Машиностроение, 1978. – 109 с. **3.** Седуш С.В., Щербина С.В., Нижник А.В. Новый инструмент для сборки и разборки резьбовых соединений / Информационный листок №80-94. – Донецк: Центр научно-технической и экономической информации, 1994. – 2 с. **4.** Щербина С.В. Применение гидравлического устройства для сборки резьбовых соединений большого диаметра / Прогрессивные технологии и системы машиностроения. Международный сб. научн. трудов. – Донецк: ДонГТУ. – 1999. – Вып. 7. – С. 211-214. **5.** Якушев А.И. Влияние перекосов опорных поверхностей и предварительной затяжки болтов на прочность резьбовых соединений // Вестник машиностроения. – 1953.– № 7. – С. 7-10. **6.** Седуш В.Я., Щербина С.В. К определению податливости промежуточных деталей резьбовых соединений. – Алчевск: ДГМИ. – 2000. – Вып. 12. – С. 207-212. **7.** Седуш В.Я., Щербина С.В. Сборка крупногабаритных резьбовых соединений методом приложения осевых сил / Защита металлургических машин от поломок. – 2002. – Вып. 6. – С. 116-122.

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USING AN UNSPECIALIZED SOFT FOR EXECUTING THE CLOSE-RANGE PHOTOGRAMMETRY MEASURING IN THE SHIPBUILDING AND SHIPREPAIR

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Abstract. *The available software that suitable for digital image processing with sufficient accuracy for a shipbuilding is selected. The performances of the experience of using the close-range grammetry for a checking work in the shipbuilding and shiprepair are shown.*

The probably operations for shipbuilding and ship repair to execute with this software are determined.

Introduction. With the beginning of the general using of welding in shipbuilding the problem of accuracy of manufacturing and mounting ship units appeared [1]. The technology of the hull assembly has passed from the “part by part” method to the sectional method, but reduction of a fitting-on work on the slipway related with the installing and mounting sections or parts with guaranteed assembly welding gap between constructions is a complex problem.

The fitting-on work increases labor intensity of hull erection work and demands the usage of hard physical work and sometimes is rather inconvenient because of the equipment installed in the section before. They are especially labor consuming at the open final assembly yard such as the slipway and fore-slipway area and as consequence slipway stage term is increased. The reduction of slipway stage term and measures directed to accelerate of ships delivery at lower production costs and to increase an overall performance of shipyard.

In practice the problem of the great volume of the fitting-on work is connected with the following technological stages, processes and their characteristics such as:

- accuracy of checking and alignment work;
- verifying and measuring work;
- accuracy of auxiliary equipment and facilities;
- errors of machinery, cutting and tools;
- influence of welding damage and buckling and of the ways to eliminate them;
- drawbacks of some manufacturing methods;
- human factors.

There have two ways to solve this problem:

- increase accuracy of manufacturing and forecasting errors;

- determinate the allowance by digital methods and burn it in the shop using the robotic complex and automatic cutting [2].

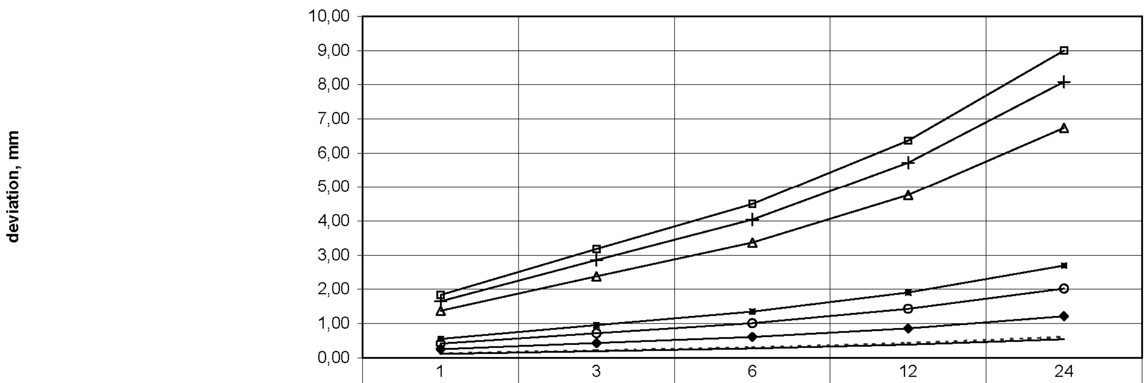
It is necessary to know which of the way will be economically efficient. This factor directly depends on the manufacturing conditions and labor costs.

