Object-Oriented Engineering Test-Stand for a Double-Sided Co-Axial Processing of Openings in Products of a "Column" Type

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Abstract: **The report deals with methodology for design of a specialized stand. The problem for achieving the required accuracy is solved when manufacturing concentric holes in large welded parts. The suggested concept assures simultaneous manufacturing of the holes using special equipment eliminating in this way the mistakes from multiple positioning.**

Key words: **automation, object-oriented engineering test stand, "column" type products, co-axial processing, 3D models**

I. Introduction

The processing of co-axial openings with classical methods often leads to inaccuracies negatively affecting the product qualities. This is the case especially with welded objects where lingering tensions can be observed. Objects of the presented research are column-type products that are distinguished through their large sizes and significant weights.

II. Problem stating

Aim of this research is the building of an engineering test stand (ETS) for automated processing of openings in welded "column" type constructions and to identify their disadvantages. The following action types were performed: defining of technical parameters for the engineering test stand; defining of requirements towards the test stand (technical, economical etc.); development and testing of a methodology; conceiving of structural variants; variant analysis and choice of the optimal one; completing of technological documentation for original parts Manufacturing; completing the Manufacturing schemes and drawings; conceiving of typical units and aggregates.

III. Definition of technical parameters and requirements for the test stand

No preliminary inquiries suggested the presence of any technical solutions allowing a simultaneous double-sided coaxial processing of welded products.

The test stand must consists of:

- **Body** providing possibilities for fixing and functionally combining transporting and power components. The body has to be composed on the base of special corpus elements;
- **Transportation-fixing elements** allowing to pass the welded construction between work positions, to allocate and precisely fix it according to a determined in advance position and to guarantee a resistance to cutting forces. Those elements include:
  - **One horizontal linear table** for transportation (passing) alongside the X- axis;
  - **Two vertical tables –** for transportation (passing) of power elements alongside axis У and $У_1$ via a movable carriage on roller guideways; the motion is created by an AC motor with break gears and gear reducer with a ball screw; the change of position is accounted for by a increment line;
  - **Two movable carriages** driven by an AC motor with break gears and gear reducer with a ball screw; The exact positioning is guaranteed by hydraulic break gears.
  - **Two turntables** – for securing the moving and passing of tools along axis Z and W. They are driven by AC motors and the position changes are accounted for through PES.
- **Power components** for providing the basic rotational cutting motion; the cutting is performed by two power heads driven by AC motors; the change of tools follows over a hydraulic collet; the spindle balancing is mechanically done;

The design and building of ETS requires:

- To conceive an one-position test stand of the "combine" type permitting the execution of various technological processes and operations like: boring, chafing, jig-boring, drilling through interpolation (spiral-like), screw threading.
- To guarantee technical potential allowing the performing of different operations on the test stand:
  - Boring of holes with diameters in the range from 3 to 50 [mm] and standard tolerance level IT12.
  - Chafing – openings with diameters in the range from 3 to 50 [mm] and standard tolerance level IT6 and rancidity Ra from 1.25 [μm] to 0,32 [μm].

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Jig-boring – openings with diameters up to 150 [mm], maximal tolerance level IT6, level 6 in geometrical accuracy and rancidity R_a=1,6 [μm]

- Milling – surfaces with rancidity R_a=5 [μm]
- Cutting of screw treads in the range M4 to M32 and level 6 in the geometrical
- Positioning accuracy – ±0.005[mm]
- Repeatability of positioning –±0.005[mm]

The ETS design seeks to introduce a planned innovative technology and to satisfy several economic requirements and indicators:

- ➢ Rise in productivity - double;
- ➢ Rise in quality and reduction of droppings – 20%;
- ➢ Investment reimbursement – 3 years;
- ➢ Exploitation duration – 15 years.

IV. CONCEIVING OF STRUCTURAL AND COMPOSITION VARIANTS – METHODOLOGY, TESTING, ANALYSIS AND CHOICE OF AN OPTIMAL VARIANT.

Prior to the AL design a matching methodology oriented at the automated production of the chosen object needs to be developed. In the given case the object is a product of the “column” type.

