Practice Report

3D Measurement and Analysis of a Ship Block

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Introduction

Modern shipbuilders have widely adopted the concept of modular construction and are realising the benefits associated with these methods [1]. Further improvements in productivity can be achieved if these modules are accurately built, avoiding the traditional excess material normally trimmed during the erection process.

It is by no means an easy task to achieve this goal. The construction of neat hull blocks requires rigorous dimensional control at each of the production phases. Hull erection is the most critical assembly phase. The huge 3D block structures assembled during this phase should be accurate enough to be positioned and aligned efficiently.

This application report describes how the DCA-TC system is used to measure and to analyse the 3D block structures assembled during hull erection. An example of such a structure is the double bottom of an “ecobox” type of carrier. A simplified 3D drawing of such a block is shown in Fig. 1.

The DCA-TC System

The method

The principle of the method is to bring the CAD data to the production site in order to compare the actual structure with the design values. The deviation of the actual data from the design data is obtained immediately during the construction process. The actual and the design data will then be processed with the dimensional analysis software to illustrate the results both graphically and numerically.

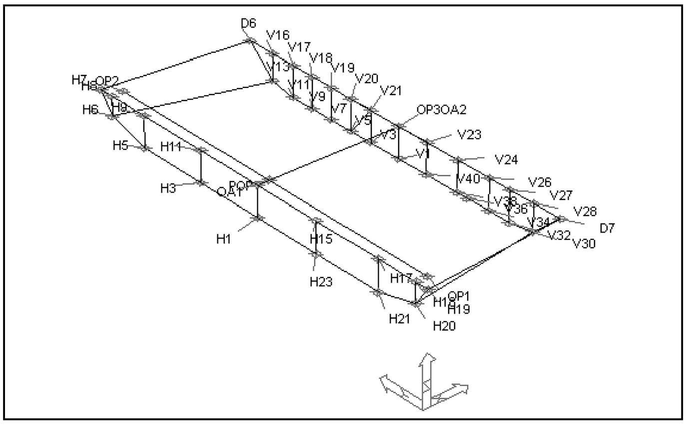


Fig. 1. A simplified 3D wire frame drawing of a double bottom type of structure. The drawing was created using the DCP20 program of DCA-TC System

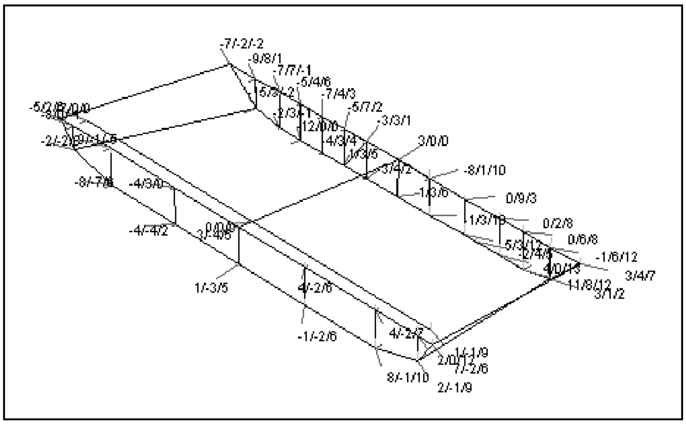


Fig. 2. One example of the graphical results. The actual-design x , y , z differences are shown at each object point

The system

The DCA-TC is a single sensor 3-Dimensional Control and Analysis System for shipbuilding and similar industries. The system comprises the following components (see the system diagram in the product brochure):

- Leica TC2002 – a high accuracy industrial 3D sensor as the measuring device
- A.M.S. DCP10 – a powerful on-board dimensional control program installed in a rugged handhold Control Unit and used for the dimensional control tasks at the production site,
- A.M.S. DCP20 – a dimensional analysis program run on a PC and used to present the results graphically and numerically

Dimensional control task

Execution of the measurement and analysis of the results are only parts of an overall dimensional control task. To achieve reliable and consistent results, standard dimensional control procedures must be developed for each production stage. These procedures should be an essential part of more general manufacturing instructions. Amongst other items, the procedures should provide detailed descriptions of the following issues:

