The information technologies use at difficult technical objects condition control

S I Evtushenko 1*, T A Krahmalny 2, V A Lepikhova 2, M A Kuchumov 2

1 Moscow State National Research University of Civil Engineering, Yaroslavskoye Highway, 26, Moscow, Russia
2 Platov South-Russian State Polytechnic University(NPI), 132 Prosveshcheniya street, 346428, Novocherkassk, Russia

E-mail: evtushenko_s@novoch.ru

Abstract. The complex technical objects’ durability, operational reliability and safety depend on a complex set of factors. These factors impact result is the objects elements stress-strain state, formed at the construction stage and changed during the operation period under the growing damages influence, changed in the physical and mechanical materials properties, as well as the soil foundation condition.

Introduction
The complex technical objects building structures state inspection is a particularly acute task due to their rapid aging. Thus, over the last two decades, the snow load and seismicity scores have been increased in construction standards, which specifies the natural and climatic factors impact, permanent and temporary loads on objects and, as a consequence, new damage and defects appear in the structural elements. Existing methods of monitoring the objects technical condition very often do not sufficiently take into account the arising structural damage parameters, the causes of their occurrence and development over time. An effective solution to these problems can be a system for monitoring the industrial buildings condition using modern information technologies. Referring to the history of this issue, it should be noted that many scientists considered a scientifically based assessment of the technical condition, operation and ways to extend the buildings and structures life cycle. So, the work of R.A. Samitova is dedicated to engineering monitoring of complex building structures. O.V. Garamov addressed the problems of improving the operation process efficiency to the preventive monitoring system elements development and implementation. Under the leadership of I.G. Ovchinnikov the complex engineering structures strength monitoring operation and the carrying out process scientific organization problem is solved. An important contribution to solving problems of assessing the reliability of buildings and structures according to external signs was made by A. Dobromyslov. The theoretical significance of these studies is to improve the methods for conducting the complex technical objects surveys and determining the technical condition of building structures with damage.

Development essence
The construction objects state constant monitoring is a very costly measure, which is becoming more and more economical due to the new special equipment and software use. Prospective scientific developments in this area make it possible to ensure the objects safety and to obtain maximum information about an object state in new formats of digital representation [1] with minimal financial expenditures.

To monitor the complex technical objects state, it is proposed to use a monitoring system based on information systems for collecting, transmitting, storing and processing digital data and allows the geometrical characteristics continuous monitoring, as well as existing defects and damage to complex technical objects (Figure 1) [2, 3].

The system includes a data processing center (DPC) on the basis of a computer and at least one system for collecting and transmitting information, consisting of a controller and sensors connected to the controller by a communication line. The data center allows, thanks to broadband access to the Internet, to conduct continuous monitoring of the incoming information and promptly respond to the measured parameters deviation beyond the established limits. A patent for utility model has been obtained for this system [2].

![Figure 1. The difficult technical objects monitoring system structure](image)

The system is integrated with a sensor measuring the crack opening width, which works as follows. When a crack opens, the distance between the sliding stem stop and the device, which are fixed on the crack’s different sides is changed. The movement amount through the rheochord current collector enters the analog-to-digital converter, and then the microcontroller transmits the movement value over the air to the receiving data center module integrated into the computer. The structure of sensors connected to the system is also integrated inclinometer (inclination sensor angle), designed to measure the deviation angles from the vertical. The sensor uses a plate-pendulum, mounted on supports on a magnetoelectric damper with a power correction of the side plates and an electronic balanced mixer [4]. The system of the building elements state monitoring allows real-time measurements and automating the transmitting data process via wireless communication channels. In the information processing center, data on the controlled object are analyzed and processed. The block “Main menu”, being the data center control element, allows to make a transition to working with the complex technical objects’ registry, the statistics block and the monitoring block. The “Objects Register” block includes work with the archive, the new object registration block, the block of editing information about the object and the monitoring results registration block. The objects regular inspections results are recorded in the block “The inspection results registration”. In the “Statistics” section it is possible to obtain the data on all objects from the registry, emergency facilities that are inoperative, partially operational, require major repairs, maintenance, according to the earliest survey date, according to the survey latest date, according to the least residual resource. The objects inspection forms are integrated into the system and contain characteristic defects and damage to each element (more than 200 types of defects and damage are represented in the system). Based on the detected defects entered parameters, the system assigns the technical condition category
to each element of the object, and in conclusion displays the general technical condition of the object and performs the residual resource calculation.

