Selection of layout structure Geometry for Mini Milling machine by using Boolean-Algebra Method

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***Abstract*— This paper shows the details and results of operations concerning the selection of geometric kinematic structure for a modification in designed milling machine, with regards to the generation and pre-selection of the numerous variants with reference to present structure. The selection of a suitable layout can best be carried out by structural analysis using the Boolean-algebra technique (BAT). In this method, the machine tool structure of any complexity can be represented in the form of a combination of symbols (with 4 variants). By this technique from various alternatives (4!=24) get the best fit options which fulfill the all constraints and out of these options select the best fit option.(XYOZ)**

***Index Terms*—optimization, Structural design, Portable mini machine, Boolean –Algebra etc.**

I. INTRODUCTION

In the process of design and construction of a machine tool at the initial stage of developing the overall concept an appropriate geometric-kinematic structure (G-KS) must be selected. The correct solution of this task is particularly important in terms of the properties that are crucial for its future technical and operational indicators of the designed machine tool. Errors at this early stage cannot be improved by the subtlety of approach and diligent implementation of further stages. The machine tool's geometric-kinematic structure or layout design can be defined as the over-all picture of its structure and functional features, including the set of movements necessary to perform cutting tasks and distribution of these movements among the major units and components. Description of layout design or structural design should indicate the location of these elements in the carrying system of the machine tool. By this work the details and results of operations concerning the selection of geometric kinematic structure for a modification in designed mini milling machine, with regards to the generation and pre-selection of the numerous variants of its structure with reference to present structure. The selection of a suitable layout can best be carried out by structural analysis using the Boolean-algebra technique (BAT). In this method, the machine tool structure of any complexity can be represented in the form of a combination of symbols. Fig1.1 shows the main components of a vertical mill in a side-view.

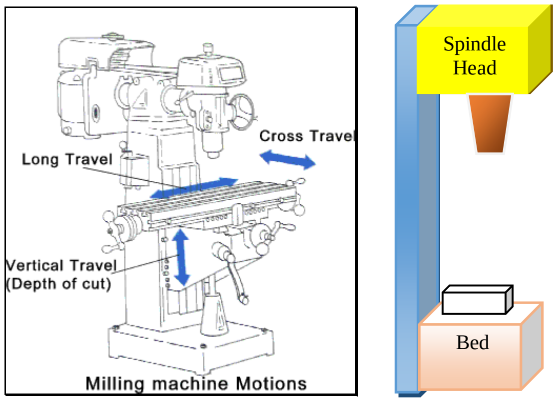


Fig.1.1 Basic milling machine

II. METHODOLOGICAL BASIS FOR THE SELECTIONOF GEOMETRIC-KINEMATIC STRUCTIRE OF THE MACHINE TOOL

The selection of a suitable layout can best be carried out by structural analysis using the Boolean-algebra technique. In this method, the machine tool structure of any complexity can be represented in the form of a combination of symbols. Let us introduce a set of symbols for this purpose. Let X, Y, Z represent the basic reciprocating displacements along the corresponding co-ordinate axes and U, V. W the additional displacements in the same directions. A, B, C represent rotary motions about axes X, Y, Z while D and E represent the additional rotary motions. The lower case letters of all the symbols defined above indicate the auxiliary setting motions for the corresponding coordinate axes. If individual element of the carrying system are attributed values on the axes on which they are moving rectilinear (X, Y, Z) or rotating around them (around the axes A, B, C) and the symbol O denotes the stationary body (Stand, bed, base) - then structural formula is constructed as follows: [work piece –WP] symbols of coordinate axes corresponding to the directions of movements of the successive elements of the carrying system and the determination of the stationary body. The stage of G-KS determination should be broken into the following phases:

1) Generation of complete set of G-KS variants for the entire class of machine to which the manufactured machine belongs
2) Pre-selection of the G-KS allowing for the structural

constraints

3) Analysis of selected properties of the carrying system in the variants which selected structural features
4) Comparative evaluation of variants and the synthesis of solutions; the choice of optimal structural variants, allowing for the consider constraints and the properties

