Transfer Line for Manufacturing of Armatures for Electric Hand-Held Tools

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Abstract: **Subject of the presented research is an armature set used in manual electric tools. A methodology for assembly automatic lines design is developed and tested in regard of the mentioned subject. The methodology is presented in a block format and all interactions between the single stages are shown. On hand of a preceding optimal route trajectory developed by the authors 3 variants of automatic lines were generated, analyzed, evaluated and the optimal one was selected.**

Keywords: **automation, automatic line, armature, variability, optimal variant, 3D model.**

I. INTRODUCTION

Assembly automation is a complex, versatile and very labor-consuming process. Hard work is needed to feed the assembly positions and to perform assembly operations. To overcome this situation all major and backup assembly operations must be automated.

Some essential problems must be considered, among them: choice of appropriate automation subjects, optimization of the technological process for automated manufacturing, generating of structural variants of automated Manufacturing systems, analysis and evaluation of automatic lines (AL) variants and choice of the optimal one, determination of basic features of the automated complexes.

In most cases automation is done on hand of existing machines. As a rule the latter must have an automated work cycle and, if possible, a programmable control unit.

II. PROBLEM BACKGROUND

Aim of this research work is to design an AL based on the newly developed technology for automated production of armature Ø53. Following typical actions were undertaken: developing of AL oriented methodology; testing the methodology and generating of AL variants; design of the first work position (machine for gouge isolation); design of aggregate for coupling the second work position (winding machine) with the AL; design of the forth work position (wedging machine); design of the third work position (machine for welding the coil-ends with the commutator). For every single work positions 3 D models were prepared and based upon them typical aggregates underwent engineering analysis.

The article features 3D models of just one work position (the fourth one – wedging machine) due to page number restrictions.

III. AL VARIANTS– ANALYSIS, EVALUATION AND CHOICE OF THE OPTIMAL ONE

Automated Manufacturing of high quality armature is based on a preliminary developed technological process realized on an automated complex of the type automatic line (AL). Such complex is very appropriate due to the differentiation of technological operations.

Prior to the AL design a matching methodology oriented at the automated production of the chosen subject needs to be developed. In the given case the object is **Armature Ø53** (Fig.1).

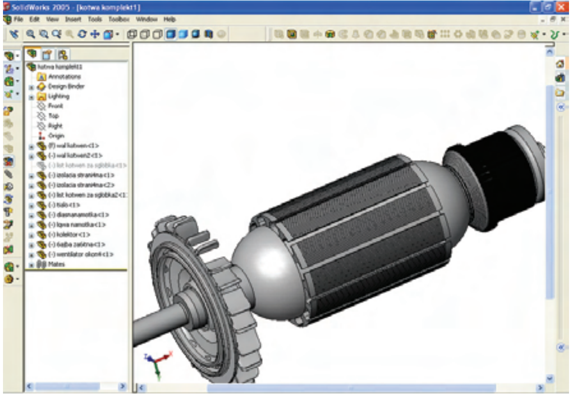

Fig.1 3D model of Armature Ø53

The methodology for AL design comprises:

- Synchronization and optimization of the technological process;
- Conceiving of AL variants;
- Defining the work positions number;
- Design of the single work positions;
- Design of the automated parts flow;
- Developing of the transportation and manipulation systems;
- Preparing of a preliminary specification for purchasable components of the intended AL ;
- Acquirement of the purchasable elements in line with the specification;
- Project conception development;
- Deliberation of variants, analysis, assessment and choice of the optimal variant;
- Simulation of the AL optimal variant functioning;
- Preparation of design documentation on hand of the ideational project;

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- Development of routine technology for production of original aggregates and assembly groups;
- Preparation of specification for production of original aggregates and assembly groups;
- Conceiving of schedule for producing and testing of aggregates and assembly groups;
- Development of methods for control tests of each aggregate and assembly group;
- Initiating a Journal for precise and detailed recording of surveillance results and corrections ;
- Exercise of active authorial control during the parts production and assembly in line with the time-table;
- Performance of functionality tests and verification of aggregates and groups according to test methodologies;
- Undertaking of fundamental repair operations on existing production machinery intended as parts of the AL;