As a result of the conducted research is detected that the greatest influence on the accuracy is checking work, irrespective of ways of the solution of the problem [3].

The verifying works were united in one group and were named “The checking works”. The checking works comprise the following checking processes:

- at the open final assembling yard for keel laying of the ship;
- at the installation of hull units on the final assembling yard and their fairing;
- at general checking.

These activities are not labor consuming but are very imperative and have the largest deviation (Fig. 1).



	1	3	6	12	24
welding shrinkage of girder 0,23	0,12	0,21	0,30	0,43	0,61
welding shrinkage of joint plate 0,45	0,25	0,43	0,61	0,86	1,21
thickness irregularity of plate 0,20	0,11	0,19	0,27	0,38	0,54
curvature of edge 0,75	0,41	0,71	1,01	1,43	2,02
plasma arc cutting 2,50	1,38	2,38	3,37	4,76	6,74
welding gap 1,00	0,55	0,95	1,35	1,91	2,69
semi-automatic cutting 3,00	1,65	2,86	4,04	5,72	8,08
measuring 3,34	1,84	3,18	4,50	6,36	9,00

unit quantity of dimentional chain, n

Figure 1. Influence of the technological processes on a dimensional chain.

Such traditional check facilities as a hose level water gage, a waterway plank, a plumb, a measuring reel and a teodolit are replaced with optical laser devices. That practically eliminates the possible errors at complete the checking work. There is the problem: the high accuracy techniques of the verifying works are labor consuming or expensive. The main idea of this research is to reduce cost and labor intensively of checking work at well accuracy.

The perspective alternative is introducing measuring systems on the close-range photogrammetry basis. The main drawbacks of similar systems are high price of the specialized software for the digital images processing with satisfactory accuracy and necessity of preliminary marking the key points on the surface of a measured object [4].

The mathematically simple technique of coordinates recalculation the object on the images in the coordinates directly of object in practice of application is complicated by supplementary rules of cameras arrangement, availability of orientation points, necessity of camera calibration, pleasing of reference lengths on the surface of an object etc. These conditions reduce the photogrammetry advantage level [5]. To decrease this influence it is necessary to complicate the mathematical vehicle that leads to raising the project cost. Many corporations that develop software are not capable to solve the problem and others estimate work at the project as groundlessly expensive. However there are programs for processing the photography not oriented directly on shipbuilding that one could adapt for the problem solution with some corrections of technology.

The main contents and outcomes of activity. The main idea of experiment is measurements on the close-range photogrammetry basis with usage of the unspecialized software for images processing and without usage of the marking target. Using a non-professional camera.

On the basis of the similar programs there can be obtained the close-range photogrammetry system by the costing less then 4500 USD that 10-times less than the cost of similar systems (V STAR-E), and the software cost will be less than 1000 USD. The similar experiences were executed in the shipbuilding and heavy engineering industry of the USA, Canada and other countries (Table 1).

Table 1. The comparative table of the standard and unspecialized systems of measurements on the close-range photogrammetry basis.

Close-range photogrammetry systems	Accuracy, mm	Cost, USD	Labour-intensiveness, conventional unit	Soft in system cost, %
V STAR-E	from ±0.1 to ±0.8	150000	1	92%
On unspecialized soft based	from ±1.0 to ±3.6	4500	0.5-1.5	29%

The research and analysis of the world experience have shown that the considered system can be applied in the Ukrainian shipyards. The next is possible.

In the shipbuilding:

- definition of geometrical parameters of the assembled unit or section;
- definition value of a deleting allowance, the compare of the obtained data and the designed or required with taking into account data from established before designs;
- monitoring of keelblock positions during ship's constructions;

In the shiprepair:

- the coordinates definition of a changed segment of the hull, accurate definition of repair volumes;
- the value definition of general longitudinal bending at disassembly and mounting the designs, extraction and loading the machines and the mechanisms including afloat position;
- data definition for manufacturing of new pipe lines and systems;
- obtaining coordinates for manufacturing of keel blocks and cribbing, definition of their deformations.

The problem of necessity of the key points marking of designs in practice is related with following:

- actual accuracy of measurements in compliance of the shipbuilding standard demand;
- characteristics of the camera, requirement for illumination;

- the shape of a measured design and availability of clear edges;
- connection the local and ship's coordinates system, reference lines and plane;

Summing it possible to define activities accepting the renunciation of targets. After that it is defined indispensable quantity of pictures, for each kind of activities outgoing from possible and indispensable accuracy.

