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ERRORS EVALUATION AT SHIP STERN TUBE BUSHES MANUFACTURING PROCESS

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ABSTRACT

Among the manufacturing operations required to be realized into the ship building domain, stern tube bushes machining is one of the most important, because it has a high influence onto the good functioning of the ship propulsion system in time. Problems may appear because we are talking about pieces with very large dimensions, which are adjusted after their assembly by welding on the ship hull; additional errors may occur during or after machining, caused by ship body thermal or mechanical induced deformations. In this paper, we investigate the opportunity of using an on-line adaptive control system of the cutting process (boring), which will enable a superior precision of stern tube bushes machining process.

KEYWORDS: stern tube bushes, boring, errors, adaptive control.

1. INTRODUCTION

In ship building domain, the stern tube bushes are used as support for the stern tube, which is the hole in the hull structure for accommodating the propeller shaft to the outside of the hull. The propeller shaft is supported in the stern tube by two bearings – one at the inner end and one at the outer end of the stern tube – called stern tube bearings [1, 2, 3]. The bushes are first fixed by welding on the hull, and then they are adjusted by boring, before introducing the stern tube, Fig.1, [6].

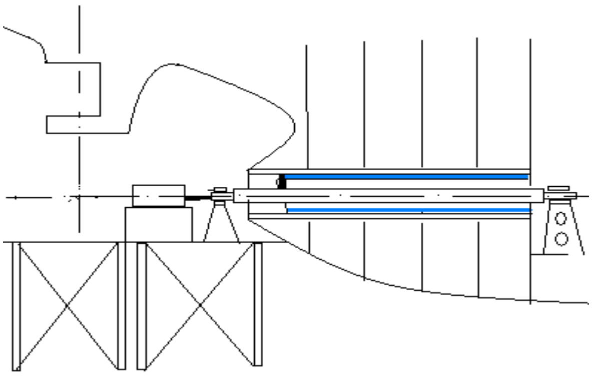

Fig.1. Stern tube bushes adjusting, by boring [6]

Stern tube bushes inner surfaces machining is done by using a boring bar and a special device (Fig.2, [6]). The results obtained by using this system are often poor, because of more specific inconvenient:

- Although the manufacturing system has a relative good stiffness, because the bar is long (over 7 meters) and because it is impossible to use middle bearing for the bar, elastic deformations do appear;
- Vibrations appear during the machining process, with negative effects onto the generated surface quality;
- The clearances variation in the sliding bearings, along the boring bar, has also a negative influence concerning the shape of the generated surface;
- The two bushes, assembled by welding on the ship hull, are the subject of deformations – their own or induced by diverse external factors (thermal or mechanical); if boring process is realized when the deformations are high, the impact on the generated surfaces is very bad.

The manufacturing system used to do stern tube bushes inner surfaces machining may be considered as a special one, not only because of the dimensions of the manufactured pieces, but also because the place of a traditional machine-tool bed is taken by the manufactured workpiece – a structure more or less stable and, anyway, in connection with other structures, through the ship hull.

There are three types of errors to be considered: errors due to the manufacturing system (system errors); errors due to the cutting process (process errors) and errors due to ship hull deformations, after the machining process is done. The first goal of this paper is to reveal some of the errors which appear after machining the stern tube bushes. In other words, we want to know which is the level of the damages caused by mechanical and thermal deformations to the stern tube bushes inner surface, assumed as correctly manufactured by boring.

Once the errors map known, after a first, roughing pass, it will become possible to find the corrections to be made at the finishing pass, in order to obtain the required quality of the final surfaces; thus an adaptive control system might be used to improve the precision of stern tube bushes inner surface and a scheme for such a system is also suggested, in principle.

2. ERRORS THAT APPEAR AFTER THE MACHINING PROCESS IS OVER

From the three upper mentioned categories of errors, the first two were already analyzed [5], so we further insist on the third category: errors due to ship hull deformations, after the machining process is finished. At their turn, they are induced by two types of solicitations: mechanical or thermal.

2.1. Errors caused by gravitational forces

There are many ship components which are installed on the ship hull after stern tube bushes machining by boring is accomplished. Because these components are very heavy, ship hull deformations appear and the alignment between the two stern tube bushes axis is damaged. This inconvenient might be eliminated if the errors are known and measured, in association with their causes.

We tried to measure the deformations that appear after the installation of each one of the most significant components, in a concrete case. On the fore stern tube bush we put a laser beam generator; on the dry dock we put a target to focus the laser beam on it, see Fig.2. The distance between the laser generator and the target was of 5500 mm.

