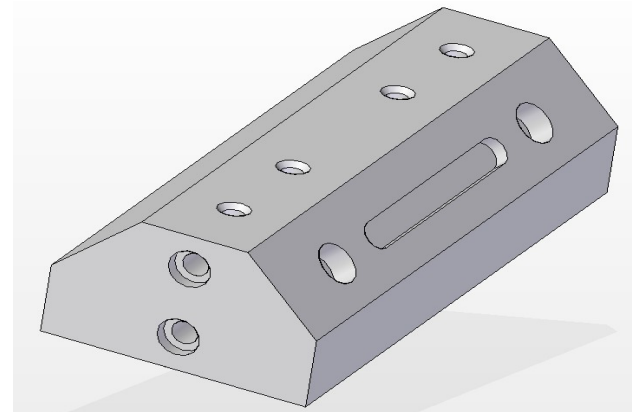


Fig. 10. Piece example

3.2. Defining of the process which must be realised on the piece

Because the piece is unframed into a into a parallelepiped with dimensions 230 X 100 X 60mm, we begin from a parallelepiped blank, with dimensions 232 x 100 x 61mm. There was provided machining allowance because it will be processes the faces on which are finding the holes.

The piece is positioned on underside, OZ axis being placed at the intersection of the median planes (transversal and longitudinal). The zero-piece point ($x = 0$, $y = 0$, $z = 0$) it's on the underside, at the intersection of two median planes.

In tab. 1 are presented some of processing which are executed on the piece.

Table 1.

		The necessary processes					
		Necessary movements					
No	Label	TX	TY	TZ	RX	RY	RZ
1.	Positioning at the end of the piece	1	1	1	0	0	0
2.	Linear interpolation	0	1	0	0	0	0

	(milling on the superior face)						
3.	Positioning to execute the hole $\varnothing 8$.	1	1	1	0	0	0
4.	Axial processing – 2 points. Realisation of the hole $\varnothing 8$.	0	0	1	0	0	0
5.	Positioning to execute the hole $\varnothing 8$.	0	1	1	0	0	0
...
44.	Axial processing – 2 points. Realisation of the hole $\varnothing 18 \times 5$.	0	0	1	0	0	0
45.	Positioning to execute the channel 18×102 mm.	0	1	1	0	0	0
46.	Axial processing – 2 points. Realisation of the hole $\varnothing 18 \times 5$.	0	0	1	0	0	0
47.	Linear interpolation – Channel processing	0	1	0	0	0	0
48.	Tool – piece retreat	1	1	1	0	1	0

In the follow table is presented the matrix of the necessary motions.

Table 2

Table of the necessary movements

Necessary movements	1	1	1	1	1	1	0
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Based on the operations previously define and of the necessary movements (a part of them presented in fig. 11) it is accomplish the matrix of the necessary movements (which can be executed by the tool or by the piece) and it crossing at the next stage, that to generate configurations variants of the minimal kinematic structure.

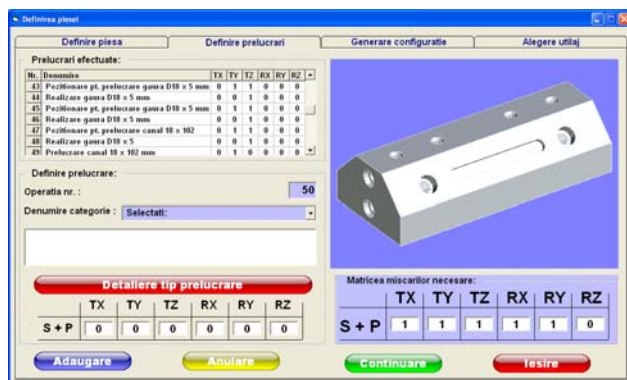


Fig. 11. Window module “Processes defining” afferent to the analysed piece

3.3. Determination of the minimal kinematic structure to manufacture of the piece

In figure 12 is presented the module window „*Generation configuration*” on which can be observed the matrix of the necessary motions, obtained after all the manufacturing processes was defined.

The required motions can be executed both, by the tool and the piece, but not simultaneous.

Also, in some cases, it may impose certain restrictions, so that some movements it will be realised even by the tool, even by the piece or an auxiliary device mounted on the machine.



Fig. 12. Module window “Generation configuration”

For this variant was chosen to realise rotation movements round OX and OY axis through some device, imposing to the tool – piece assembly only the translation movements (with options either tool, either piece).

Following of imposed of restrictions has as result eight variants of kinematic structures, as follows (table 3):

Table 3.