Experience. To compare the coordinate values determined by this equipment with those coordinates determined by a tape-measure.

The targets used to measure coordinate points (it is necessary for definition of coordinates of curved surface at shiprehear) were not advised for the photogrammetry technique (they have not a retro-reflective effect). To determine the section edges the coordinate targets are not used, but on the surface unit were placed etalon part to define the linear size (the distance between two grabber was measured).

This research was complied on the structure of the cargo vessel of middle tonnage. The measurement project focused on the planar unit in the area of middle, shown in Figure 2. The size of the unit is 20440x9100x1430 mm. Measuring sketch of butt-end is shown in Figure 3.

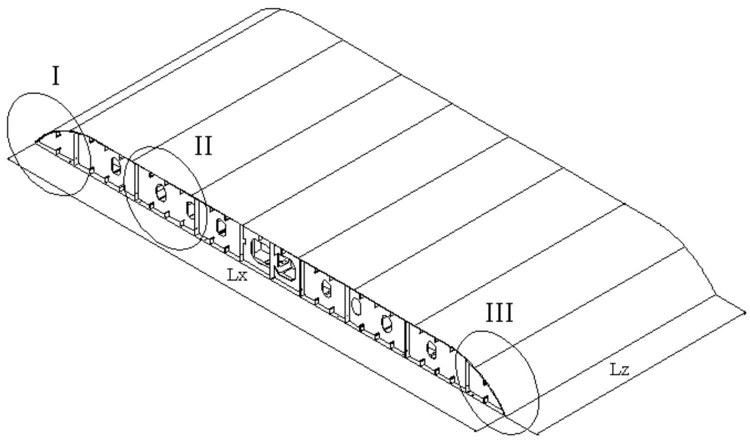


Figure 2. Sketch of measuring. Overall dimensions of a bottom unit: Lx –length of the unit, Lz – width of the unit.

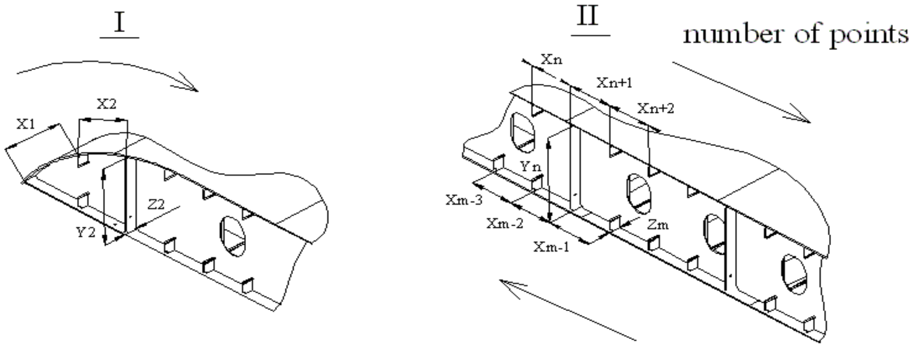


Figure 3. Measuring of a unit butt-end. X-point on the unit surface. I – bilge region, II – flat area, Xm,n… – coordinate of a point on an axis X, Yn – on an axis Y, Zm – on an axis Z.

To define curved 81-ts targets were placed on unit surface (Figure 4). Ones at one's own choosing arrangement and the second time at well-ordered target arrangement. The true sizes were obtained by the conventional way by measuring reel, plumb and tape-measure.

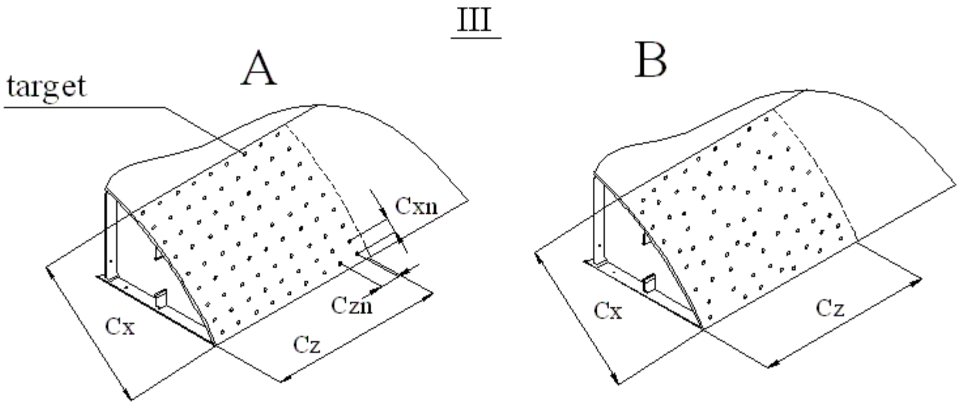


Figure 4. Measuring the curved surface, coordinates X and Z . A: at well-ordered target, arrangement B: at one's own choosing target arrangement. Cx, Cz – projection of the surface, Cxn, Czn – interval between targets.