The methodology for design of an engineering test stand for (ETS) for automated processing of openings in welded “column” type constructions comprises stages listed below:

- ➢ Synchronization and optimization of the technological process;
- ➢ Generating of engineering ideas;
- ➢ Conceiving of variants;
- ➢ Definitions of parameters for the working zone;
- ➢ Definition of kinetic parameters;
- ➢ Ideation project generating;
- ➢ Variant analysis and evaluation;
- ➢ Choice of the optimal variant;
- ➢ 3D model of the chosen optimal EST variant;
- ➢ Simulation of the EST functioning;
- ➢ Definition of main EST indicators;
- ➢ Design of basic EST units;
- ➢ Design of fixing and positioning devices;
- ➢ Design of EST equipment;
- ➢ Optimization of the work cycle;
- ➢ Preparing of a preliminary specification for purchasable components of the intended EST;
- ➢ Design of CNC system for EST;
- ➢ Acquirement of the purchasable elements in line with the specification;
- ➢ Preparation of design documentation on hand of the ideational project;
- ➢ 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 EST;
- ➢ Conceiving and coordinating of time schedules regarding assembly, tests and industrial implementation;
- ➢ EST assembly at the plant in cooperation with plant’s representatives under active authorial control;
- ➢ EST programming and tuning;
- ➢ Arranging of functional tests and pivotal production;
- ➢ EST tests and exploitation start at the plant;
- ➢ Conceiving and applying of Instructions for safe exploitation of EST;
- ➢ Training of EST operators selected among the plant’s staff;
- ➢ Assessment of the commercial efficiency of the EST implementation;
- ➢ Warranty maintenance and optimization of the EST;
- ➢ Conclusions from the EST implementation and conceptions for further researches.

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 POAWS;
- ✓ 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.

For the products considered in this article the basic technological route sets Varian 1. In Variant 2 the technological operations are performed consecutively and in any given moment a toll positioned in one of the spindles is active. In Variant 3 small openings are processed simultaneously multi-spindle devices.

The assessment of results for different variants of the technological process shows that the first one is optimal for a trajectory technology featuring a maximal summarized coefficient $\mathbf{K_{O1} = 0,396}$.

Table1 shows the application of typical technological route for double sided coaxial processing of the product type “Column 6040818".

When generating variants of an ETS for double sided coaxial processing the bellow listed variables are implemented:

- 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

Fig 1 displays principle schemes of the single variants. The variant shown in Fig. 1 is considered as a basic one.

➢ The basic variant (Variant I) comprises following components:

- Base;
- Longside table with transmission;
- Cross-table with 2 transmissions – left-handed and right-handed;
- Columns with spindle holding transmissions - left-handed and right-handed;

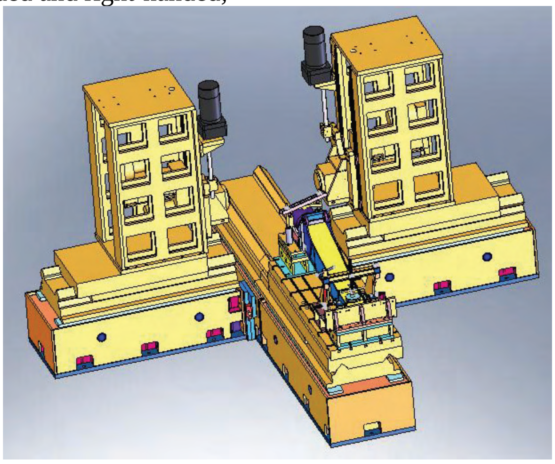

Fig. 1. 3D Model of the basic variant of an ETS for double sided coaxial processing of openings in welded constructions

- Spindles with drives - left-handed and right-handed;
- Positioning and fixing device for processing the product type “Column”;
- CNC system.

Table 1 Typical technological route for double sided coaxial processing of the product type “Column 6040818"

№	Operation title	Tool		Cutting mode		
				V[m/min]	**S**[mm/r]	**n**[min^{-1}]
0	Fixing the part in the device in bases A and B			-	-	-
20	Part centring			-	-	-
30	Jig-boring of opening A	ТИ 002-01-2004	Г	60	0,1	300
			Ч	80	0,07	390
40	Jig-boring of opening B	ТИ 002-01-2004	Г	60	0,1	390
			Ч	80	0,07	510
50	Jig-boring of opening C"	ТИ 002-01-2004	Г	60	0,1	325
			Ч	80	0,07	425
60	Boring of 2 openings X	Borer	Ц	30	0,05	910
			П	20	0,07	750
70	Boring of 2 openings Y	Borer		-	-	-
80	Drilling of surface A"	Front milling machine		50	0,2	320
90	Boring of 3 openings on "Surface A"	Borer	Ц	30	0,05	765
			Г	20	0,07	620
100	Manual - chamfer 1x30° for opening "B"	Manual shutter		-	-	-
110	Cleaning of all sharp edges			-	-	-
120	Self regulation			-	-	-
130	Filling in of individual control card			-	-	-
140	Part unloading			-	-	-
150	Cleaning of the device and machine table			-	-	-
160	Cleaning of particles from the rough processing of openings A and B, change of tools			-	-	-
Legend: Г – rough processing, Ч – clean processing, Ц – central boring, П passage boring Г – blind boring						

Two more variants with typical features were generated:

Variant II – Used are the same structural elements as in Variant 1.This variant intends 2 devices for positioning and fixing of the processed part and a table with extended length. When a part is processed on the second ETS device it is possible to remove the finished product and to proceed with the next one’s positioning and fixing. Thus the supporting non-overlapping times needed to change objects can be reduced.

