Technology of individual tensioning of strings in pre-stressed constructions – development and the implementation work

Andrzej Jurkiewicz [1], *Tadeusz Cygankiewicz* [2], *Marcin Apostoł* [1]

Abstract: The article, discussing the role of the pre-stressed and string concrete elements that are progressive in comparison with reinforced concrete constructions, contributes to the string concrete pre-tensioning technology development in Poland.

Key words: The tensioning, pre-stressed Concrete technology, simulation.

Introduction

The contribution of the pre-stressed and string concrete elements to the building and the bridge and road engineering in Western Europe reaches as far as 90%. The pre-stressed elements are cheaper, lighter and more rigid in comparison with reinforced concrete constructions and are superior in respect of their parameters. For example, 95% of bridges built in the years 1985-1995 are the string- and pre-stressed concrete constructions.

The pre-stressing technology is more and more widely used for strengthening the drawing shafts and for excavation anchoring. Therefore, the necessity of developing a new, original, patent clear and cheaper string concrete pre tensioning technology has arisen in Poland.

Pre-stressed Concrete Technology

The pre-stressed concrete technology consists in improving the strength parameters by application of compressive stress during the concrete setting process (Fig.1).

The state of stress within the pre-stressed construction is achieved by purposeful, preliminary string tensioning and due to the transmission of stressing forces with adherence (string concrete) or with an appropriate anchoring (post-tensioned prestressed concrete).

The principal properties of the constructions are as follows:

- Transmission of tensioning forces by constructional elements of small cross section due to high resistance of the compressing steel. This property enables the use of the large-span constructions (houses, bridges) or heavy loads (e.g. nuclear reactor halls).
- Providing the scratch resistance.
- Decreasing the construction deformation due to the intensive action of compressing forces.
- Pre-stressing improves the concrete fatigue life under the repeatedly variable load conditions (fatigue strength).
- Pre-stressing enables the application of concrete at low temperatures, e.g. for liquefied gas containers (-150°C) instead of very expensive Nb-Ni steel.
- Due to utilization of properties mentioned above in some reasonable applications a considerable reduction in costs have been achieved in comparison with the use of other materials. This refers to the floors in housing, roofing of industrial halls, bridges and strengthening of mining excavations.

[1] *Dr.inż. Andrzej Jurkiewicz* and *Mgr.inż. Marcin Apostoł*, University of Mining and Metallurgy, Faculty of Mechanical Engineering and Robotics, Departament of Proces Control, al. Mickiewicza 30, 30-059 Cracow, Poland, tel. 048 012 17 30 80, fax. 048 012 33 91 03

[2] *Mgr.inż. Tadeusz Cygankiewicz*, Coal-mine KWK „Janina", Libiąż, Poland, tel. 035 322 51 wew. 5897
(Received: December 20, 1997)

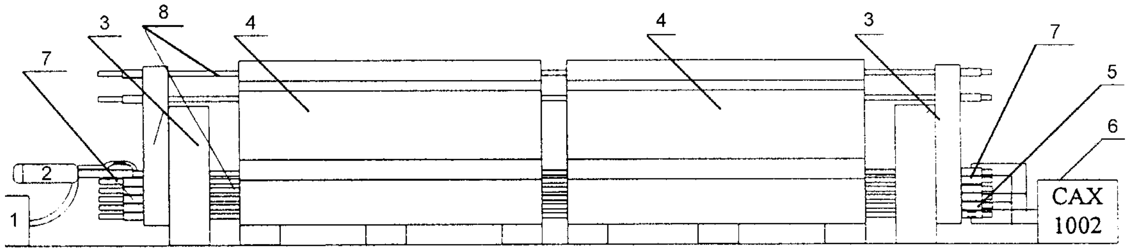

Fig.1. Example of prestressing line. 1-hydraulic drive-control unit, 2-tensioning and conveying device, 3-pressure block, 4- girder mouduls, 5-tensometric sensors, 6-tensometric bridge, 7-anchoring clamps, 8-strings.

