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POSITION CONTROL OF BEARING SLEEVES ON LOCKS AND DAMS WITH THE USE OF INNOVATIVE SOLUTION

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The problem of preserving geometric design conditions by the device of locks has been presented in the paper. The problem was illustrated by the alignment of the shaft flap bearing sleeves of the sluice on the navigable channel. The assembly design required the coaxial bearing sleeves with an accuracy of no more than 0.5 mm. Thanks to first – class measuring equipment and the author's innovative solution (Axisymmetric telescope centring device No. EP12460083.4) protected by the European Patent Office it was possible to achieve this goal. The reference axis is determined by the axis of outside bearing sleeves previously brought to one level. The innovative device is mounted at the outside bearing sleeve on one side of the lock and the target plate is mounted in the axis on the outside sleeve on the other side of the lock. The aiming line of the telescope and center of the target plate determine the reference axis for other bearing sleeves. Thanks to the innovative solution the desired accuracy was achieved, measurement time was shortened significantly and safety conditions of persons performing measurements were improved. The invention may be applied to other similar cases.

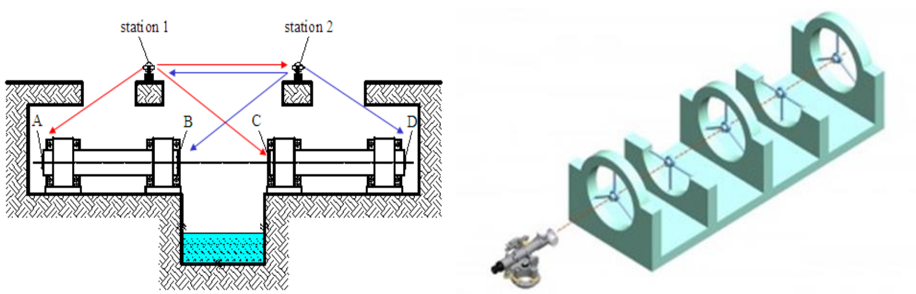
Keywords: Civil engineering, Geodetic metrology, Alignment, Channel, Invention.

1 INTRODUCTION

The problem of alignment of large machines and equipment (e.g., rolling mills or paper machines, the elements of sluices, weirs and dams) appeared with their creation. In case such devices or the elements of hydrotechnical objects (e.g., sleeves, runners, the axis of rails) are not properly positioned there appear symptoms such as vibrations or inconsistent with the design additional load values. Vibrations and shock loads are transmitted from devices to the building structures (usually reinforced concrete structures), which generally are not designed for long-term action of such loads. The effect of such behaviour can be damages (scratches, cracks etc.) of the reinforced concrete (e.g., weirs and dams structures). In extreme cases, it can lead to construction disaster and exclusion from service. Due to the size of machines and devices being set as well as high demands of precision, conventional methods cannot be applied in metrology and surveying (Deumlich 1982, Kavanagh 2004). Therefore, new solutions should be found which enable the alignment of large machines and devices in an effective and comparatively simple way. The engineering field dealing with the setting of machines and equipment can be described as geodetic metrology (e.g., submillimeter measurements in the range of dozen meters). The author, from dozens of years was engaged in the alignment of large machines and equipment. The paper presents the innovative solution entitled Axisymmetric telescope centering device (European Patent Office, Patent No. EP12460083.4 (Anigacz 2012)) serving particularly for the alignment of machinery and equipment. The usefulness of the device has been shown, among other things, at the example of the alignment of the flap of northern chamber Klodnica Sluice on the Gliwice Chanel in Poland.

2 ANALYSIS OF THE STATE OF KNOWLEDGE

Anigacz (2013) presents the way of the flap shaft alignment sleeve used in 2010 in the southern twin chamber of the Klodnica Sluice on Gliwice Chanel in Poland. The way of measurement depended on an indirect determination of the sleeve axis. The standard geodetic equipment (Total Station Leica TC2002) with the highest angular measurement accuracy of 0.5 " was used here. The essence of the measurement was based on mutual aligning the two sleeves in an axis (points B and C) of the two total stations (station 1 and 2) by the method of successive approximations (Figure 1a). Then, the sleeves A and D were aligned in such a determinated reference axis. However, such a way of measurement is labor-intensive and sensitive to weather conditions. Among other methods and devices there should be mentioned solutions of Brunson and Faro company from the US and Pruftechnik-Wibrem (2014) Polish-German company. Brunson company's offer includes, inter alia, an interesting way of alignment (Figure 1b), using a specially designed level, 545-160 Series Multipurpose Precision Sight Level (BIC 2008).



