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AUTOMATIC DRILLED HOLES POSITION CORRECTION FOR A SHIP WINDOW

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Abstract

The article presents how to measure and correct the position of the holes on the example of the ship window frame. Ship window frame is manufactured from welded blank and then bent on the bending machine and welded. In order to minimize shape deformation the frame is straightened by hand. Linear dimensions of the frame are about three times larger than the dimension of the location of the holes relative to the edge of the frame. The quality criterion for ship window requires all drilled holes to be located in a straight line. To reach this goal a special procedure was developed to distribute holes in the frame on the base of the window frame shape deviations measured first before drilling. In the following section design of a special machine tool– coordinate drill equipped with a measuring head, as a unit being able to measure and drill automatically. It allows to shuttle processing of frames and to simplify their identification. Construction of the drive and control machining is also presented. The machine has been implemented in a local company, which is a global leader in the production of ship windows.

Keywords: *position correction, ship window, shape deviations*

1. Introduction

Production of marine equipment, carried out by specialized companies, is characterized by a not very large series of windows of differing geometric features. This forces the use of flexible production, which can quickly be adapted to new products. Ship windows are the outer structure of marine equipment and aesthetic factors are very important. Windows mounted in the hull of the vessel must hold dimensions of the frame for their proper assembly. The windows often have other features too, such as translucency in various weather conditions, fire and radiation protection, and others. The requirements and economic balance of shipowners, enforces automation for this kind of production.

2. Frame manufacturing technology and sources of frame shape errors

Ship windows consist of a frame window and glass package with elements attaching it to the frame. A exemplary window is shown in Fig. 1, the frame cross section elements of the package mounting shaft is shown in Fig. 2. The technological process of manufacturing marine window frames consists of the following steps:

- generate a workpiece in a T-profile form. It is obtained by linear welding of a structural steel flat bar with a stainless steel rod of square section. Due to the unbalanced position of the rod relative to flat profiles during bonding the workpiece will get large plastic deformation in two planes. To compensate deformation, the rolling mill or if necessary the hydraulic press is used, to improve straightening,
- bending frame corners on CNC bending machine,
- closing the frame with butt welding unit,
- weld treatment on a special CNC milling [1],
- straightening of selected frame parts,
- machining of the holes,
- painting,
- assembly of the window.

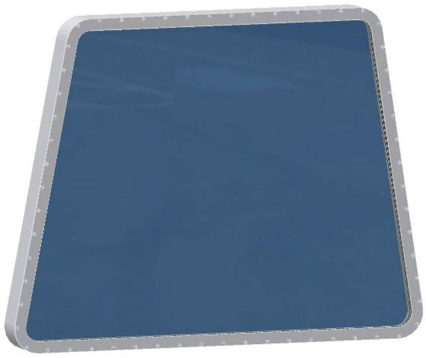


Fig. 1. Design form of ship window

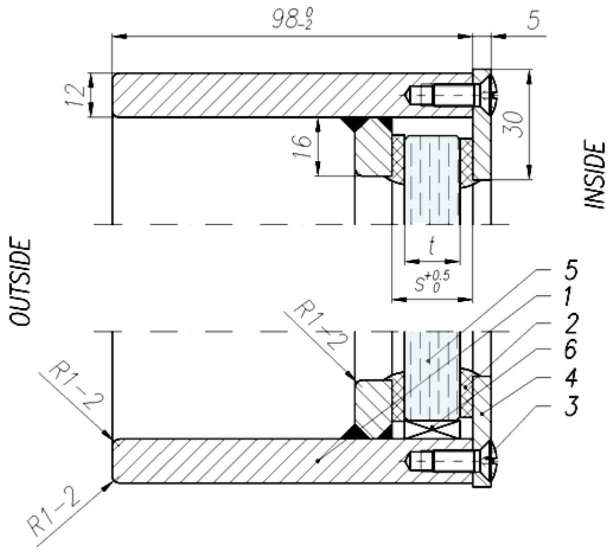


Fig. 2. Window ship cross section: 1 - window frame, 2 - rubber seal, 3 - screw cap, 4 - windows fixing package overlay, 5 - windows pack, 6 - spacing insert