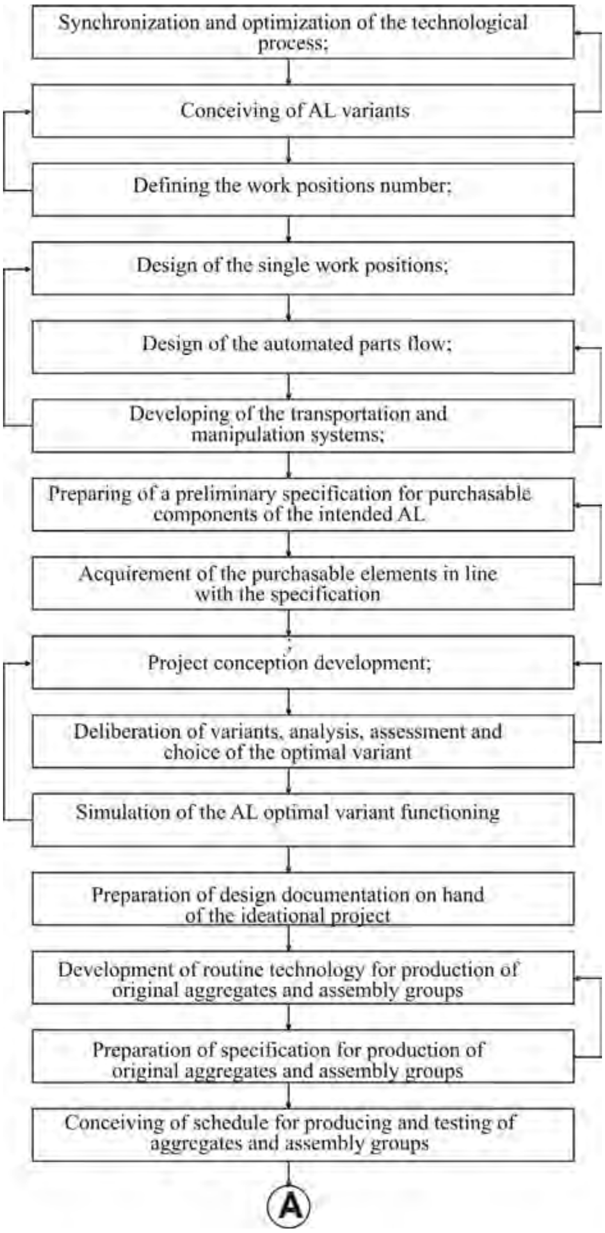

Fig.2a Methodology for design and implementation of Al for armature manufacturing

- Conceiving and coordinating of time schedules regarding assembly, tests and industrial implementation;
- AL assembly at the plant in cooperation with plant’s representatives under active authorial control;
- AL programming and tuning;
- Arranging of functional tests and pivotal production;
- AL tests and exploitation start at the plant;
- Conceiving and applying of Instructions for safe exploitation of AL;
- Training of AL operators selected among the plant’s staff;
- Assessment of the commercial efficiency of the AL implementation;
- Warranty maintenance and optimization of the AL;
- Conclusions from the AL implementation and conceptions for further researches.