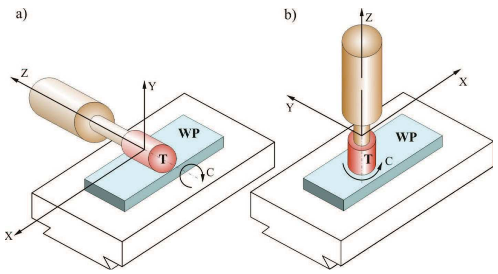


Fig 2.1 Coordinate system axis orientation for describing movements in (a) Horizontal and (b)vertical milling machines

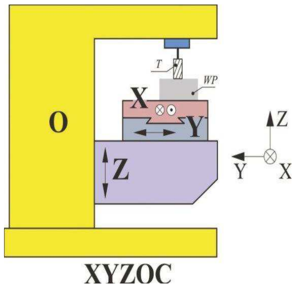


Fig 2.2: The carrying system and a formula describing the G-KS of vertical milling machine

Operations relating to the realization of stage 1-generation of the set of geometric kinematic structures of machine tools are illustrated in the fig 1.3

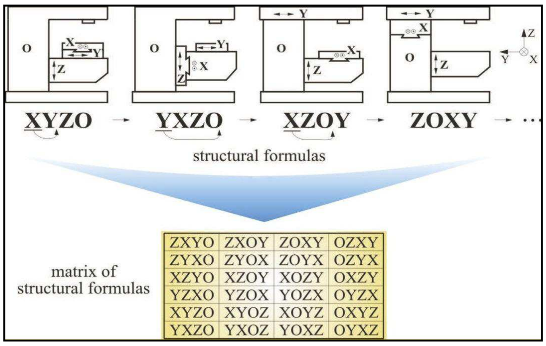


Fig 2.3 The generation of the set of G-KS variants in a machine tool with a three dimensional machining space and a vertical spindle axis orientation (in every structural formula the C symbol – spindle rotation around the Z axis – is omitted)

III. SELECTION OF OPTIMAL VARIANTS OF KINEMATIC STRUCTURE:

The description of the basic G-KS model includes mobile and stationary units forming the kinematic chain. Formalizing a general description of the model, the following symbols have been adopted to mark its components. The basic G-KS variant, can be recorded as: XYZO (in accordance with the formal conditions adopted). Performing permutation (without repetition) on the elements of basic design allows full array of possible options for structural design. This action can be presented in the form of the following relations:

$$T_{WS} = n! = 4! \qquad \ldots\ldots\ldots\ldots1$$

Where: T_{WS} – the array of structural design,

n – Number of G-KS modules under consideration.

In the presented case of four mobile modules and one stationary model, the use of equation1 gives 24 different variants of the structural code.

The set of these criteria has been defined based on the conclusion from the expectations analysis of mobile machine tools users. The method allows the user to adopt any number of conditions. Furthermore, the conditions have been formulated in a way ensuring the lack of interactions, which means that the order of applying various conditions does not affect the final result. Formally, the elimination conditions take the form of the structural code of corresponding to the selection criterion. The process of elimination takes place using Boolean operations on the adopted sets of conditions and a full array of structural models.

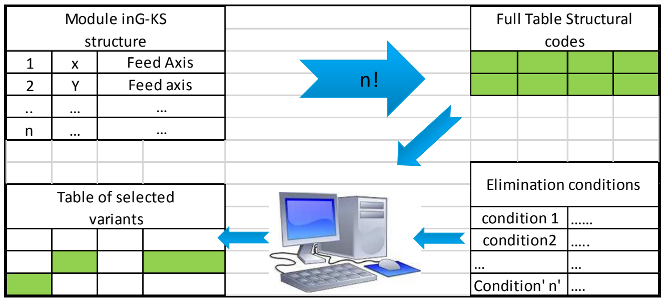


Fig. 3.1. G-KS – Elimination program scheme

IV. DESIGN OF STRUCTURE LAYOUT

There are four Stages in structural design by Boolean-algebra technique:

Stage 1: Generation of the set of geometric kinematic structures of machine tools

Stage 2: Pre-selection of the full set of G-KS variants that takes into account a structural constraint. Again, it is useful to draw on the concepts, information and formalization of operations.