The tape measure 20m (RZ second class of accuracy) were checked in laboratory (table 2):

Table 2. Tape-measure checking performance.

Interval, mm	Effective size, mm	Maximum tolerance from rules
0-1000	1001.4	999.7-1000.3
0-2000	2001.9	1999.6-2000.5
0-5000	5002.5	4999.1-5000.9
0-10000	10003.9	99998.4-10001.7
0-20000	20007.7	19997.2-20003.2

This check is really effective but according to the requirements the measurements must be done in the following way [6]:

$$\Delta l_m = \pm[0{,}30 + 0.15(l_i - 1)]\ mm \qquad (1)$$

were: $\Delta\ l_i$ – quantity full and not full of meters in the measured distance. Calculation formula 1 is in table 2.

The targets used were created by cutting out circular shape papers, diameter = 5mm. At well-ordered target arrangement target's step was 100 mm (Cxn, Cxn Figure 4). Target used only for curved surface Measuring point of a butt-end are determined from edge girders and plates in the pictures.

A digital camera “Olympus SP-500UZ ” was used to acquire the images in the study. The features of this camera include:

- 6 Megapixels resolution;
- 6.3mm - 63mm focal length range;
- Manual and Automatic Control;

The camera cost in 2006 was approximately 400 USD.

Camera Calibration was executed in compliance the simple way of soft manual.

There taken 40 images from the ground level, ladder and neighboring structures without flash for butt-end, and 6 images for curved surface (region 1000 X 1000mm Cx, Cx Figure 4)) for each experience.

The time was 3 p.m. The sun was shining.

The images were taken without zoom. The distance of the shooting was 1-3 m at measuring of a curved surface and 2-20 m at measuring of a curved surface.

The distance between two targets and the distance between two girders were used as the standard length.

Obtain really accuracy limitation of tape measure accuracy (formules2-3).

The linear accuracy of the close-range grammetry is only compared with tape measurement.

The general accuracy of the close-range grammetry is calculate as:

$$\Delta = \sqrt{\Delta_X^2 + \Delta_y^2 + \Delta_Z^2} \quad (2)$$

were: Δ - a mistake of a point’s coordinate,
"X","Z","Y"- coordinates of point

Importantly the coordinates, of which axes are similar to the plane of the images, were much stronger than the coordinates of which axis were generally perpendiculars to the plane of the images.

The final accuracy for both cases from probability theory:

$$\Delta_{A\Delta} = t\sqrt{\sum_{i=1}^{m-1} \lambda'_{Ai} \Delta_{Ai}^2} \quad (3)$$

were: Δ_{Ai} included - Δ *F*- a mistake of the close-range grammetry and Δ *T* - a mistake of the tape measure

λ'_{Ai} = 1/3, distribution law is not definite
t - 1.65, if *P* =10.0%

The final accuracy from minimum-maximum method:

$$\Delta_{A\Delta} = \sum_{m+n} \Delta_i \quad (4)$$

were: Δ_i included - Δ *F* - a mistake of the close-range grammetry and Δ *T*- a mistake of the tape measure

If necessary get δ:

$$\delta = \frac{\Delta}{2} \quad (5)$$

Formula 5 may be useable for compare with other measuring methods.

After processing and calculation accuracy Table 3 was completed:

Table 3. Comparing measurement accuracy.* Deviation from curve on the drawing (Figure 5), ** Positions of targets, liner coordinates, *** The curve was executed semi-automatically.