Tensioning and Conveying Devices

Brief foredesign

In the years 1992-1995 at the Academy of Mining and Metallurgy in Cracow the tensioning and conveying devices UNT-10 and UNT-15 were developed. The working cycles of these devices were controlled in two ways:

- through the tensioning device, with hydraulic manipulators (dividers) of special design and remote control units;
- through the hydraulic unit, with hydraulic manipulators (dividers) equipped with the control levers.

An experience resulting from utilizing both these solutions leads to the conclusion that the control carried out by the hydraulic unit is superior in respect of technical, ergonomical aspects as well as working safety of the staff operating the tensioning device. However, the working cycle control with throttling decreases the efficiency of hydraulic system. Thus, we decided that the tensioning device should be controlled by the hydraulic unit.

In addition the following preliminary assumptions have also been adopted:

- possibility for tensioning (stressing) the strings (ropes, strings, bars, wires) of any length and diameters ranging from 15 mm up to 18 mm;
- holding a string with the inner jaws during the feeding pressure dissipation;
- introduction of the hydraulic disanchorage system for the inner jaws;
- introduction of an universal convolution spacing;
- the feeding pressure ranging from 2 MPa up to 32 MPa;
- the force tensioning a string of 250 kN;
- ensuring the working cycle sequence by structural relationships between the control dividers in order to eliminate any errors in the working sequence of the device;
- fatigue life of the working and control elements of above 100 thousand cycles;
- equipping the device with the anchorage head;
- possibility for the use a water-oil emulsion;
- modular design enabling a change of application and repairs through the exchange of individual subassembly only;
- working stroke of 300 mm for the total device length of 900 mm;
- possibility for the application of the device for purposes other than pre-stressing, e.g. for conveying under very difficult conditions, i.e. in mining, metallurgy, industrial rescue work etc.;
- originality and patent clearance.

Working Cycles

The working sequence of the tensioning device includes the following cycles after introducing a string into the inner clamp (Jurkiewicz, 1997) of the inner head (Pluta et al., 1996):

- holding a string (with the inner clamp 2 of the inner head 1); a hydraulic medium, fed under pressure through a channel inside the piston rod, acts on the inner clamp cylinder which moves the jaws and clamps around the seized string.

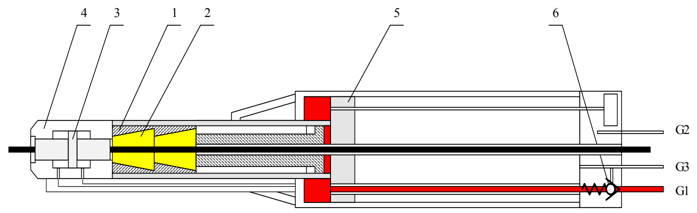

Fig.2. Holding a string.

- tensioning a string (up to the force set by the operator); a medium fed under pressure acts on the valve piston (Jurkievicz et al., 1995b) inside the chamber A and moves it, producing the desired force value,

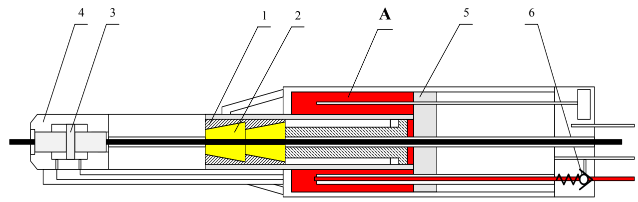

Fig.3. Tensioning a string.

- anchoring a string; a pressure impulse applied to the anchorage piston (Jurkievicz et al., 1995a) of the anchorage head (Jurkievicz et al., 1995) moves the jaws of the conical self-locking clamp and clasps them around the tensioned string,

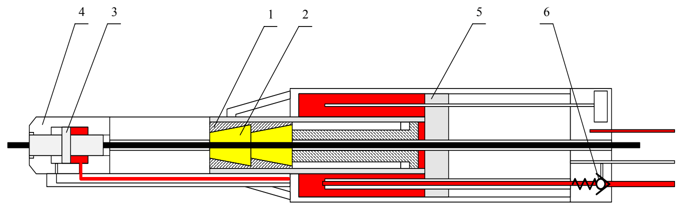

Fig.4. Anchoring a string.