Stage 3: Analysis of selected property of the carrying system in variants with selected structural features,

Stage 4: A comparative assessment of variants and the synthesis of solutions; the selection of the optimal structure in terms of considered constraints and characteristics

Stage 1: **Generation of the set of geometric kinematic structures of machine tools**:

The full set of GK-S variants was generated by the formal permutation of five components of the underlying structural model (e.g. in the form XYZO as in Figure 2.2). As a result, 24 GK-S alternative variants were obtained, whose entries were collected in a matrix of structural formulas, shown in Fig. 4.1

ZXYO	ZXOY	ZOXY	OZXY
ZYXO	ZYOX	ZOYX	OZYX
XZYO	XZOY	XOZY	OXZY
YZXO	YZOX	YOZX	OYZX
XYZO	XYOZ	XOYZ	OXYZ
YXZO	YXOZ	YOXZ	OYXZ

4.1matrix of structural formulas

Stage 2: Pre Selection with conditions:

Commencing the pre-selection of a set of GK-S variants, four most significant according to the work, constraints were chosen for the selection of the proposed machine tool. These constraints, taken from a study express the respective structural characteristics and the formal logical formulas, along with subsets of GK-S variants, as a result of operation of the given constraints on the full set of structures.

a) Condition 1:

- **The content of the condition:** the elimination of the impact of the weight of the work piece on the movement of a vertically moving unit.
- **Structural feature**: the work piece does not move vertically.
- **Logical formula of the condition:**

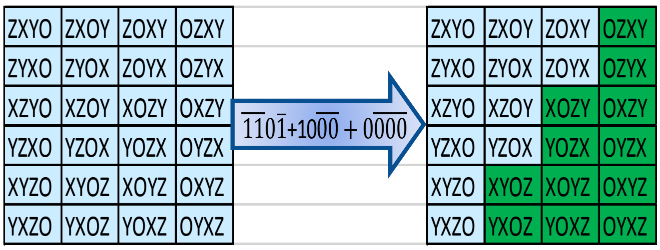
$$\overline{1}101+1\,\overline{00}0+0\overline{000}$$

Where: 1 : a carrying system unit moving vertically,

$\overline{1}$: a carrying system unit not moving vertically (negation 1).

$\overline{0}$: a carrying system unit that is not a stationary body (the negation of 0).

Operation of the condition:



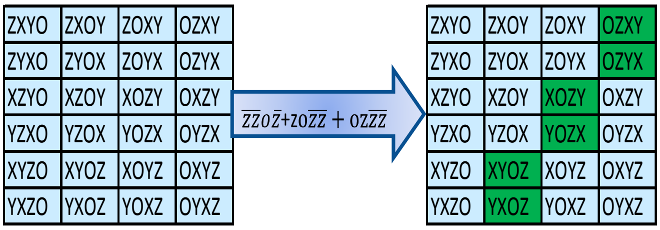
b) Condition 2:

The content of the condition: the ability to increase the path of the dead movement of a unit moving in the direction of the spindle axis (Z axis), in order to facilitate the easy of exchange of tools — without increasing the length of guide ways in charge of other movements.

Structural feature: a unit moving in the direction of Z axis is adjacent to a stationary unit in the "tool branch" of the carrying system.

- **Logical formula** $\overline{ZZ}OZ+Z\,O\overline{ZZ}+OZ\overline{ZZ}$
- Where: $\overline{Z}$ — a carrying system unit not moving in the direction of Z axis (negation Z).