Parts of unit	Distance, m	Liner mistake of close-range photogrammetry systems, mm	General mistake of close-range photo-grammetry sys-tems, mm		Mistake of the tape measure at similar length, mm
			Formula 3	Formula 4	
butt-end (4 images)	0-5	3.6	2.6	6.1	2.5
well-ordered target arrangement*	0-2 curved	non	4.3	6.2	3.3 (1.9**)
one's own choosing target arrangement*	0-2 curved	non	4.8 ***	6.7	3.3 (1.9**)
big length (Lx, Lz, Figure 2, 4 images)	0-21	15.4	10.5	25.0	9.6

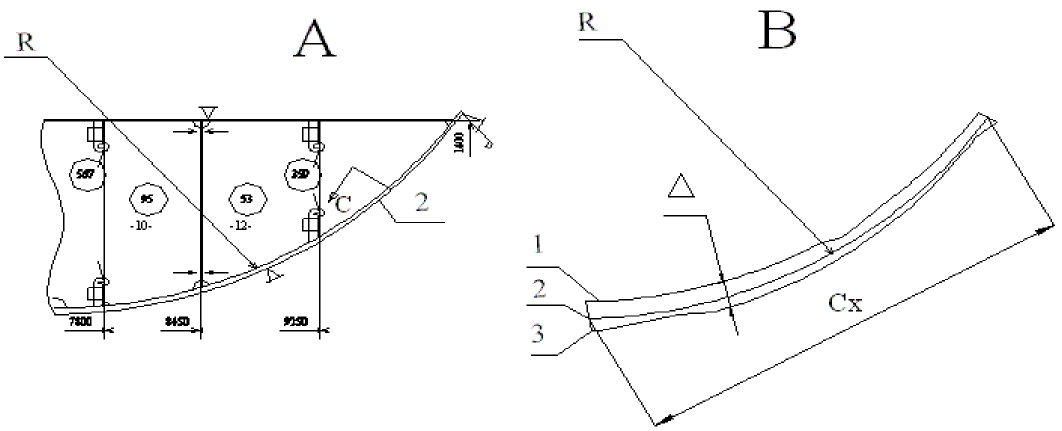


Figure 5. Determinate of the close-range photogrammetry mistake at the measuring of the curved surface. A – fragment of the drawing, B – sketch of curved measuring. 2 – outline of cover, 1-3 – outline of close-range photogtammetry drawing. Δ – close-range photogtammetry mistake (Table 3), Cx – from Figure 4.

Apparently, in the simple experiments the photogrammetry is the competitor to traditional measuring instruments.

Besides the arbitrary arrangement of targets has an insignificant effect for a measurement accuracy of curvilinear surfaces, about 12 percent from table 3.

Executing process takes 4 hours fore determinate 50 points manually and 81 semi-automatically.

Notice. Each image since fourth lead to increase accuracy on 0.25 mm.

Conclusion. The modern device for verifying works allows not only to define a position of a design in space, to test its geometry, to meter, but also to execute the obtained outcomes.

A relatively low-cost digital camera can be used to create images of 3D coordinates. Coordinate accuracy was obtained which is suitable for many applications in shipbuilding and some industrial measurement applications.

The speed and convenience of the imaging process compared to measuring coordinates with a maximum possible accuracy is very attractive. As consumer grade camera resolutions increase, the accuracy of low-cost photogrammetry will be increased and be more widely utilized.

Further research: additional camera positions, improved camera angles and the use of different flash configurations would be useful to test the effect they may have on improving accuracy.

The offered system does not allow to process results in a real time, however with an output of new versions of the software, probably, it will be possible to decide this problem and expanding the nomenclature of works.

References. 1. Постройка корпусов судов на стапеле: Справочник / Л. Ц. Адлерштейн, А. Я. Розинов, В. Ф. Соколов, М.Р. Шраерман. – Л.: Судостроение, 1977. – 303 с. 2 . Градецкий В.Г., Рачков М.Ю. Роботы вертикального перемещения. – М.: Тип. Мин. Образования РФ, 1997. – 223 с. 3.Савицкий И.А. Предельная точность изготовления плоскостных секций цилиндрической вставки среднетоннажного судна по различным стандартам // Рибне господарство Украйні. 2006. №5/6 С. 65—68. 4. Савицкий И.А. Исследование опыта применения оборудования на основе цифровых технологий для выполнения проверочных работ при строительстве корпуса судна //Прогрессивные технологи и система машиностроения. 2007. №33 С. 227—233. 5. Лобанов А. Н., Буров М. И., Краснопевцев Б. В. Фотограмметрия: Учебник для вузов. –М.: Недра,1987. – 309 с. 6. Точность в судовом корпусостоении / В.Л. Александров, Л.Ц. Адлерштейн, В.В. Макаров, В.Ф. Соколов, Н.Я. Титов. – СПб.: Судостроение, 1994. – 171 с.

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