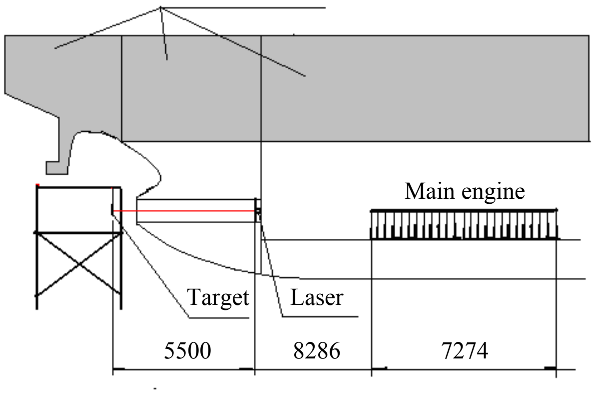

Fig.2. The measurement of deformations caused by gravitational forces

The deviation between the spot initial position on the target and its position after installing a certain component was measured. Two kinds of effects were noticed, concerning the spot displacement direction – up or down. Thus, the following deviations were observed:

- 2.9 mm (down) after installing the main engine (having a 220 t weight);
- 2.2 mm (down) after installing the steam & electricity generators (65 t weight);
- 14.6 mm (down) after installing the PP 12 group (520 t weight);
- 5.15 mm (up) after installing the upper-works (550 t weight).

The reason why the spot moves into opposite directions is the kind of deformation suffered by the ship hull. When the spot goes down, it means that the whole structure is compressed; in this case the relative position between the two bushes axis doesn't change very much, because they are moving together in the same manner. Things change when the spot goes up, because this is indicating a hull deformation of bending type (see Fig.3) and this leads to a inclination between the two bushes axis.

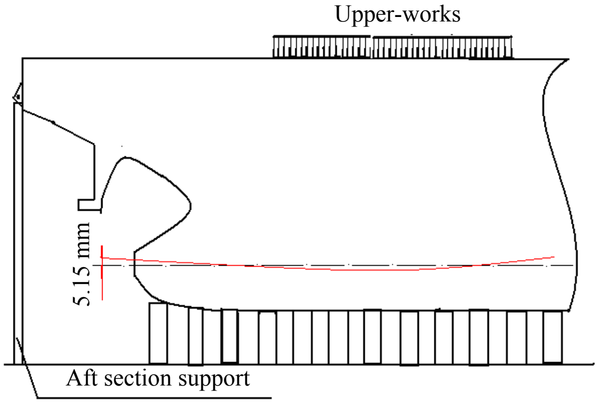

Fig.3. The ship hull deformation when the laser spot goes up

We must notice the fact that because the target was placed on the dry dock, it certainly didn't move when diverse weights were put on the ship hull, while the laser beam generator moved down, together to the ship hull, because its supports suffer a certain deformation under the heavy loading. Thus, the magnitude of the spot displacement is not very relevant, but the direction of the displacement it is.

2.2. Errors caused by the thermal field

A non-uniform thermal field can be induced into the ship hull by two different sources of heat: the sun and/or the welding processes (necessary to realize the diverse components installation). This is leading (through dilatation phenomenon) to a ship hull shape and dimensions modification and further, to an alteration of the relative position between the stern tube bushes axis.

We realized an experiment to analyze the effect of the ship hull non-uniform heating on the stern tube bushes axis position (direction). The ship hull section where the stern tube bushes are placed is on a support, on the dry dock, with the stern tube axis in vertical position, Fig.4.

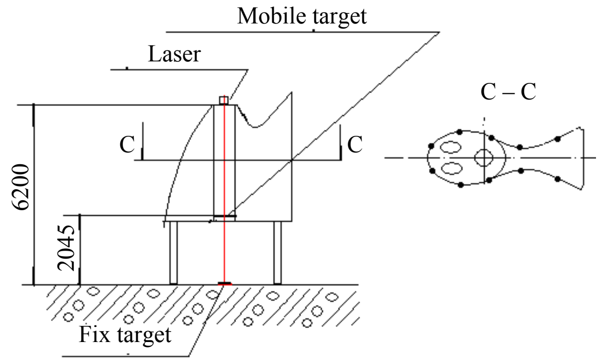

Fig.4 Measurement of the errors caused by the thermal field

A laser beam generator is placed on the exterior side of the aft bush, while a target to focus the beam on it is put down, on the dry dock. The position of the spot on the target is monitored during 8 hours, when the outside temperature and the sun position are changing the most.

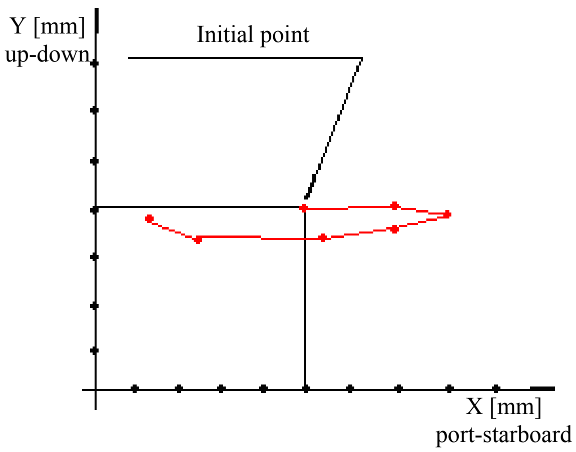

Fig.5 The spot trajectory on the target

The temperatures on the both sides (starboard side and port side) of the hull section were measured, together with the temperature at the ground surface. The results are shown in Table 1.