The automated system in the autonomous mode produces a reminder about the need to carry out a survey when the deadline for the next scheduled inspection of the object normalized by the rulebook [5] is approaching. The program may schedule a survey for the current month, quarter, semester and year.

**Development approval**

Let us consider the system application features when examining boilers and chimneys.

According to BC 89.13330.2012 [7], a boiler room is a complex of buildings and structures with boiler installations and auxiliary process equipment designed to generate thermal energy for heat supply. Boiler rooms were surveyed to determine the compliance of their condition with the industrial safety requirements established [8]. Surveyed boilers were commissioned in the sixties and eighties of the last century and are separate.

The building structures examination showed that in all cases the boiler houses buildings did not fully meet the industrial safety requirements due to the presence of separate building structures in a limited working condition.

At the same time, it was possible to isolate the characteristic defects and damages, as well as the structures most vulnerable to their formation.

In particular, in all cases there were damage to brick enclosing structures caused by various factors, including the foundation draft, long service life and atmospheric effects. Characteristic defects in this case are cracks in the brickwork, destruction in local areas, as well as the brickwork soaking and weathering. It is worth noting that the window siphon lack from galvanized roofing steel is a frequent cause of the bricks soaking.

The blind area and adjacent territories unsatisfactory condition was also observed, and, as a result, longitudinal and transverse cracks along the walls, fractures, as well as overgrowth and the blind area cluttering were noted.

Particular attention in the buildings’ boiler examination is paid to the roof condition. As a rule, it is performed flat with the use of roll materials, which causes the risk of occurrence of characteristic defects, such as cracks and tears of the roofing carpet, swelling, damage to the waterproofing layer. Because of these damages, the roof leaks, which leads to the slab coating soaking. Due to the timely repair of the roof serious damage, we did not find those in the boiler houses examined by us.

All identified characteristic defects were introduced into the automated monitoring system.

According to the fire and explosion hazard degree the boilers are classified as "G". To ensure the explosion resistance in buildings of category “G”, easy-reset structures (ERS) with an area of at least 0.03 m² / m³ of the room free volume should be arranged [9]. In all the objects surveyed, only windows and ventilation grilles served as such structures, but this turned out to be enough. The ratio of the ERS area to the room free volume in the examined boiler houses was 0.07–0.1 m² / m³.

According to BC 89.13330.2012 [7], the separate boiler houses buildings should be carried out in the I and II fire safety equipment fire hazard class fire resistance degrees. The functional fire hazard boiler class - F 5.1 [10]. Due to the fact that the boiler houses main constructions are made of non-combustible materials (brick, concrete), the space-planning and constructive solutions of the buildings comply with fire safety requirements.

The boiler house chimney is an independent responsible engineering structure operating in particularly difficult conditions of high wind loads, temperature extremes, flue gases aggressive effects, physical and mechanical loads. It is worth noting that most of the operated brick chimneys, has almost reached its operational life of 50 years [11, 12]. Moreover, many pipes are operated with deviations from the design conditions and without proper monitoring of the current technical condition, which makes them, and so time-consuming repairs even more difficult, and also increases the emergency situations risk.
Characteristic damage to brick chimneys is:

- the lining destruction, most often caused by a deviation from the design values of the temperature and humidity conditions, frequent changes in the temperature of the exhaust gases, as well as the gas mixture explosions, the so-called “flip”;
- the trunk curvature and roll due to uneven precipitation of the foundation and the inconsistency of the structures calculated actual working conditions;
- the vertical and horizontal cracks formation in the brickwork, often observed in the initial operation period of the pipe during its first heating;
- metal structures corrosion due to insufficient or untimely maintenance;
- bricks and masonry mortars weathering caused by vapors condensation formed during the fuel combustion on the inner surface of the walls;
- baffles, stratification of brick and brickwork due to soaking or condensation, as well as in the temperature regime violation;
- brick chimneys tip destruction due to the effects of precipitation and negative temperatures in the winter;
- distortion or damage to steel structures;
- absence or damage to the lightning receiver, corrosion or breakage of the current lead, ground loop destruction.