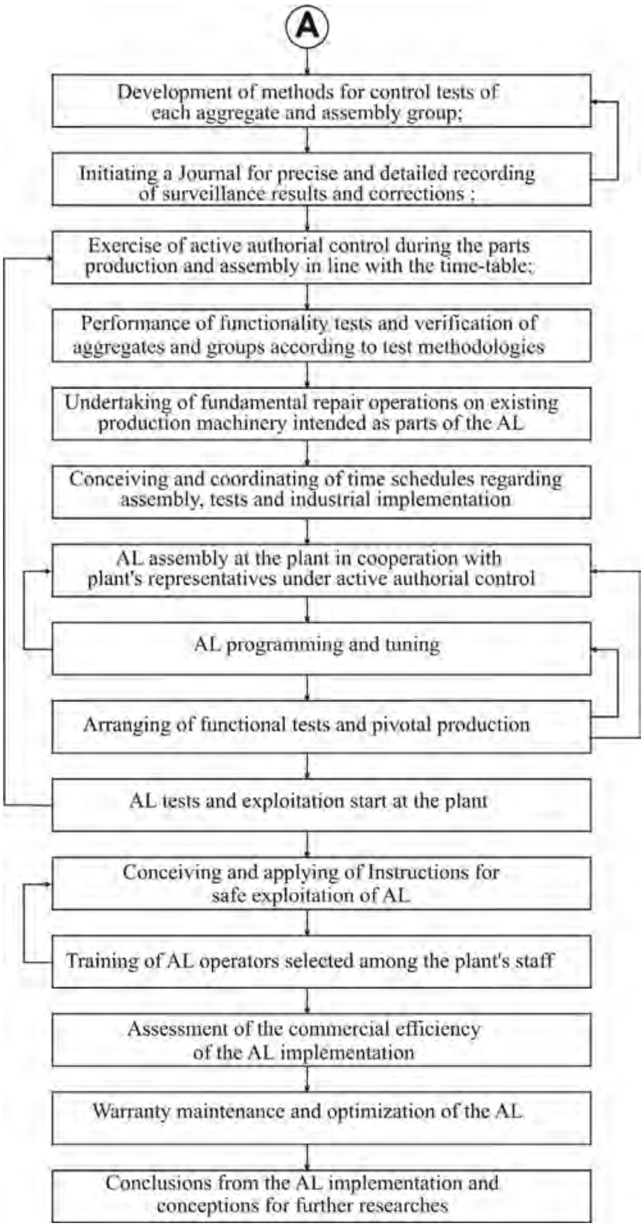

Fig.2b Methodology for design and implementation of Al for armature manufacturing

The above listed main stages and their interactions are visualized on Fig. 2a and Fig.2b.

The automation of the part flow must meet a series of requirements:

✓ The feeding with details automation must be “compatible” with the production machinery in a way that allows for repairing, tuning and operating activities;

✓ The feeding with details automation must provide for repair works and exploitation that are not depend on the machinery type;

✓ The feeding with details automation must lead to minimizing of machine delays in the Al;

✓ The feeding with details automation must guarantee a minimal change in the production machinery;

✓ The feeding with details automation must proceed with technical devices of a sophistication level similar or lesser than that of the existing machines (mechanical part, electrical control, pneumatic drive);

✓ The feeding with details automation must be least time and money consuming;

✓ The feeding with details automation must proceed with an optimal operations synchronization in order to minimize delays on the single work positions;

✓ The feeding with details must provide for a flexible interaction between work positions so that failure in one position does not harm the functioning of the others.

The assessment results for different variants of the technological process regarding the Manufacturing of high quality armature shows that the second one is optimal for a trajectory technology featuring a maximal summarized coefficient **K_{O2} = 1,182 (Table 1)**.

When generating AL variants for the production of high quality armature the bellow listed variables are put in use:

- Structural units type;
- Structural units model;
- Structural units drives;
- Structural units control;
- Transportation and manipulation modes
- Mutual positioning of structural units
- Types of positioning and fixing of processed parts
- Types of changing the automation objects;
- etc.

The basic AL variant includes a number of structural units:

- Work position for fixing of isolation sideline plates and the commutator.
- Work position for fixing full-scale groove isolation.
- Work position for winding the armature coils – 2 pieces.
- Work position for welding the coil-ends to the commutator channels.
- Work position for wedging the armature channels through isolation plates.
- Work position for testing the armature electrical parameters.
- Work position for armature impregnation with polyester pitch.
- Work position for fixing of disk and ventilator.
- Work position for armature balancing.
- Work position for end-control the armature electrical parameters.
- Stepper transporter.
- AL automatic control system.
- Work position for bearing fixing.