By graphical representing the spot motion on the target, the trajectory from Fig.5 resulted.

It should be noticed that the stern tube bushes axis direction significantly changes under the effect of non-uniform heating of the ship hull and this could seriously affect the results obtained when machining the bushes surfaces by boring.

The effects of the thermal field generated by the welding processes are very difficult to be experimentally evaluated, because of the different effects superposition.

As a conclusion to this section, we must notice that the relative displacement between the two bushes is far more important than the absolute displacement of each bush; if they have both the same direction of modifying the initial position, then although each one has an important displacement, the cumulated effect is not so negative.

In our case, some preliminary measurements showed that the errors concerning the relative position between the two bushes axes, caused by mechanical and thermal deformations, are smaller than 1 mm. This means, on one hand, that stern tube bushes inner surfaces manufacturing, before all the hull structures are assembled, is possible. On the other hand, it also results that a mean of all three types of errors (system, process and deformation errors) cumulated, could be compensated at once.

3. ERRORS COMPENSATION IN THE BUSHES BORING PROCESS

The idea of realizing an on-line adaptive control of the cutting process, in order to improve the stern tube bushes machining precision, might become feasible, if the experimental research will further confirm the supposition about the relative displacement between the two bushes. It requires a model of the errors that appear as a consequence of the conditions on which the process takes part.

To find the errors model, we must build, firstly, a data base, by recording each cutting process parameters (e.g. the cutting force variation, the tool position etc.) together to the errors map of the surface generated under those conditions.

Then, the errors appearing after bushes inner surfaces are machined, caused by gravitational forces or by non-uniform thermal fields, must be considered. In fact, because they certainly do appear, the machining system should generate a surface different from the theoretical, desired, one and which, after all the other external factors produce their effects, transforms into the aimed surface.

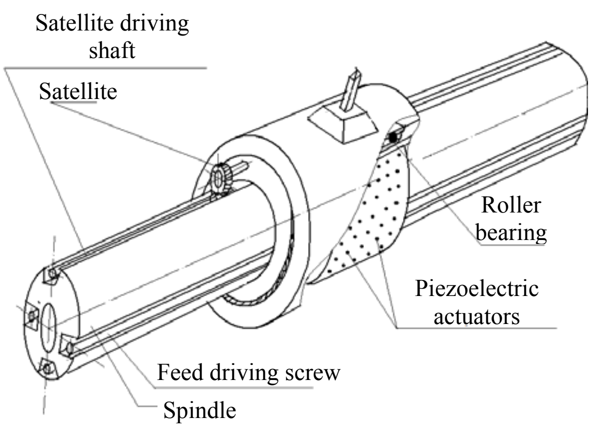

Fig.6 The system for the adaptive control of the bushes boring process, in principle, [5]

Table 1 The spot displacement, depending on the exterior temperature

Time	Port side temperature (˚C)	Starboard side temperature (˚C)	Ground temperature (˚C)	Spot displacement (mm)	Temperature difference between files (˚C)
07:30	8,15	19,20	17,0	Origin	11,05
08:50	10,40	24,80	21,5	2mm to starboard side	14,4
10:30	16,84	38,82	33,0	1mm to starboard side	21,98
11:40	21,85	36,22	39,2	1mm to port side	17,37
12:36	25,40	35,14	41,05	1,5mm to port side	12,74
14:00	29,10	33,20	42,4	3mm to port side	4,1
15:00	31,44	29,45	36,0	1mm to port side	1,99

Thus, the system for the adaptive control of the bushes boring process will, finally, be able to anticipate the corrections to be made at the finishing pass, in order to generate the appropriate surface.

In Fig.6 there is presented the principle scheme of such an adaptive control system, to be attached to the currently used boring bar device. It is based on a system of piezoelectric actuators, placed under the tool holder device, on a sliding bush; they are connected to an electrical source through a mobile system of wires. The magnitude of the voltage to feed the actuators is established by the control system, depending on the magnitude of the errors to be compensated, by moving the tool holder on radial direction.

4. CONCLUSIONS

The machining of stern tube bushes inner surfaces is a difficult operation, because of a great number of specific factors and conditions. In the dedicated literature, there are few specifications about the solutions used by the shipyards to solve the problem.

In addition to the classic errors which appear when machining a workpiece by cutting – errors due to the manufacturing system (system errors) and errors due to the cutting process (process errors) – in the case of stern tube bushes inner surfaces there is also the problem of errors caused by the interactions with the ship hull.

Both the installation of diverse heavy ship components and the non-uniform thermal field induced by the sun radiations can be a source of significant errors, concerning especially the relative position between the two bushes inner surfaces.

A steady solution to improve the precision of stern tube bushes inner surfaces precision could be the use of an on-line adaptive control system, based on a system of piezoelectric actuators. By drawing machining errors maps, depending on the concrete cutting conditions, for a number of processes as great as possible and by correctly anticipating the errors that will appear after the machining process is ready, it will be created a background for the adaptive control system to be able to ensure a satisfactory final precision.

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