An important component of the technological process is to implement a package of shaft holes. These holes are made simultaneously in frame 1 and overlay 4 and serve to attach the glass package 5 with gaskets 2 and spacers 6 by means of fixing package 4 and screw caps 3. The design documentation specifies the number and location of the holes relative to the edges of the frame. Due to the large dimensions of the frame and the class of accuracy adopted for machining, we are dealing with shape errors of the same order of the dimensions determining the position of the hole in the transverse direction to the frame (the frame in cross section). In practical realization the location of the hole was obtained by measuring the distance from the edge of the frame to the drilled hole. Holes were made to the mid-thickness of the frame. Because for all the holes that distance was the same, the location of the holes relative to the external frame of reference had errors similar to the shape errors of the window frame. Tab. 1 shows the frame shape errors occurred, in the example of a rectangular frame, these errors also occur for frames in the shape of a parallelogram, trapezoid, and others.

3. Theoretical background to hole position correction

The task to improve the visual geometric features consisted on the distribution of the position of the holes in a way that they lied on one line and at the same time that their outline didn't reach the edge of the frame by a distance shorter than 0.5 mm. Efficient was to carry out measurements of the frame attached to the machine tool table and then adjusting the position of the holes. Measurements carried out in the holes framework are presented in Fig. 3:

- in the corner of the frame, in the middle of the arc,
- at points distant by a fixed amount from the end of the arc corner of the frame,
- in a certain number of points equally spaced on the straight parts of the frame.

To carry out framework measurements measuring sensors adapted for this purpose were used in the tip. Foray to the measuring point was carried out in a direction perpendicular to the theoretical position of the frame. The observed deviations of the dimensions correspond to the 13 accuracy class curved window frame. For a window with a length of 3000 mm it corresponds to a tolerance of 3.3mm. Hole spacing with constant distance is not possible: the holes located on the edge of the sheet metal would exceed the 12mm thickness. Thus, their location must be designated for each processing case individually, Fig. 3.

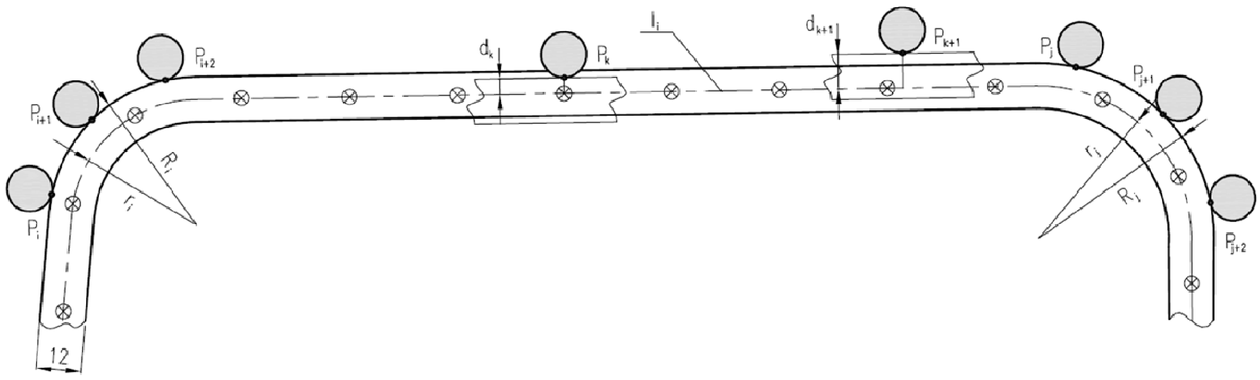
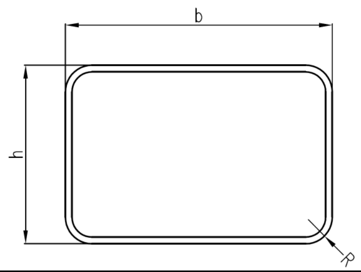
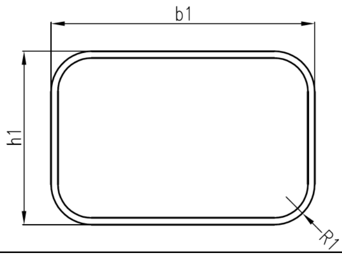
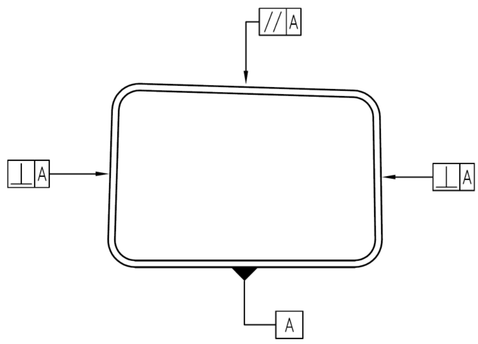
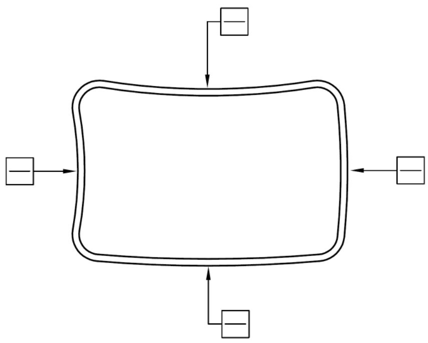
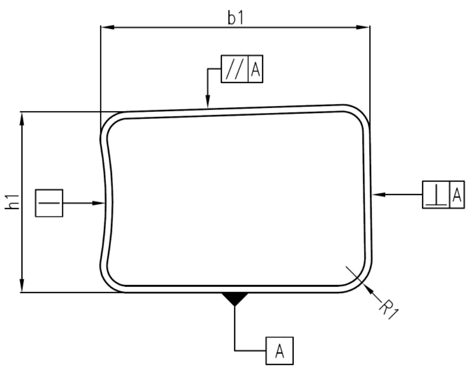