All the chimneys detected defects correspond to the above-mentioned characteristic groups and were entered into the automated monitoring system.

An example of a survey object, the results of which are given in this article, was a brick chimney of a 45 meters high boiler house, located in Millerovo, Rostov Region and commissioned in 1981. The chimney survey purpose was to determine the technical condition of the structure and its compliance with industrial safety requirements [13].

Chimney is designed to remove flue gases from five boilers running on natural gas. The temperature of the exhaust gases entering the pipe is about 150 °C.

The pipe height above the relief level is 45.093 m. The outer trunk diameter varies in height from 5.16 m at the level of the base to 2.56 m at the tip level. The barrel inner diameter varies in height from 3.3 m in the basement level to 1.8 m in the level of the tip. The laying of the barrel of the pipe is made of clay M100 brand on cement-sand mortar M100 brand, and the foundation is made of monolithic reinforced concrete M250 (B 20), glass type.

The barrel lining is provided for the entire height and is made of clay M100 brand on a cement-sand mortar brand M50. The lining thickness varies from 120 to 250 mm. The clamping rings of the pipe are made of strip steel 100 × 8 mm in the amount of 33 pcs. arranged at full height. The running ladder consists of brackets with a diameter of 20 mm (round steel) and fencing (brackets with strips attached to them). Brackets are installed on the outer and inner pipe sides with a pitch of 400 mm. The traffic light platform is located at the mark of +39.120 m. The platform width is 750 mm, the enclosing railings height is 1100 mm. Bearing structures of platforms - cantilever beams from channel number 14, rigidly embedded in the laying of the pipe. Lightning protection of the pipe is provided by a lightning receiver from a pipe with a diameter of 42 mm and a lightning conductor with a diameter of 10 mm connected to the ground loop. Entering ducts into the underground pipe. The flue cross section size along the external contours of 730x1240 mm. The duct cover is made of sheet steel. The flue bottom mark is 1,650 m.

As part of the survey, the pipe full-scale measurements, including the determination of the roll, the visual and instrumental examination of the pipe structures and the masonry materials strength determination were carried out.

During the chimney foundation instrumental examination, a decrease in the foundation concrete strength inside the pipe was found, the reason for which was the absence of glass lining and elevated temperatures of exposure to flue gases.
An important aspect of the chimneys’ examination is the pipe roll geodetic measurement. The structure roll was 345 mm, which does not exceed the allowable value of 375 mm for a given pipe height according to BC 13-101-99 [14], but we recommended to continuously monitor the inclination of the pipe, which at the time of the survey was 0026’21”.

The trunk examination showed that there are superficial damages of the brickwork over its entire height, including at the site in the tube top to a depth of 120 mm due to poor bricks quality, as well as in the sealing zone of individual chassis brackets and cantilever beams from the channel light. When inspecting the lining, which is usually most susceptible to destruction due to the direct aggressive effects of fuel combustion products, it was found that its brickwork is exfoliated and collapsed, and there is a lining brickwork surface destruction in certain areas in the upper part of the pipe.

In a previous regular survey of the chimney in 2013, the chimney tip brickwork destruction was established. In the recommendations for operation it was indicated to shift the brickwork of the chimney top. At present, it has been noted that the pipe head has been restored, the brickwork has been shifted. Another “weak point” of boiler chimneys can be metal structures. As a result of the survey, it was found that the welds of the fastening elements of the lights of the traffic light platform are missing or destroyed, and the bolted joints are subject to corrosion and are not tightened. The running staircase metal shackles are deformed. At the same time, the corrosion-resistant coating of the pipe metal structure is generally in satisfactory condition. As recommendations for further safe operation of the brick chimney, it is possible to specify: the destroyed brickwork restoration by plastering and subsequent barrel pipe marking, repairing the traffic lights metal structures, lining the basement glass and refurbishing the basement lining.