Table 1 Optimal trajectory technological process

№	Technological operations	Machine times [s]
1.	**Operation 1** - fixing of isolation sideline plates on the commutator – left and write and **Operation 2** – fixing the commutator	30
2.	**Operation 3** –fixing the full-scale groove isolation	12
3а.	**Operation 4** – winding of armature coils	48
3б.	**Operation 4** – winding the armature coils	48
4.	**Operation 5** – welding the coil-ends to the commutator channels	48
5.	**Operation 6** – wedging the armature channels through isolation plates	12
6.	**Operation 7** – testing the armature electrical parameters.	12
7.	**Operation 8** – armature impregnation with polyester pitch.	20
8.	**Operation 9** – fixing of disk and **Operation 10** – fixing of ventilator	30
9.	**Operation 11** – armature balancing	44
10.	**Operation 12** – end-control the armature electrical parameters	10
11.	**Operation 13** – fixing of a bearing	5

On Fig.3 the principal scheme of the basic AL variant is displayed.

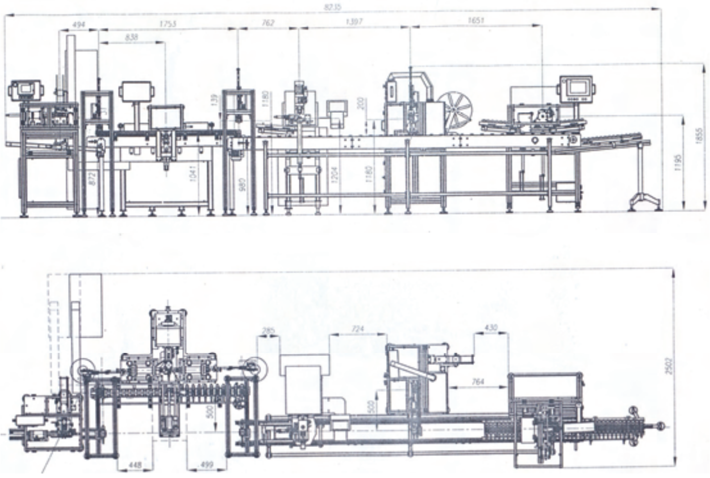

Fig.3 Basic AL variant

The basic variant poses as Variant 1:

- Work position for fixing of isolation sideline plates on the commutator.
- Work position for winding the armature coils – 2 simultaneously functioning pieces.

- Work position for wedging the armature channels through isolation plates.
- Work position (test stand) for end-control the armature electrical parameters.

The established work positions are modernized as follows:

- Work position for fixing of isolation sideline plates and the commutator.
- Work position for welding the coil-ends to the commutator channels.
- Work position for armature impregnation with polyester pitch.
- Work position for fixing of disk and ventilator.
- Work position for armature balancing.

The conception intends a manipulation and feeding system on each working station. The systems consist of industrial robots plus diverse automation devices executing according functions.

Two more variants with bellow listed features were generated:

- ➢ According to variant two all structural units must be repeatedly designed excluding the old work positions.
- ➢ Variant three is similar to the basic one except for the bearing assembly position..

Electronic control system variants meant for a concurrent, double-sided, co-axis processing of openings in closed constructions are assessed upon criteria including:

- Productivity
- Reliability
- Automation level
- Flexibility level
- Economic indicators

For designing of automation devices the most frequently used is the ***cycle productivity*** **$Q_ц$**.

$$Q_Ц = \frac{1}{t_Ц} = \frac{1}{t_P + t_{сп.н}}$$

where:

$t_ц$ cycle time;

t_P – machining time;

$t_{сп.н}$ – supporting non-overlapping time

An automation of existing units aims a maximal reduction of $t_{сн}$ in order to accomplish the highest possible productivity level.