Variant III uses the same structural units. Two spindles process the large openings while two more do the same with the smaller ones. Thus the technological cycle time can be diminished, yet on the other hand the equipment's design becomes more complex and complicated. The complications with the design are due to the fact that for proper functioning the spindles must be granted independence from each other.

The variants of an ETS for double sided coaxial processing are assessed upon criteria including:

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

For choosing an effective ETS variant for double sided coaxial processing relative (non-scaled) coefficients are applied and the summarized coefficient $\mathbf{K_{oi}}$ for each of the discussed variants i (i = 1÷ m; m – number of variants) is calculated.

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

where:

n – number of non-scaled coefficients

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

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

Following criteria (non-scaled coefficients) are applied:

$$\left| \begin{array}{l} K_1=\lambda \\ K_2 = K_\Gamma \\ K_3 = K_A \\ K_4 = (1 - K_G) \\ K_5 = 1/n \end{array} \right.$$

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

In our case the method of non-scaled coefficients will be applied in order to perform a qualitative analysis prior to choosing the optimal variant. Table 2 features the quantity values of non-scaled coefficients as well as the summarized coefficient for the separate variants.

Assessed are the next three variants:

- **Variant 1** – Basic variant featuring one device for fixing the processed part and two swindles for parallel processing of the openings.
- **Variant 2** – features 2 sections for fixing the processed parts.
- **Variant 3** – characterized by 4 swindles: 2 for the large and 2 – for the small openings.

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	0,7	0,7	0,3	0,278
V_2	2,3	0,85	0,8	0,7	0,2	0,219
V_3	2,5	0,75	0,7	0,7	0,15	0,138

$$\mathbf{max\ \{K_{oi},\ i = 1 \div m\ \} = max\{0,278;\ 0,219;\ 0,138\} = 0,278}$$

The assessment results for all variants prove that the first ETS variant for double sided coaxial processing of is the optimal one due to the summarized coefficient value $\mathbf{K_{O1} = 0,278}$.

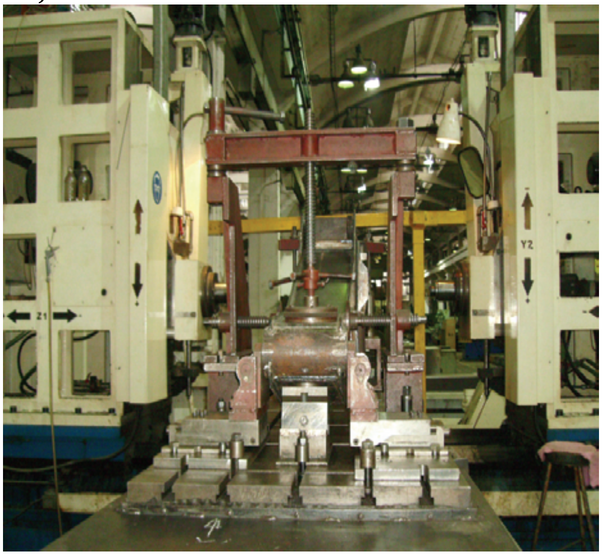

Fig. 2. Prototype of automated machine

V. PLANNED PARAMETERS FOR THE PLANNED ETS

The design and building of the test stand must reach following technical characteristics:

- Controllable axis - 5;
- swindles 2;
- simultaneously controlled axis - 3;
- maximal range of the tools:
  - along axis X-2700 [mm]
  - along axis Y_1 and Y2 -720 [mm]
  - along axis Z и W -500 [mm]
- functional passage along the axss:
  - по ос X -1 ÷2000 [mm/min]
  - по ос Y_1 и Y_2 - 1÷6000 [mm/min]
  - по ос Z и W -1 ÷ 4000 [mm/min]
- скорост на бързите премествания по осите
  - along X-up to 2 [m/min]
  - along Y_1 and Y_2- 6÷9 [m/min]
  - along Z and W -4÷5 [m/min]
- swindle spins -10÷2000 [min^1]

CONCLUSIONS

- Developed is a methodology aimed at designing an engineering test stand (ETS) for automated double sided coaxial processing of openings in welded "column" type constructions.
- Generated are variants of an engineering test stand (ETS) for automated double sided coaxial processing of openings in welded "column" type constructions. The same are analyzed and evaluated and the optimal one is selected on the ground of the non-scaled-coefficient method.
- Created is 3D model of the basic variant of an engineering test stand (ETS) for automated double sided coaxial processing of openings in welded "column" type constructions. The model is used for performing of engineering analysis, generating of control software and completing the Manufacturing documentation.