Fig. 3. Determining the line of holes

Tab.1. The most common errors in the shape of the window frames

Original frame shape	Common errors description
	Correct frame
	Errors in the linear dimensions of the frame: width and height, radius values errors
	Parallelism and squareness errors of the window frame sides
	Frame sides straightness errors
	Superposition errors: • frame linear dimensions: width and height, radius, values errors, • parallelism and perpendicularity of the sides of the window frame, • frame side straightness.

A drilling procedure starts with the designation of hole centre i and the corner-rays R_i and spacing of the holes arc $r_i = R_i$ - 6 mm. The line of openings between successive corners l_i will be tangent between them. To determine the possibility of a correct implementation of the holes is sufficient to calculate the distance d_k of the measuring points P_k made on the straight parts of the frame to the corresponding tangents l_i [2]. The distances satisfying the condition $3.5 \leq d_k \leq 8.5$ are the basis for analysis termination. It's then possible to determine the coordinates of the desired number of holes evenly spaced on the holes line. Distances not meeting the above condition for the M6 thread used disqualify performed calculations, but are however the basis for further search for a correct solution. They generally consist in modifying the position of the line of holes l_i depending on the condition of not meeting the acceptable values of d_k and the position of a particular "defective" point relative to the radius corner. The modification consists in the rotation of the line corresponding to the center of the radius of the right corner and its offset. Such a case requires correction of the position of the holes on the line of the corner holes arc. It comes down to the calculation of the spacing distance of the measurement points of the new corner holes line and verifying the condition of correctness of the position of the hole.

4. Construction of a machine tool to drill holes with automatic placement correction

For the practical implementation of the automatic position correction in terms of production, construction of a special CNC drilling unit equipped the measuring system was economically justified. Following design assumptions were specified, they were the basis for constructing a technical project:

- frame radiuses measurement,
- frame sides measurement,
- frame height measurement in the corners and on the frame straight sides,
- tool length measurement,
- uniform distribution of the holes,
- correction of position holes in a direction perpendicular to the frame,
- automatic tool change,
- performed operations: pre- drilling, drilling, post- drilling, counter boring, threading,
- generating g-code file compliant with a ISO code,
- archiving actual shape of the frame and the position of all drilled holes.