With the development of modern automation devices the accomplishment of minimal cycle times is intended, i. e. both t_p and $t_{сн}$ to be of minimal values.

To reach **maximum productivity** levels the tact **τ** must be minimized.

$$\tau = \max\{t_{цi}, i = 1 \div m\} \rightarrow [\min]$$

Productivity is defined by the equation:

$$Q = 3600 / \tau \ \ [pc/h]$$

The cycle duration of the technological process of cleaning metallic surfaces before painting them depends on:

$$t_ц = \sum_{i=1}^{m} t_{цi} \rightarrow [\min]$$

where:

i – number of sequence of the technological operation;

$t_ц$ – total cycle time [s];

$t_{цi}$ cycle time of the i – numbered operation;

m – number of operations.

In many cases the main indicator for the productivity level is the rise in productivity λ, which considers the latter as a result of the automation compared with the status quo, i. e.:

$$\lambda = \frac{Q_a}{Q_0}$$

where:

Q_a – productivity level in the variant with automation

Q_0 - in the existing situation

For choosing an effective AL variant for Manufacturing of high quality armature relative (non-scaled) coefficients are applied and the summarized coefficient **K_{oi}** for each of the discussed variants i (i = 1÷ m; m – number of variants) is calculated.

$$K_{oi} = \prod_{j=1}^{n}(K_{ij}), \ i = 1 \div m$$

where:

n – number of non-scaled coefficients

As optimal is regarded the variant, which features a maximal coefficient **K_{oi}**, i. e.:

$$\max\{K_{oi}, i = 1 \div m\}$$

Following criteria (non-scaled coefficients) are applied:

$K_1 = \lambda$
$K_2 = K_Г$
$K_3 = K_A$
$K_4 = (1 - K_G)$
$K_5 = 1/n$

The described approach is more objective since it eliminates the factor of subjectivity and provides for the choice of the optimal solution.

Table 2 features the quantity values of non-scaled coefficients as well as the summarized coefficient for the separate variants.

Table 2 Quantity values of non-scaled coefficients

K_i **V_i**	**K_1**	**K_2**	**K_3**	**K_4**	**K_5**	**K_{Oi}**
V_1	**2,1**	**0,9**	**0,9**	**0,8**	**0,35**	**0,476**
V_2	**2,2**	**0,92**	**0,9**	**0,8**	**0,25**	**0,364**
V_3	**2**	**0,93**	**0,85**	**0,75**	**0,30**	**0,356**

$$\max\{K_{oi}, i = 1 \div m\} = \max\{0{,}476; 0{,}364; 0{,}356\} = 0{,}476$$

The assessment results for all variants prove that the first variant of AL for Manufacturing of high quality armature Ø53 is the optimal one hence it features a summarized coefficient **$K_{O1} = 0{,}476$**.

IV. CREATING 3D MODELS OF A WORK POSITION FOR AUTOMATED WEDGING OF GOUGE ISOLATION INTO THE GOUGE

Fig.4 shows the 3D model of a work position for automated wedging of gouge isolation material into the gouge. Backgrounds for creating the 3D model of the position are the basic armature parameters. The 3D models were created with the help of the CAD System Solid Works.

The work position for automated wedging of gouge isolation into the gouge comprises the following basic aggregates:

- 3D model of the base - Fig. 5
- 3D model of the carriage - Fig.6
- 3D model of the fixing mechanism - Fig.7
- 3D model of a mechanism for cutting and bending - Fig.8
- 3D model of a mechanism for submitting the wedge - Fig.9
- 3D model a mechanism for cutting the wedge - Fig.10
- 3D model of a mechanism for submitting the wedge material - Fig.11
- 3D model of a manipulator - Fig.12
- 3D model of a control desk - Fig.13