Operation of the condition:



c) Condition 3

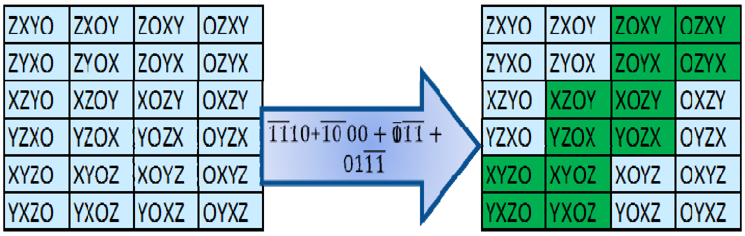
The content of the condition: increasing the structural stiffness of the machine tool

Structural feature: a unit moving vertically is adjacent to a stationary unit.

Logical formula:

$$\overline{1}110+\overline{1}000+\overline{0}00\overline{1}+0\overline{1}1\overline{1}$$

Operation of the condition:



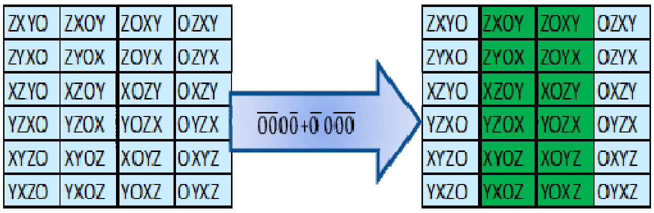
d) Condition 4

Content of the condition: masses of moving units are arranged in two branches ("work piece" and "tool"-related) of the carrying system of machine tool, there is no "pyramid" of weights.

Structural feature: movable units are arranged on both sides of the station, unit.

Logical formula: $\overline{000}0+\bar{0}\,0\,\overline{000}$

- **Operation of the condition:**



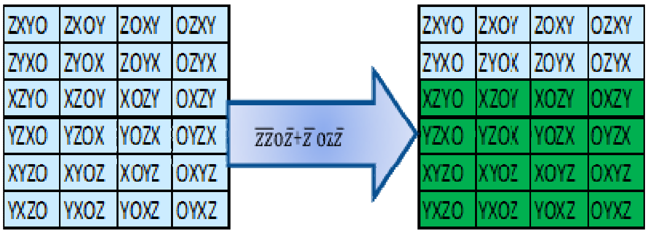
e) Condition 5

Content of the condition: Module of the highest weight should not move vertically

Structural feature: Z-axis should be behind the X or Y

Logical formula: $\overline{ZZ}0Z + \overline{Z}0Z\overline{Z}$

Operation of the condition:



The obtained results of the selection subsets of GK-S variants were then subjected to set multiplication, whose outcome as an intersection of sets is presented in Fig. 4.2.

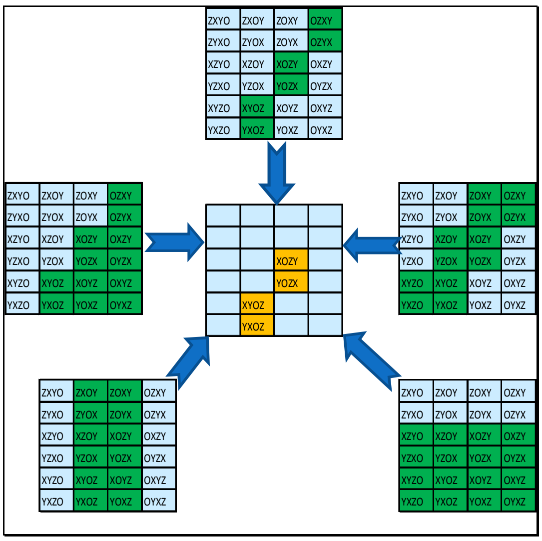
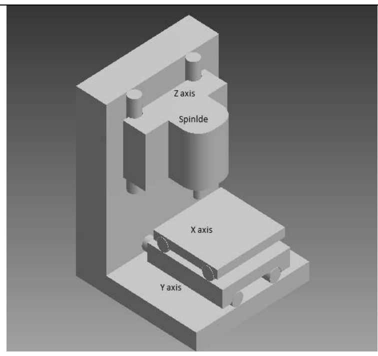
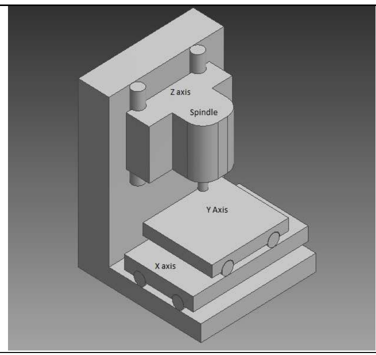