(a) (b)

Figure 1. The traditional way of the measurements by: a) Anigacz (2013), b) Brunson (BIC 2008).

However, the way of the alignment shown in Figure 2 is time-consuming. Time-consuming is due to the need of aligning the level so that its centerline passes through the centers of extreme sleeves determining the reference line. The manufacturer of the level does not provide the way with what type of device we can align in the reference axis. However, the Faro Company has developed a device called the Laser Tracker. Gassner and Ruland (2008) presented the example of calibration and the use of the device for measurements of high accuracy. It is a universal device for coordinate laser measuring. As a result of measuring the spatial coordinates of points with submillimeter accuracy are obtained. In the set with the measuring arm the device has very large measurement capabilities. The principle of measuring the concentricity of the sleeve depends on indirect determining the axis from measurement of coordinate points on the circumference of the sleeve. The Faro Laser Tracker is a very high-tech device requiring specialized software and specialized service. The device weighs tens of kilograms, and it has large enough dimensions which is an important limitation to work in situ. The above chosen methods of alignment are effective although time-consuming and they require the use of expensive specialized equipment and highly qualified staff. Deumlich (1982) in a comprehensive publication presented the construction and operation of the measuring instruments including alignment instruments. Hennecke and Werner (1986) and Kavanagh (2004) provide examples of alignment of such structures as: tunnels, pipes, rotary kilns and turbines in power plants. Anderson and Mikhail (1998) present laser devices for setting out. Schofield and Breach (2007) provide examples of applications of the different setting out methods in construction. Kahmen (2006) and Witte and Schmidt (2006) describe a method for the fixed sight line a special case which is the alignment method proposed by the author.

3 DESCRIPTION OF THE INVESTIGATED OBJECT

The sluice with the channel was put into operation in 1941. Due to the damages of the existing flap and its drive it was decided to replace it for a new one and the old mechanical drive leaning on toothed wheels for the hydraulic one. The test of usefulness (implementation) of the developed innovative solution was carried out during the exchange of the Klodnica Sluice flap (Figure 2). The steel flap is 12 m long, 3 m high and weighs 40 tons. The sluice consists of two twin chambers of parameters: 10.40 m the difference in water levels, 71.8 m length, 12.0 m width, 9,500.00 m^3 of water used for locking. The rotary movement of the flap is realized by means of two shafts arranged in four sleeves (two on each side (Figure 3b), located in the walls of the sluice – Figure 3a).

(a) (b)

Figure 2. A view of the sluice flap: a) before mounting, b) after mounting.

The flap in the southern chamber was changed in 2010. The flap in the northern chamber was changed in 2014. Measurement problems arising during the work in 2010 made the author look at the analysis of the problem more carefully. The result was creation of a new innovative device to increase the efficiency and accuracy of the survey work. The invention received protection in Polish and European Patent Office (Anigacz 2012) with the financial support of the Polish government.

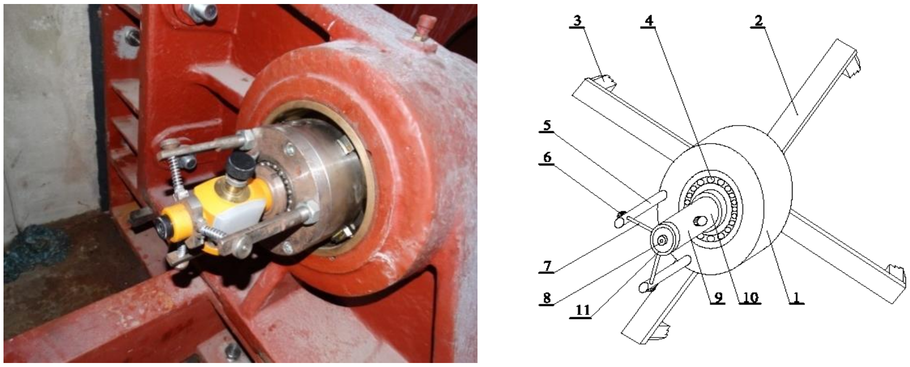
(a) (b)

Figure 3. A view of the position of the sleeves: a) in the sluice wall, b) the mutual positioning of the sleeves (view from the inside of the sluice).

4 THE PROPOSED SOLUTION AND APPLICATION EXAMPLE

The experience acquired during the exchange of the flap in 2010 resulted in the development of a new quality equipment, the advantages of which are: (i) improving the accuracy of measurement, (ii) reducing the measurement time, (iii) improving health and safety conditions of work and (iv) to a large extent making contractors independent of the weather conditions. The main difference between measurement methodology previously implemented and the measurements made with the use of the developed patent depends on a qualitative change in the approach to solving the problem, that is a transition from indirect measurements to direct ones.