- return; after applying the control impulse to the piston chamber B, the moving subassemblies of the device return to their starting positions.

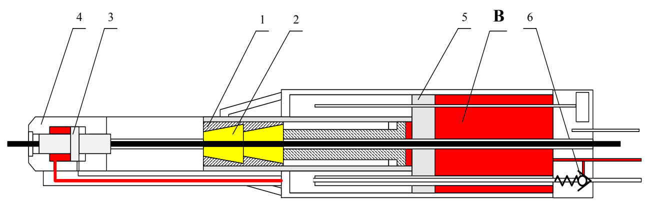

Fig. 5. Device return.

- disanchoring of the inner jaws; after applying the control impulse to the chamber of the anchorage piston (Jurkievicz et al., 1995) the jaws are released.

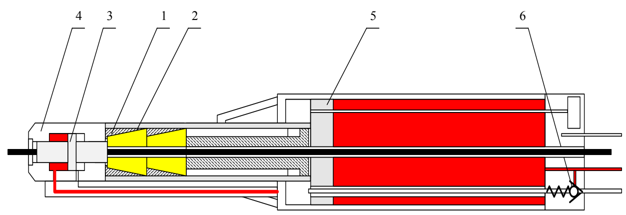

Fig.6. Disanchoring of the inner jaws. 1 - Inner head, 2 - Two-conical inner clamp, 3 - Anchorage piston, 4 - Anchorage unit, 5 - Tensioning unit, 6 - Hydraulic processor tracking the pressure increase in order to avoid releasing of the tensioned string in the case of pressure failure.

Hydraulic Drive-Control Unit

The function of the hydraulic unit is to feed the working chambers of the UNT tensioning and conveying device in a pre-set sequence for the set working parameters, enabling a change of these parameters. In order to ensure a smooth change of the main pump efficiency, in place of the edge throttling used so far, an asynchronous motor is used. The motor speed is adjusted with an inverter with the vectorial control. In order to eliminate pressure pulsations, the charging gear pump located inside the main pump suction manifold is applied. Such solution has a positive effect on improving prestressing conditions and proper operation of the device.