Variants of kinematic structure

Var	STX	STY	STZ	SRX	SRY	SRZ
1.	0	0	0	0	0	0
2.	0	0	1	0	0	0
3.	0	1	0	0	0	0
4.	0	1	1	0	0	0
5.	1	0	0	0	0	0
6.	1	0	1	0	0	0
7.	1	1	0	0	0	0
8.	1	1	1	0	0	0

Var	PTX	PTY	PTZ	PRX	PRY	PRZ
1.	1	1	1	0	0	0
2.	1	1	0	0	0	0
3.	1	0	1	0	0	0
4.	1	0	0	0	0	0
5.	0	1	1	0	0	0
6.	0	1	0	0	0	0
7.	0	0	1	0	0	0
8.	0	0	0	0	0	0

In figure 13 is illustrated the window of „*Generation configuration*” module after searching of all possible configurations.



Fig. 13. The window of “Generation configuration” after searching of all possible configurations

From the all eight possible variants it was choose to continue with variant number 2, it was chosen this variant because is very common (tab. 4):

Table 4.

For further the chosen variant						
Variant 2	STX	STY	STZ	SRX	SRY	SRZ
	0	0	1	0	0	0
	PTX	PTY	PTZ	PRX	PRY	PRZ
	1	1	0	0	0	0

In figure 14 is presented the window module „*Generation configuration*” after was chose the kinematic structure variant.



Fig. 14. The window of “Generation configuration” module after selecting of one kinematic structure

3.4. Equipments selection

Based on the chosen variant, it passes out at the next module „*Equipment selection*”.

After consulting of the equipments database it was obtained a number of 51 machine tools with adequate configuration.

In figure 15 is presented an equipment from the database of which configuration correspond with the selected configuration.



Fig. 15. Equipment from the database which configuration correspond with the selected configuration

4. CONCLUSIONS

Identification of the kinematic structure of the required machine tool to realise a part constitute one of the stage which must follow-up when is realise the manufacturing technology.

Usually are many more variants of kinematic structures which can satisfy manufacturing necessities of a certain part, but also are situations when the operations complexity on which is supposed a part imposed a laborious study of the movements that must be executed by the machine tool and/or the piece.

Also, depending by certain restrictions (manufacturing series, manufacturing accuracy etc.) it can opt for an existent machine tool or to getting a new machine with an adequate kinematic structure.

Starting from these theoretical considerations, it was opportune considered that to realise software which allow determining the minimal kinematic structure of machining centres.

It was created a database with all possible structures (in a number of 728) and a database with equipments/machining centres from which to be extracted just those

equipments which correspond to a certain kinematic structure.

5. REFERENCES

1. Antal, T.A. – *Visual Basic pentru ingineri*, Editura Risoprint, Cluj-Napoca, 2003;
2. Apro, K. – *Secrets of 5-axis machining*, ISBN 978-0-8311-3375-7, Industrial Press Inc., New York, SUA, 2008;
3. Brecher, C., Esser, M., Witt, S. – *Interaction of manufacturing process and machine tool*, CIRP Annals – Manufacturing Technology 58 (2009) 558–607;
4. López de Lacalli, L.N., Lamikiz, A. – *Machine tools for high performance machining*, ISBN 978-1-84800-379-8, Springer, Spania, 2009;
5. Mircea A. – *Contribuții privind modelarea și simularea structurilor cinematice ale centrelor de prelucrare și compensarea erorilor de poziționare și orientare ale semifabricatelor* – Teză de doctorat, Universitatea Tehnică din Cluj-Napoca, Cluj-Napoca, Romania, 2011.

MODALITĂȚI DE DETERMINARE A STRUCTURILOR CINEMATICE MINIMALE ALE CENTRELOR DE PRELUCRARE

Rezumat: Dezvoltarea din ultimii ani a tipurilor de mașini unelte a permis realizarea unor repere mai complexe, cu costuri mai scăzute. Identificarea structurii cinematice a mașinii-unelte necesare realizării unui reper este una din etapele care trebuie parcurse atunci când se realizează tehnologia de fabricație. De asemenea există mai multe variante de structuri cinematice care pot satisface necesitățile de prelucrare ale unui reper, însă există și situații când complexitatea operațiilor la care este supus un reper impune un studiu laborios al mișcărilor pe care trebuie să le execute mașina-unelte și/sau piesa. Ca urmare, prezentul articol prezintă un software al cărui rol este acela de a selecta mașina-unelte adecvată prelucrării unui anumit tip de piesă.

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