- objectives of the dimensional control
- definition of the measurement and setting out stages
- definition of the design data to be used
- specification of the form of results
- development of the instructions to extract and download the design data
- development of the measurement instructions
- delivery of the actual information for the company organization

Downloading the design data

The design data extracted from the yard’s CAD comprises a set of critical object points on the hull. These critical points are used to control the dimensional variation of the structure by comparing the actual 3D co-ordinates with design values. The critical object are made up of the following information:

- the identification (name) of the point of interest (to be measured),
- x co-ordinate value of the object point in the Ship Co-ordinate System,
- y co-ordinate value of the object point in the Ship Co-ordinate System,
- z co-ordinate value of the object point in the Ship Co-ordinate System.

This file is created during the design of the hull block. The operator locates the points by pointing with the mouse and at the same time naming the located points. This information is saved and downloaded as an ASCII file. A simplified 3D CAD drawing created using the CAD facilities can be an essential part of the design information brought to the production site. This drawing illustrates the location of the critical object points.

Measurement preparation

The DCP20 Dimensional Analysis program is used to make the following preparations for measurement :

- importing the 3D design co-ordinates
- creation of a reference drawing to show the location of the points (if the CAD drawing is not used),
- downloading the 3D design co-ordinates to the DCP10.

The 3D design co-ordinates can be imported directly from the CAD file or they can be extracted from an object drawing and typed in. A simplified 3D wire frame drawing can be created with the DCP20 program. This drawing is used to guide the measuring process at the production site. (The drawing shown in Fig. 1 was created with the DCP20 program.)

Measurement execution

Principle Object References
In shipbuilding the object alignment (merging blocks together) is based upon the principle object references. These references are the *Bottom Plane* (sometimes called *Bottom Line* or *BL*), the *Centre Plane* (*Centre Line* or *CL*) and the *Frame Plane* (*Frame Line* or *FrL*).
The reference planes appear as reference lines on the object surfaces. These principle object references are organised in the Ship Co-ordinate System *Ship CS* in the following way

- The *Bottom Plane* is parallel to the plane defined by the x and y axis of the *Ship CS*. The plane defines the zero value for the z co-ordinate.
- The Centre Plane is parallel to the plane defined by the x and z axis of the *Ship CS*. The plane defines zero value for the y co-ordinate.
- The Frame Plane is parallel to the plane defined by the z and y axis of the *Ship CS*. The origin of the *Ship CS* defines the zero value for the frame planes.

Sensor orientation to the Ship Co-ordinate System
The 3D design co-ordinates of the critical object points are defined in the Ship Co-ordinate System. A procedure called orientation is then first carried out to obtain the measuring results in the Ship Co-ordinate System. After executing the orientation procedure the actual (= measured) 3D co-ordinates are directly comparable with the design values.

A special orientation procedure called DOM (Direction based Orientation Method) is developed to achieve fast and accurate orientation on the crowded assembly sites. The idea of this method is to make use of the direction information of the local object references. The procedure is implemented in the DCP10 program in such a way that the menu structure guides the user whilst executing the orientation, so making the operation easy and error free.

The orientation to the double bottom type of block (see Fig. 3) is done as follows:

1. Defining the reference plane
The deck of the double bottom is used as the reference plane. It is defined by the three plane points (OP1, OP2 and OP3/OA2). These plane points are measured to define the orientation (direction) of the plane.

2. Defining the reference axis
The *Centre Line* of the double bottom is used as the reference line (the x axis). It is defined by the two line points (OA1 and OA2). These line points are measured to define the orientation (direction) of the axis. (Alternatively the points OP1 and OP2 can be used to define the direction of the y axis.)