Summary
As a result of the examination, defects in the brick chimney corresponding to the above-mentioned classification have been revealed; the boiler and chimney structures state further monitoring can be carried out using the proposed automated system. At present, two invention patents, a patent for a utility model, and a certificate of a computer program industry registration have been obtained for this monitoring system and its constituent sensors [3-5, 15]. This system application, according to the authors, will lead to an increase in the complex technical objects operation safety and durability by ensuring continuous monitoring and centralized control of their geometric characteristics and the existing defects and damage state.

References
[1] Volosukhin V A 2013 Defects and damages of building constructions of bridges on meliorative channels of the Rostov region (monograph, Southern Russian state polytechnical university (NPI) of M.I. Platov, Novocherkassk).
[2] Evtushenko S I, Krahmalny T A, Evtushenko A S, Krahmalnaya M P Monitoring of technical condition of buildings and constructions as basis of complex safety in Construction (Construction and architecture) 2 (4) (5) 182-185. DOI 10.12737/17525
[3] Evtushenko A S, Evtushenko S I, Rudov N V The automated system of monitoring of geometrical characteristics of buildings and constructions (stalemate. 62724 Dewxs. Federation: MPK E04G 23/00 № 2006122822/22, statement 26.60.2006; publication 27.04.2007).
[4] Krahmalnaya M P, Krahmalny T A, Evtushenko S I System of monitoring of a condition of cracks and joints of buildings and constructions (patent 2448225 Russian Federation: MPK E04P 23/00 № 2010140257/03 statement 01.10.2010; publication 20.04.2012, Byulleten №11, application 2010140258, statement 01.10.2010; it is published 10.02.2011, Bulletin № 4).
[5] Zotov M V, Tyshchenko S G, Evtushenko S I, Rudov N V Tilt angle sensor one-plane: stalemate. 2344369 Dewxs. Federation: MPK G01C9/00 № 2006135368/28 statement 09.10.2006; it is published 20.01.2009.
[6] Set of rules 13-102-2003 *Rules of inspection of the bearing building constructions of buildings and constructions*, 2003-08-21 is entered. - M.: State Committee for Construction of Russia, SUE TsPP, 2004.

[7] Set of rules 89.13330.2012 «*Boiler installations. Revised edition Construction Norms and Regulations of II-35-76*».

[8] Federal law of 21.07.1997 № 116-FZ «About industrial safety of hazardous production facilities».

[9] Safety rules 12-529-03 «Safety rules of systems of gas distribution and gas distribution» there is item 2.5.5, 2.5.10.

[10] Set of rules 12.13130.2009 «Determination of categories of rooms, buildings and outdoor installations on fire and explosion and fire hazard».

[11] Evtushenko S I 2008 *Inspection of the operated metal chimney of the boiler house of Municipal Unitary Enterprise in Taganrog of the Rostov region, Information technologies in inspection of the operated buildings and constructions* (Materials VIII Mezhdunar. scientific and practical conference, Novocherkassk, 09.06.2008, Southern Russian state technical university (NPI), Novocherkassk).

[12] Murzenko Yu N, Nadezhin A V, Semyonov A D 2001 *Inspection of a condition of high-rise constructions with use of the principles of modeling in the «virtual reality» environment, Information technologies in inspection of the operated buildings and constructions* (Materials International scientific and practical conferences, Novocherkassk, 19-22.06.2001, Southern Russian state technical university (NPI), Novocherkassk, UNTs «Nabla») I pp. 4-5.

[13] Federal law of 21.07.1997 № 116-FZ «About industrial safety of hazardous production facilities».

[14] Set of rules 13-101-99 «Rules of supervision, inspection, maintenance and repair industrial smoke and air-channels» (Paragraph 5.7).

[15] Evtushenko S I, Krakhmalný T A, Krakhmalnaya M P 2014 *Account and systematization of characteristics of reinforced concrete bridge constructions through the water carrying out channels of the Rostov region («PENAL CORRECTION SYSTEM of ZhMS»)* (Certificate on the state registration of the program for Electronic computer №. 2014617460, № 2014615109; statement 29.05.2014).