Drilling machine is presented in Fig. 4 and 5. Drilling machine consists of guides 1, where portal 2 moves in the X direction. On the portal there are guides 3, where support 4 moves in the Y-axis direction. Support is equipped with head 5 moving in the Z axis direction. Drilling machine is equipped with two work tables 7, built on the guides 6, which allow you to work interchangeable. The workpiece is fixed to the machining table with lever handles and then the table is moved in the area of machining and then is set and fixed in the base position. The second table at this time is in the outer position which allows the secure exchange of the workpiece. After starting a job cycle the frame at the characteristic points is measured. At the frame measuring cycle is pushed (by the cylinder) out of the enclosure, and moves at the measuring points in the perpendicular to the frame direction. After the measurement at the given point, and probe tip is moving away, and measuring head will move to the next measuring point. Measuring tip is coupled to the sensor using magnetic clutch that allows disconnection in case of collision at crossings – Fig. 6. To machine holes in the frame special sequence of tools will be used: countersinking, ø5, ø6.5 drill, countersink and tapered with tap M6 holder for threading.

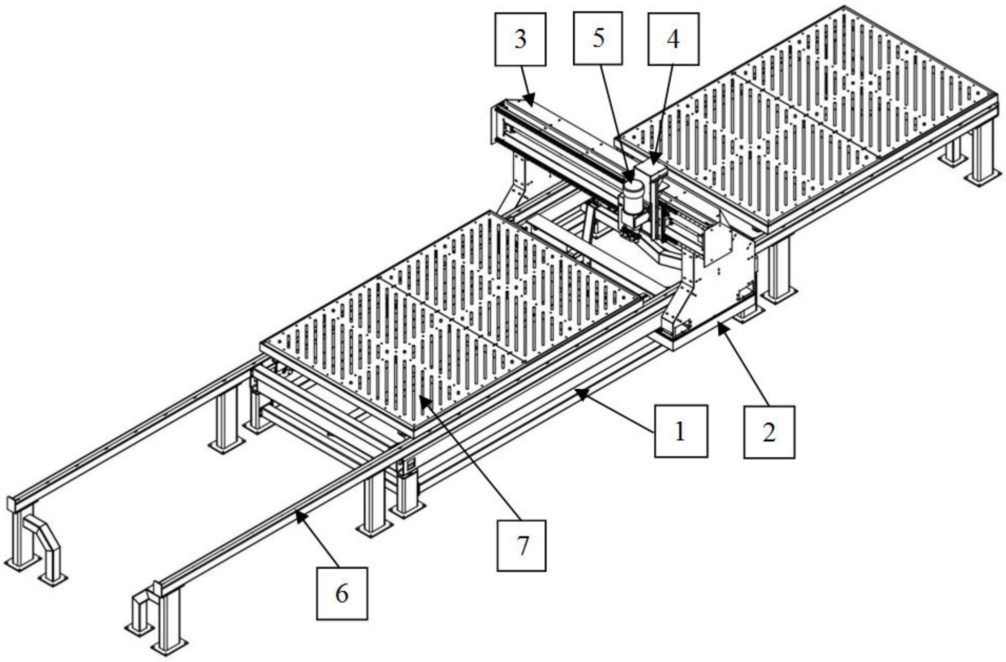


Fig. 4. Main elements of the drilling machine

Fig. 5. View of drilling machine specialized for ship frames

Fig. 6. Automatic measuring cycle of the ship frame

5. Machine tool drive and control

Control of the machine tool has been designed using Mitsubishi elements: FX3U driver [3] with positioning module, and MRJ3 series servos. These servos allow to work with a resolution of 18 bits which gives 262,144 pulses per screw revolutions. Positioning module allows independent work of both axles on the interpolation work and we have choice here, among other things, linear interpolation, circular, etc. For spindle motor control the inverter from Mitsubishi [4] was used, which is attached to the PLC driver. Control system block diagram is shown in Fig. 7 and the practical implementation we used in Fig. 8.