Fig.4.2 Result of a set multiplication of the selected G-KS

Subsets of the initially generated 24 variants of the GK-S, the pre-selection gave four variants, denoted with the structural formula: **XYOZ, YXOZ, YOZX** and **XOZY.** Moving of the Z axis and X or Y-axis mounting on Z axis table is straight way eliminate to get desire accuracy and minimizing the manufacturing and controlling optimization problem.

The CAD Representation of selected sets are shown as in table 4.1

Structural Formula	CAD Representation
XYOZ	
YXOZ	

The variants of geometric-kinematic structure that have been determined in the aforementioned manner are the basis for further designing stages consisting of an initial, simplified geometric modeling of the two variants of the guide way system calculations, in order to calculate their stiffness and select one final variant.

With the reference of above work on structural design by Boolean algebra & from the given analyses we can select the best structural design as a configuration of G-KS variants is XYOZC. The CAD assembly model is developed on Autodesk Inventor software and the design is shown in Fig. 4.3

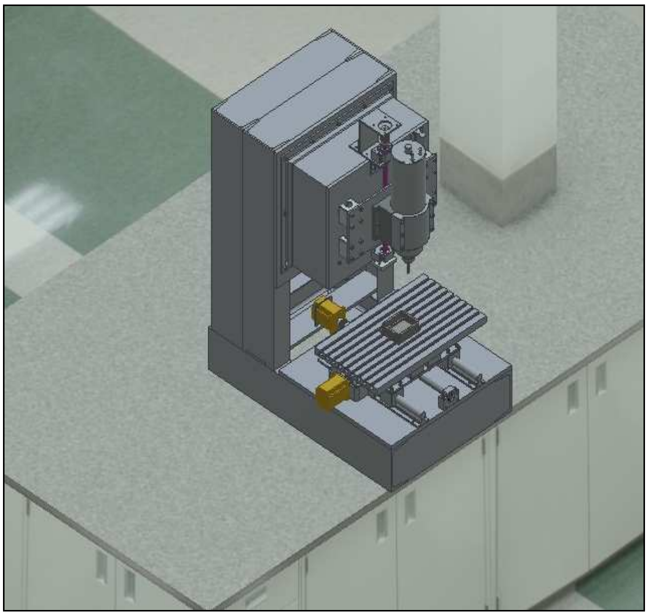


Fig.4.3 Proposed Mini Milling Machine

V. CONCLUSION

In conclusion, it was possible to formulate methods of selection of geometric and kinematic structure of the mini machine by specifying the design requirements and the development of the elimination conditions based on these requirements. From the combination of structural design with four variants i.e.24 finalize the result XYOZC (C is rotation of spindle attached on Z axis) by using Boolean algebra technique. The significant reduction in the number of variants has become possible and defining a set which best fulfilled the adopted criteria. Despite this, the final selection of the optimal geometric and physical structure (XYOZC) of the mini machine requires additional steps of determining such characteristics or properties that allow estimating individual solutions. The suggested model is on combination XYOZC which fulfill all the requirements of structural geometry and finalized with some orientation parameters.

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