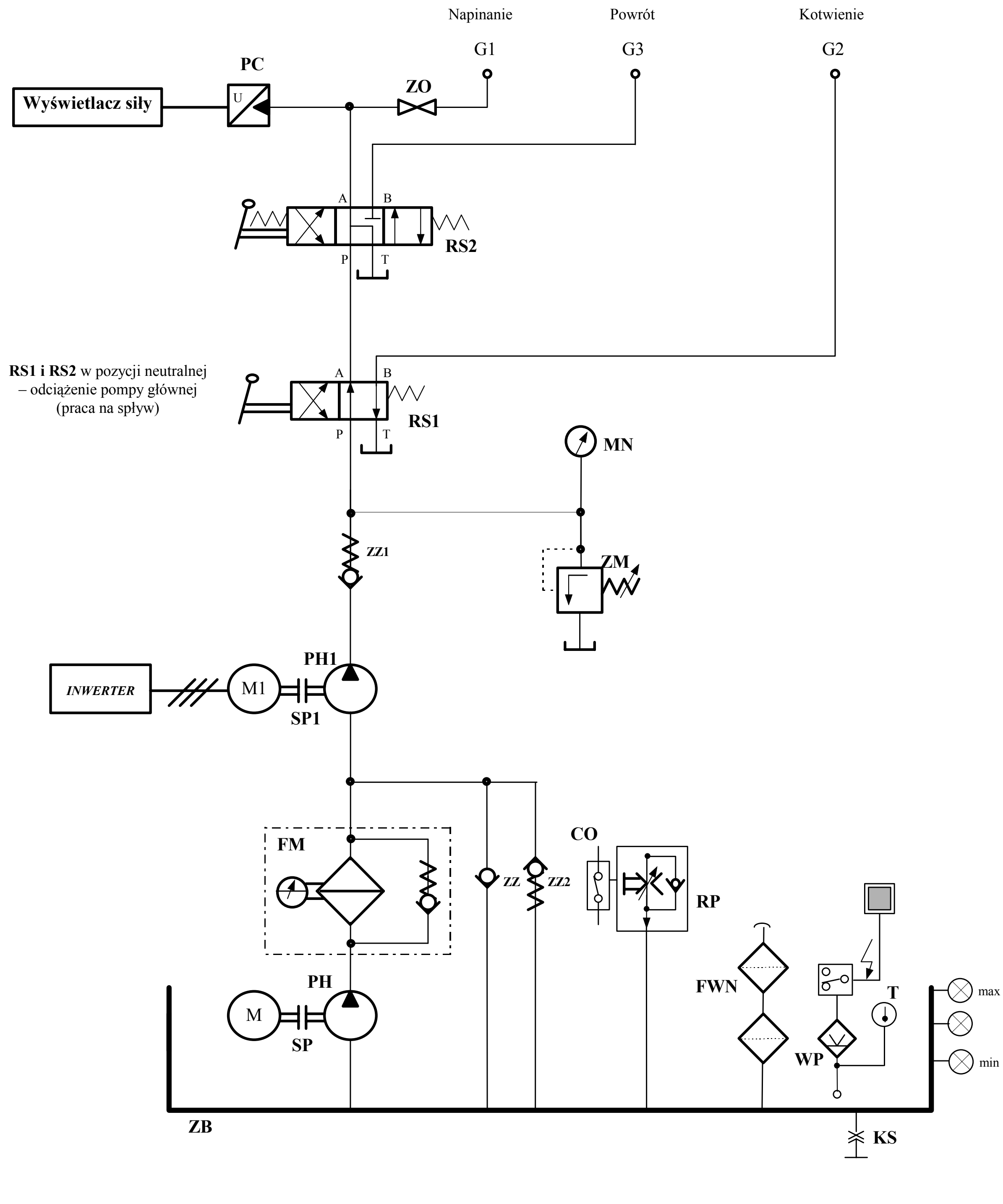

Fig.7. Diagram of the hydraulic feeder of UHBJ 10/7, 5/100 type installed with the tensioning and conveying device of UNT type.

Simulation of Prestressing Time Under Working Conditions

The system speed is one of economical factors determerming the efficiency of any system or device. Thus, the prestressing and return times should be as short as possible. In simulation presented below the power output is a main criterion limiting and deciding on the device speed. Assuming the fixed power output of 5,5 kW of the piston speed, the prestressing speed was also calculated.

Prestressing time for the 25m - beam

Fig.8. Prestressing time [s]. Length [m].