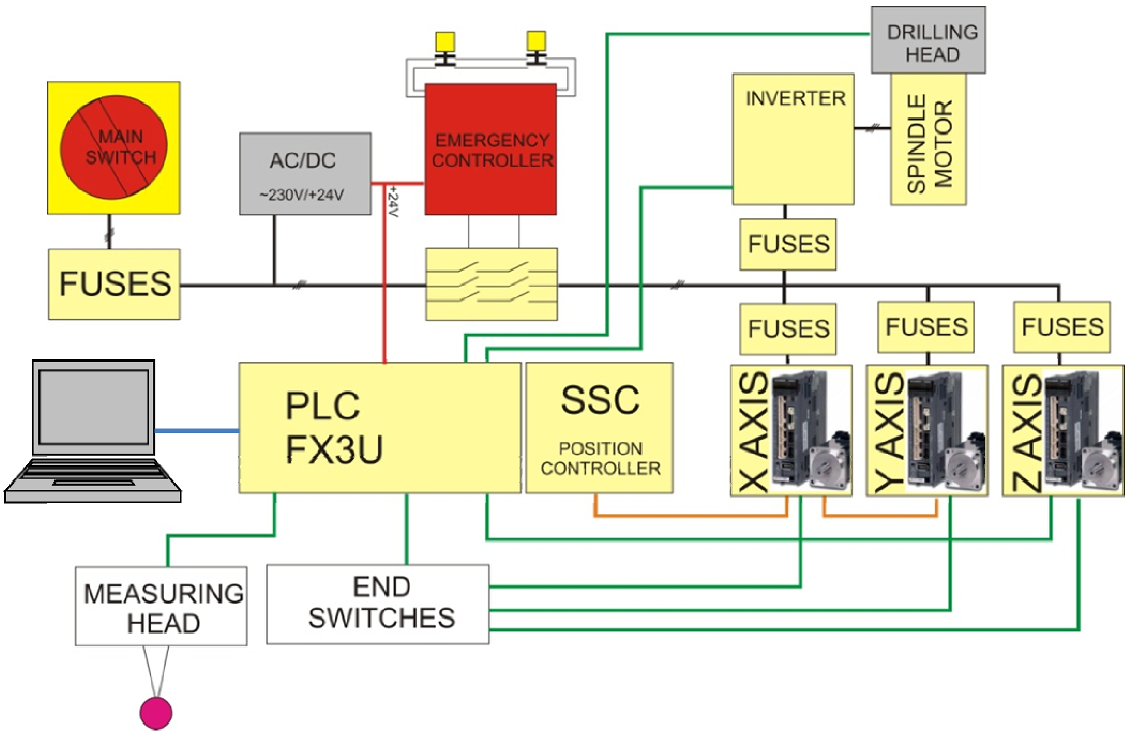
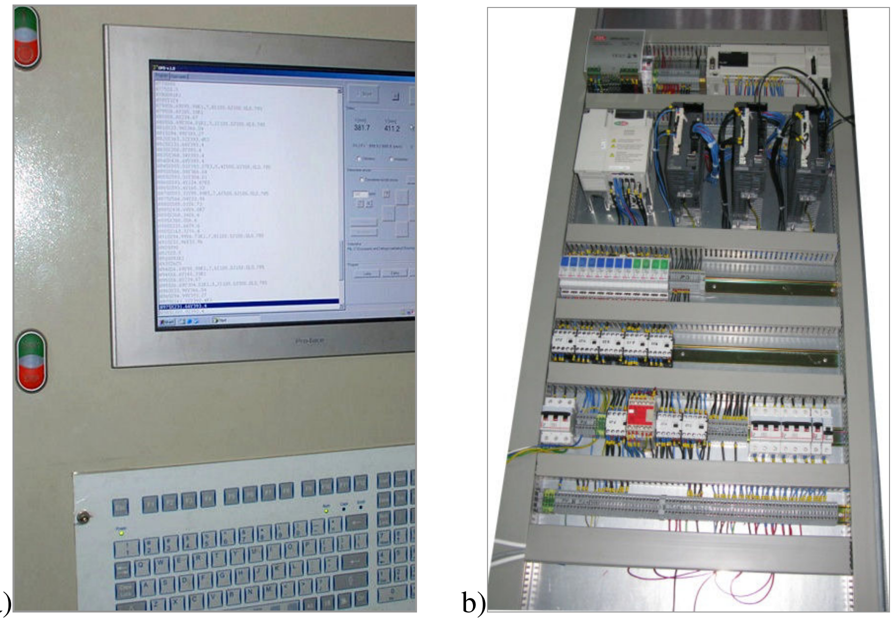