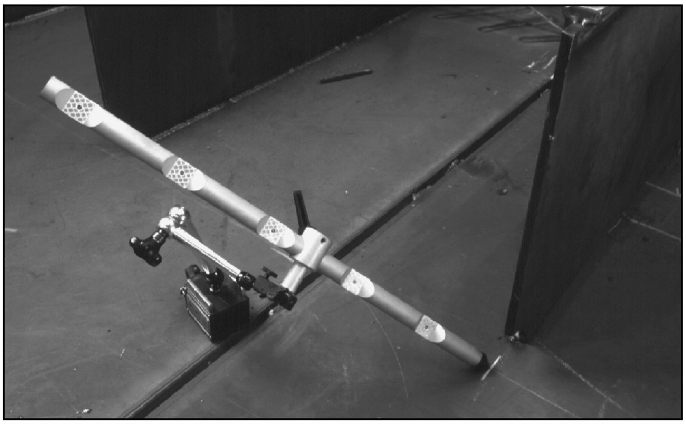
3. Defining the principle reference point
The cross point of the frame and centre line of the double bottom is used as the *Principle Object Point (POP)* of the object which is measured to define the position of the object in the Ship Co-ordinate System.

After executing these three steps the program calculates the transformation so that the actual (measured) 3D co-ordinates of the object points are obtained in the Ship Co-ordinate System.

3D Measurement of the object points

The 3D design co-ordinates of the critical object points are organised as a 3D Form (= file) in the DCP10 program (the points are illustrated in Fig 1). The name of the form is typically the identification code of the object, in this case the name is DB235. From this form the user picks up the points to be measured. The 3D Meas display which guides the operation is shown in Fig 4. On the right hand side of the display all the available commands are located. The path of the selected menus is shown on the top of the display. The following measuring information is shown at the centre:

One of possible three location to cover the whole object



Hidden point device for marking points which cannot be observed directly (e. g. they are hidden behind stiffeners)

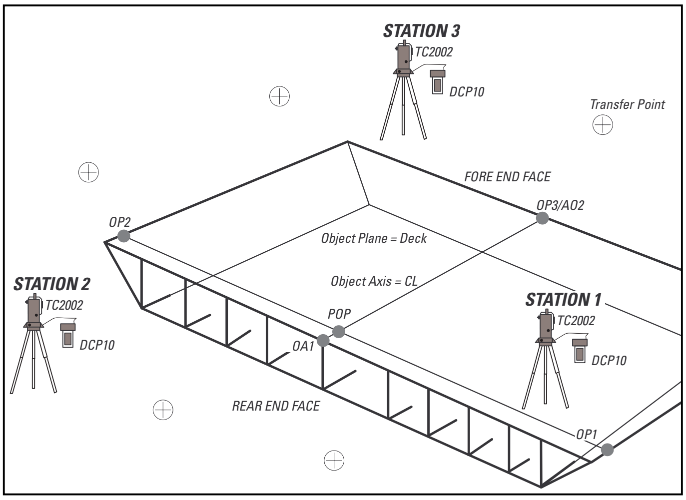


Fig. 3. The three measurement stations to access all the critical object points. The transfer points are used to orient the sensor to the original Object Co-ordinate System after each movement

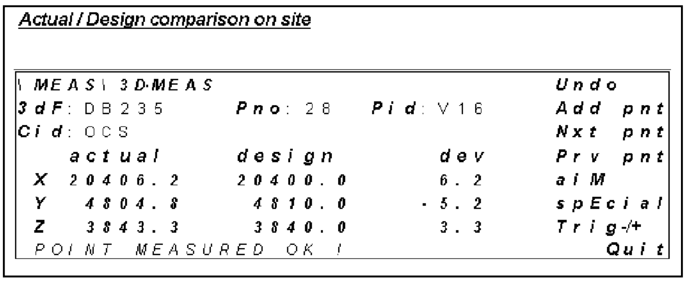


Fig. 4. The 3D Meas display of the DCP10 program showing on the right side the available commands, on the top the path of the selected menus and at the centre the actual/design information of the selected critical object point

- The name of the 3D Form (DB235)
- The order number of the point (28)
- The name of the point, Pid (V16)
- The design and the actual (= measured) x, y, and z co-ordinates
- The actual-design deviations

The design co-ordinates are used to guide the operator in detecting the object points by activating the *Aim* function. The readings of the two angles of the sighting axis are shown on the sensor display. When the operator turns the sensor so that these readings are set to zero, the sighting axis points to the design co-ordinate values of the object point. Immediately after the measurement the actual co-ordinates and the differences to design are obtained on the display.