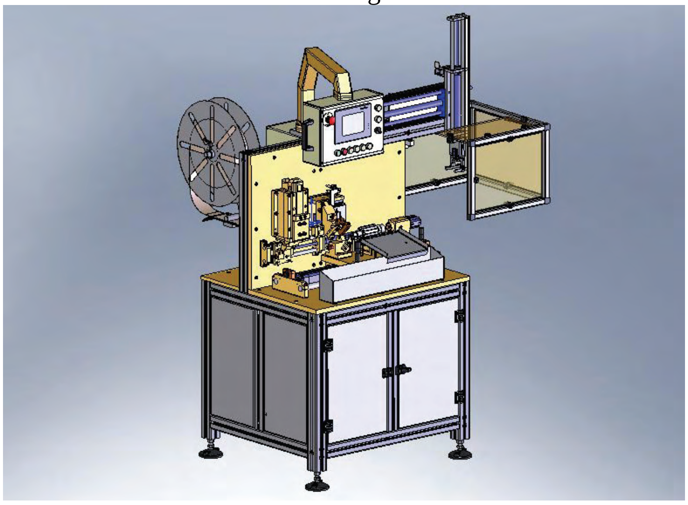

Fig. 4 3D model of a wedging machine

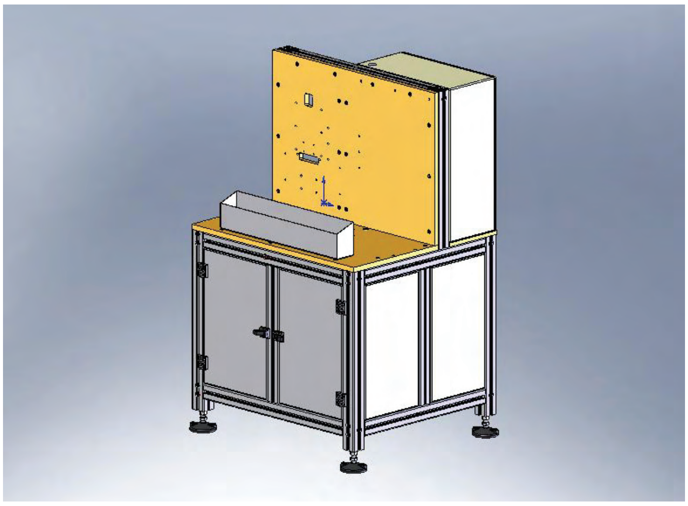

Fig.5 3D model of a base

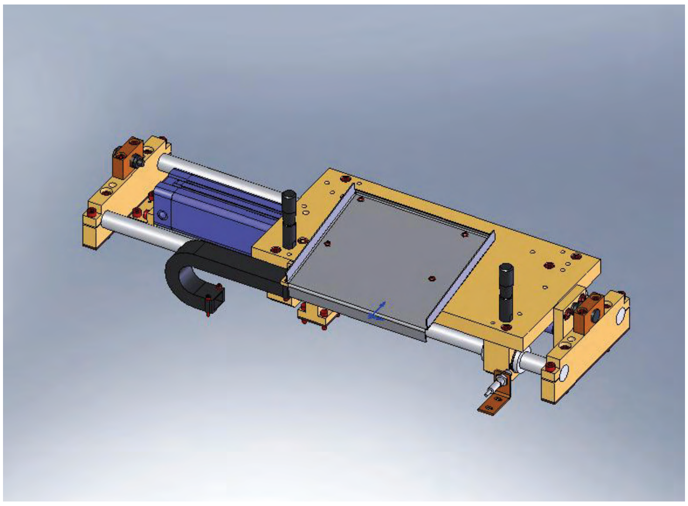

Fig.6 3D model of a carriage

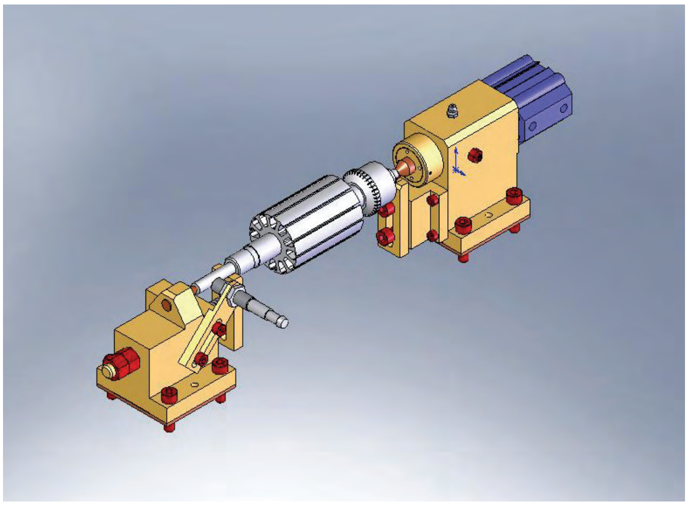

Fig.7 3D model of a fixing mechanism

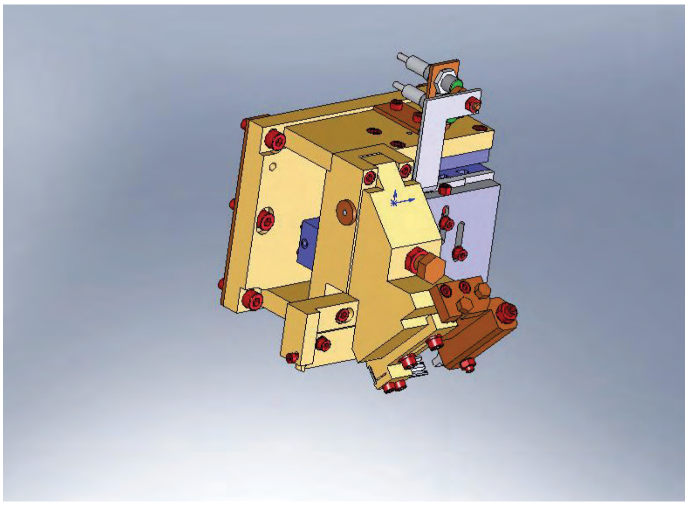

Fig.8 3D model of a mechanism for cutting and bending

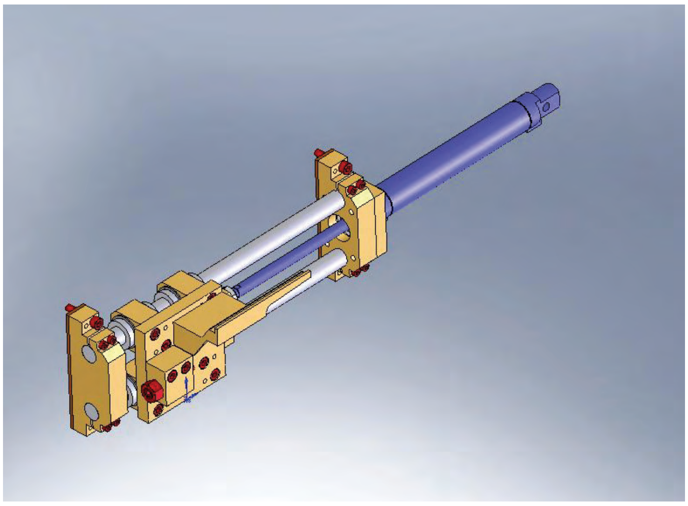

Fig.9 3D model of a mechanism for submitting the wedge

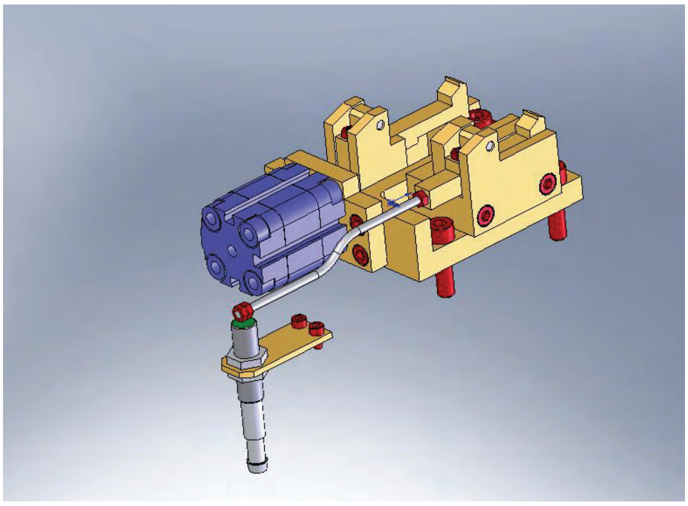