Fig. 7. Block diagram of the drilling machine control system

The controller has functions to change the position of the drilling head so it can: pick the right tool, execute cycle of the Z-axis with the specified parameters (feed rate, target position, starting position, along with an adjustable movement speed in each passage), has been implemented. Special functions are associated with the measurement in any direction you choose, spindle speed, initialization of each axis, have been programmed. For each axis there are two pairs of limit switches attached. Internally they are supported by an external controller and they belong to appropriate servo for a given axle. On each axis there also is a SW limit switch responsible for the estimating the zero position of axis, and it also is attached to the appropriate servo. PLC driver communicates with the industrial computer on the 232 link with the Mitsubishi corporate protocol, which allows to read and save any of the flags and registers, and allows the controlling software to run specific procedures in the PLC drivers and to read the status and many other values.



a) b)

Fig. 8. Control system: a) operator panel, b) interior of the control panel

6. Program to control the machine tool

The developed program to handle the drill allows to load the frame's geometrical features, the number of holes done, to load the number and the location of measurement points data, to generate the ISO for the machine tool controlling, to measure and calculate an adjustment position of each hole, data logging for identified frameworks. The geometry of the ship frame has the characteristic that between straight sections appear corners in the form of arcs. Within the frame description there is the data set describing all arcs and straight sections. Arcs describe the coordinates of the start and end points while the arcs describe the coordinates of the starting and ending points and the coordinates of the center of the arc.

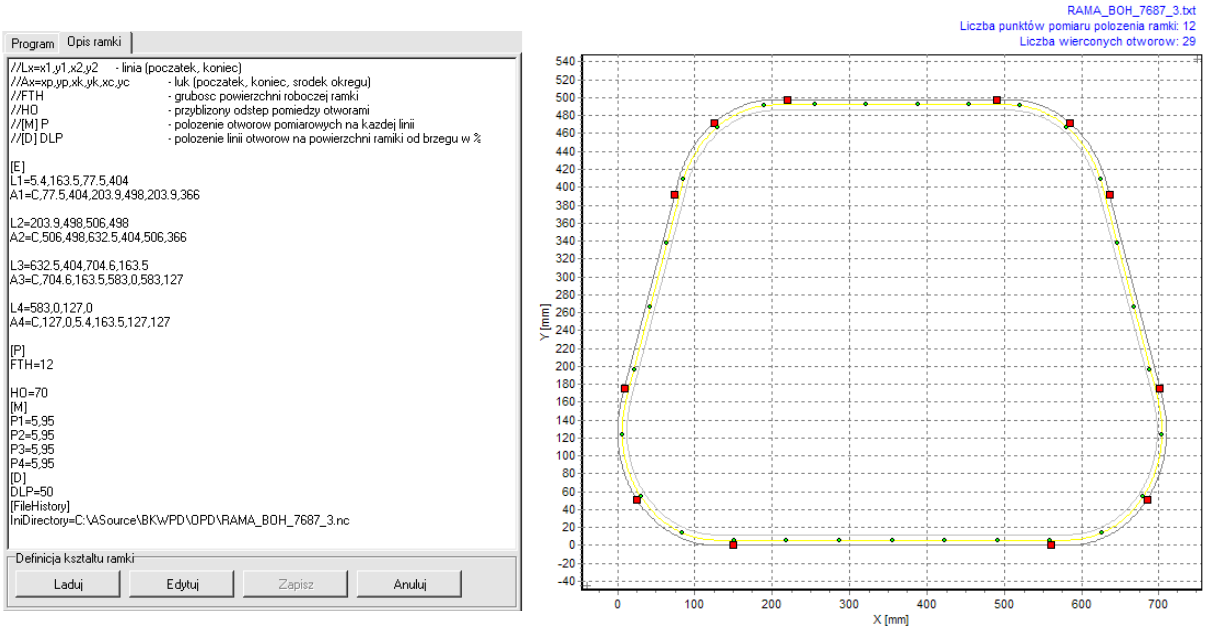


Fig. 9. Screen views for data entry and framework geometric features visualization a) input data describing the frame, b) frame drawing showing holes to drill location (green) and measuring points (red).