Change station

The critical object points are located on the two faces of the objects as well as on the top of the deck. Three measurement stations are needed to access all the object points and are schematically illustrated in Fig 3.

A set of transfer points must be measured when changing stations in order to obtain actual values of the object points in the common Ship Co-ordinate System. The transfer points are measured before and after movement. The amount of transfer points needed depends on the accuracy requirements and on circumstances at the specific site. The minimum is two transfer points when the leveling feature of the sensor is used.

The DCP10 program comprises a specific Change Station routine to guide the operator when changing station. The operator obtains accuracy information about the success of the operation immediately after each change of station.

Calculation of dimensions

The accuracy of the actual structure compared with design is obtained at each measured point, as shown in Fig 2. Operators also have the possibility of performing elementary dimensional analysis during the measuring process. They can calculate and evaluate critical dimensions such as heights, lengths, widths and diagonals. The results of this analysis are immediately shown on the display of the Control Unit. This can all be done without disturbing the measuring procedure.

Dimensional analysis

After executing the measurement the 3D Form which comprises the actual and design values of the object points is imported to the DCP20 program to perform the dimensional analysis. The Point List Page of the DCP20 program contains all the information about the object points. The program supports a large set of menus and functions to manipulate the list of point information. One important feature is tolerance control.

The measurement results are shown in terms of 3D co-ordinate differences between actual and design values at each object point on the Drawing Page, as illustrated in Fig 4. The operator can make calculations such as the distances between points and translations and rotations of the actual co-ordinate values relative to the design values. All the results are presented numerically and graphically. The dimensional analysis is most important when it is needed to evaluate the object alignment (merging blocks together) and the manufacturing accuracy of the different assembly stages in order to improve the behaviour of such production phases.

The DCP20 program provides methods to prepare a large variety of dimensional control reports. On one hand brief reports are available for internal use and on the other hand complete reports can be prepared to meet the requirements of customers and quality audits.

Benefits of the 3D measurements

The DCA-TC system is most accurate single sensor 3D measuring system. The accuracy is better than one millimetre within a wide measuring range (from 1.7 to hundreds of meters). This means that the system is well suited to all production stages of the ship building process.

The single sensor type of 3D co-ordinate measurement is the most efficient way to obtain the actual geometry of an object structure. The studies [2], [3], [4] show that the overall measuring time needed to take a 3D measurement using a DCA-TC type of system is approximately 2.0 min per point. This means that executing the measurement of a double bottom type of structure having 50 critical object points will take 1 hour 40 minutes. The same studies show that it will take 1.4 minutes to perform one scalar measurement. This means that if the same measurement (50 object points) of the double bottom structure is carried out using traditional scalar measurements (three scalar measurements per point) the execution will take 3 hours and 30 minutes. The other major benefits of 3D co-ordinate measurements compared with traditional scalar measurements is that the results are consistent, the recording of the actual data is automatically done and the dimensional analysis can be performed using advanced software tools resulting in comprehensive numerical and graphical reports.

References

1. Yuuzaki, M., Okumato, Y., An Approach to New Ship Production System Based on Advanced Accuracy Control. Proceedings of the NSRP Ship Production Symposium, New Orleans, Louisiana, Sep. 1992.
2. Horsmon, A., Lupica C., Advanced Industrial Measurement Systems for Productive Shipbuilding. Proceedings of the NSRP Ship Production Symposium, Milwaukee, Wisconsin, Aug. 1990.
3. Manninen, M., Jaatinen J., Productive Method and System to Control Dimensional Uncertainties at Final Assembly Stages in Ship Production. Journal of Ship Production, Vol 8 Nov. 1990, pp. 244–249.
4. Heikkilä, R., Manninen, M., Three Dimensional Control System for Precast Architectural Concrete Production. Concrete Precasting Plant and Technology, Issue 10 (1994), pp. 62–67.

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