Figure 4 illustrates the view and scheme of the developed device centering the telescope in the axially symmetric element, that is in the sleeve. The essence and the innovation of the device centering telescope in an axisymmetric element depends on the fact that it is equipped with the adjustable set of the telescope axis direction. The telescope objective is mounted in a self-aligning bearing centrally located inside the chuck body of the device. The structure of the device allows it to be mounted, both to inner and outer surface of an axisymmetric element, depending on which surface can be used as a reference base. The self-aligning bearing, in which the telescope is mounted, permits setting its axis in the required direction. The equally-extendable clamping replaceable arms of various lengths make possible the use of the device for centering elements of different diameters. The device has a considerably simpler construction and provides higher accuracy of setting the telescope in the axis of axisymmetric alignment element than the devices known so far. Furthermore, the alignment system permits easy adjustment of the telescope axis position. The device permits the alignment of the telescope, as well as other measuring instruments, including laser, dumpy level and theodolite. Precise centering of the telescope permits coaxial positioning of any number of axisymmetric elements over a distance of dozen meters from the axisymmetric base element with very high accuracy. Measuring of the alignment of the sleeve sluice flap was as follows.



(a) (b)

Figure 4. The implemented device: a) view on the mounted device in the sleeve, b) scheme (1 - self-centering, 2 – arms, 3 - steel jaw chucks, 4 - self-aligning bearing, 5 - pins, 6 - micrometer screws, 7 - arms of telescope, 8 - eyepiece, 9 - telescope, 10 - focus screw, 11 - clamping ring).

The device was mounted in the outer sleeve A (see Figure 1). The sight line of the telescope was located at the center of the target in the sleeve D using the micrometer screws (Figure 4b). These operations take about 10 minutes. The sleeves B and C were aligned in such designated axis. The alignment with the use of the device does not require any calculations and records. The sleeves B and C are moved as long as they are in the reference axis.

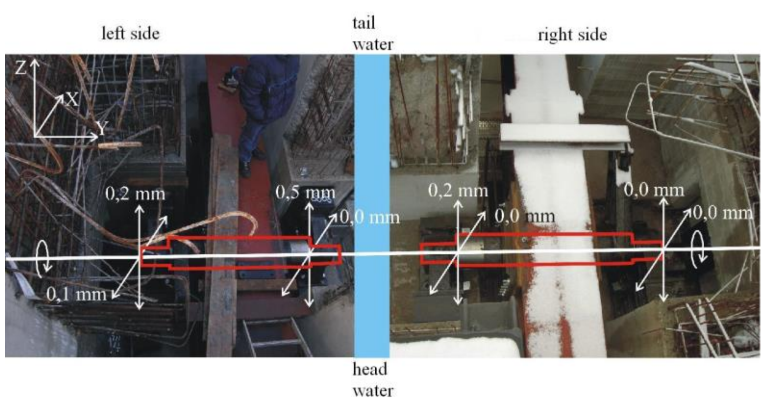


Figure 5. The results of the measurement of straightness of shaft axes.

The accuracy of the sleeve location depends more on the possibility of its setting than the accuracy of the applied device. The device itself allows for obtaining the accuracy of 0.1–0.2 mm in 20 meters. The correctness of the sleeve alignment was verified by measuring the other extreme sleeve. The obtained results were within the measurement error that is 0.2 mm. The results shown in Figure 5 are the average values of the two measurements. The correctness of the sleeve alignment was further verified by the introduction of a specially prepared test shaft. If the rotation of the test shaft ran smoothly without any noticeable turbulence the alignment was considered to be correct. The measurement of the pressure on bilateral hydraulic drive was the final inspection of the correctness of the whole sleeves - flap set. Theoretically, the two values of the pressure should be the same. In practice, due to various reasons, these values may differ up to 5%. In the present case, the condition was met.

5 CONCLUSIONS

On the basis of the practical experience gained during the case study the following general conclusions can be drawn:

1. The developed device entitled *Axisymmetric telescope centering device* proved to be sufficient for proper adjustment of the alignment of the flap sleeves of the sluice. The obtained accuracy of the sleeves alignment of 0.1–0.2 mm allows for the proper operation of the flap - drive shafts set.

2. The essential value of the innovative solution is the use of direct measurements instead of indirect ones for determining the alignment of any element. The presented solution enforces the position of the telescope axis in the sleeve axis quickly and with appropriate accuracy.

3. The device enables coaxial positioning of any number of axisymmetric elements (which are supplied with a variety of hydrotechnical objects) up to a distance of dozen meters from the axisymmetric base element. The device has a simple structure and is easy to use.

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