Fig.10 3D model a mechanism for cutting the wedge

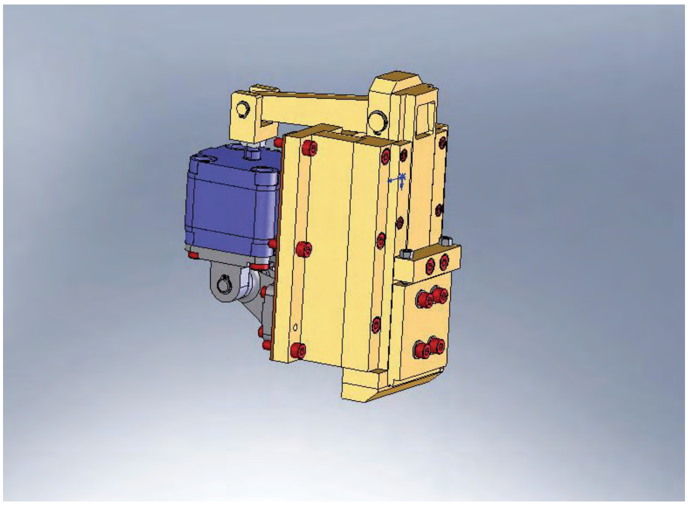

Fig.11 3D model of a mechanism for submitting the wedge material

Following the 3D models creation static and dynamic analysis were undertaken and the design documentation for an AL for armature Manufacturing were completed.

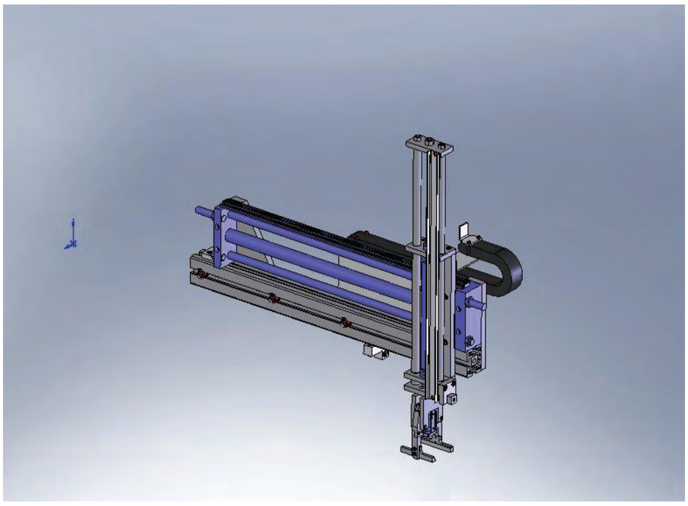

Fig.12 3D model of a manipulator

Fig.13 Prototype of automated lain

V. CONCLUSIONS

- Generated is an optimal technological process for automated assembly of an electrical engineering armature.
- Developed is a methodology aimed at designing automatic assembly lines. The methodology is tested in the armature assembly.
- Generated are variants of AL for armature manufacturing. The same are analyzed and evaluated and the optimal one is selected on the ground of the non-scaled-coefficient method.
- Created are 3D models of a work position for automated wedging of gouge isolation into the gouge.

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