This data can easily be read from executive frame – Fig. 9, or analyze specially for this purpose developed macro used in the CAD program in the company. Almost all types of windows manufactured in the shape of a rectangle, parallelogram and trapezium and ship porthole (round windows) can be described this way. After loading the geometry window and technological data the program generates a g-code controlling the machine tool according to ISO standards – Fig. 10. Code also includes instructions responsible for changing tools and serving functions such as coolant addition for a tool.

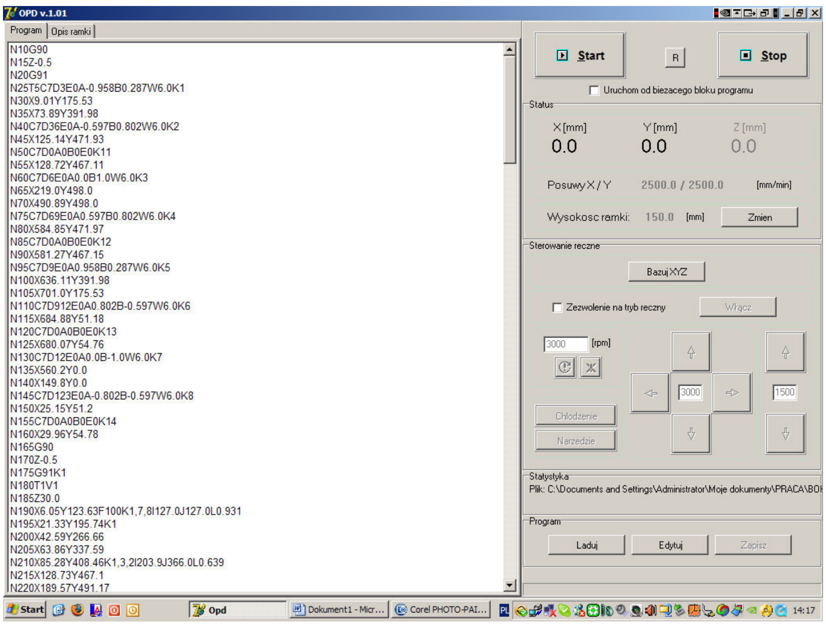


Fig. 10. View of the screen generated by G-Code code

Operator's task is to choose a program in the form of g-code or in the text form containing parametric description of the frame and desired settings for the holes placement. If a text form was selected it has to be converted additionally into a ISO code. Generating ISO code, we can decide to:

- enable measurement cycle preceding drilling,
- enable measurement at the corners of the frame (measured in the XY and /or Z),
- the type of strategy for holes position correction (linear, adaptive),
- disable some cycles used when drilling the frame.

Having established the g-code program, after fitting the frame, the operator by pressing the "GO" button runs the machine tool. Based on the initial measurement cycle, data for given correctors is determined. Correctors during drilling cycle enable to calculate the given hole position offset $<dx_i, dy_i>$, taking into account the measured deviation of the frame shape and its location on the work table. Correctors can be of two kinds. The first one have a impact on the location of the holes on the straights (sides of the frame), the other - on the arcs (corners). This division is associated with changes in the geometry of arcs, affecting not only the location of its center, but also changes of its radius. When drilling, every frame is labeled and data containing drilled holes position including applied corrections will be saved into the file. This data can be easily used in the future for the service purpose to restore defective or damage ship frame.

7. Summary

Completed theoretical studies have enabled the practical implementation of automated ship windows manufacturing for hole drilling in frames and overlays. The resulting increase in terms of work quality during the process, comparable to manual processing justifies the costs for the construction of machine tool. In addition a window elements identifying was inserted, especially for the frame, the windows and the overlay package, which allows you to restore these elements if they are damaged during the operation. Further work should include optimization of measurement procedures and machine productivity increasing.

References

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