Prestressing time for the 100m - beam

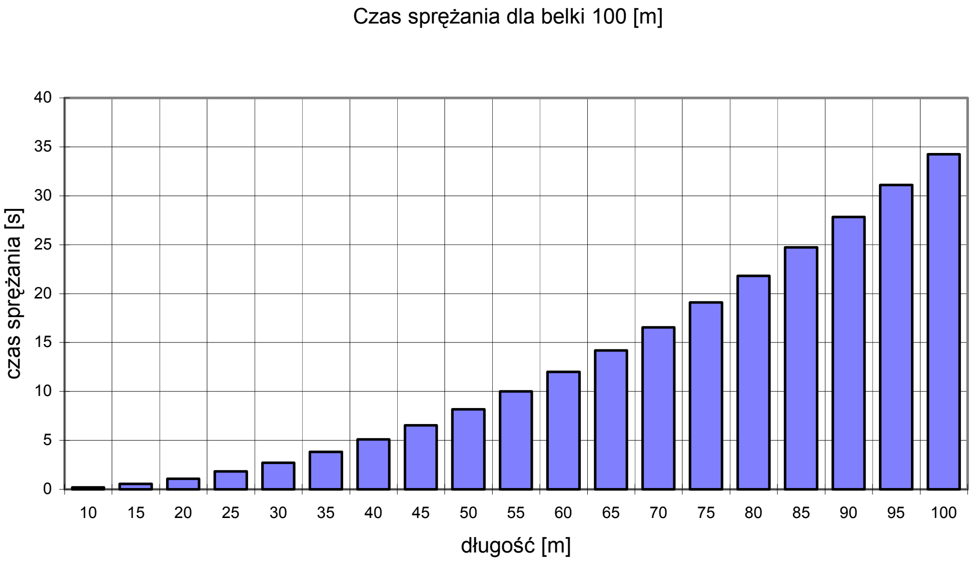

Fig.9. Prestressing time [s]. Length [m].

The determined characteristics lead to the following conclusions:
- prestressing time increases with the piston stroke,
- the power output of 5,5 kW is sufficient to ensure a proper operation,
- slower prestressing enhances quality and accuracy of manufactured elements.

The presented characteristics were determined for the hydraulic unit of 5,5 kW power output and beams of 25 m and 100 m in length.

Final Conclusions

The tensioning device in respect of its working parameters and functional properties comes up to the Western designs. The Introduction of the feeding of the inner head with the conical clamp through the adjustable check valve ensures that a string remains clasped even in the case of pressure failure. The tensioning force of 250 kN is reached under pressure of 27 MPa. This is of great importance for the work safety (in designs developed by Western companies such a force can be achieved only at pressures over 50 MPa). Also the working stroke of 300 mm and weight of 20 kg fully comply with the recent European trends.

The logic structure of the control system excludes the possibility of sending an erroneous control signal. The resetting of dividers inconsistently with the device working sequence, which could lead to the releasing a string in the head clamp, has no effect. The system is operated only if the control signals set by an operator coincide with the device working sequence. The "run-off" work during breaks in feeding the tensioning device or long interruption between cycles is an important advantage of the device. This brings considerable energetic effects and at first place, does not lead to the rise in hydraulic oil temperature, typical for the throttled flow.

The application of the inverter drive enables a smooth adjustment of piston speed, thus also choosing an appropriate tensioning speed for a string. This parameter decides on the quality of construction, especially during determinus prestressing post tensioned constructions. Such features place the hydraulic unit among the designs developed by recognized European companies.

References

Jurkiewicz, A.: *Wykonanie i badanie urządzenia napinającego UNT 15 i agregatu hydraulicznego UHBJ 10/7,5/100*. *Praca badawcza nr 5.130.02 Kraków 1997.*

Pluta, J. & Jurkiewicz, A.: Agregat hydrauliczny napędowo sterowniczy typu UHBJ 10/7,5/100 do współpracy z urządzeniami napinająco-transportującymi. *Dokumentacja techniczno ruchowa, Chocznia 1996.*

Jurkiewicz, A., Cygankiewicz, T., & Mirowski A.: Samozaciskowy uchwyt stożkowy. *Patent PL 166680, 30.06.1995.*

Jurkiewicz, A., Cygankiewicz, T. & Mirowski, A.: Samozaciskowy uchwyt stożkowy. *Patent PL 167647, 31.10.1995a.*

Jurkiewicz, A., Cygankiewicz, T., Mirowski, A. & Podsiadło, A.: Hydrauliczne urządzenie napinająco transportujące. *Patent PL 167148, 31.08.1995b.*

Jurkiewicz, A., Cygankiewicz, T., Mirowski, A. & Podsiadło A.: Hydrauliczne urządzenie napinająco transportujące. *Patent PL 170369, 31.12.1996.*