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Original Empirical Research

Determination of the Optimal Volume of Elements of Building and Engineering Structures by Non-Destructive Testing of Their Strength

EDN: YIVEUL

Nikos L. Vernezi
Don State Technical University, Rostov-on-Don, Russian Federation
✉ vernezin@mail.ru

Abstract

Introduction. Before repairing or reconstructing steel structures, it is necessary to obtain information about the strength capacities of the metal. The estimated service life of metal structures is tens of years, but it is known that the mechanical properties of the original metal change over time. Additionally, many facilities operate beyond these anticipated lifespans. As some researchers have noted, the challenge of obtaining such information is due to several factors. Firstly, in most cases, it is impossible to cut samples from existing structures. Secondly, the use of non-destructive testing methods needs to ensure sufficient accuracy in assessment. Thirdly, non-destructive testing may not be physically possible due to the design features of the object. Fourthly, survey work on the operating structure can be very laborious and expensive, requiring a reduction in volume and cost. Fifthly, when assessing the mechanical characteristics of the metal, it is important to apply an approach that guarantees the accuracy of results while minimizing work by utilizing previously obtained information on similar metals. Given these challenges, the development of a methodology that combines non-destructive testing with prior information is crucial.

In non-destructive testing of structures, methods for qualitative assessment of the condition of metal or welded joints are used, such as ultrasonic, magnetic, and radiation techniques. There are also quantitative methods for evaluating mechanical characteristics, such as using portable hardness testers. However, most methods for assessing strength characteristics, such as yield strength and temporary tear resistance, are cumbersome and limited to laboratory settings.

The methods of clarifying experimental information using a priori data by experts are conventionally divided into three categories:

– according to the priority of the weight of a priori and experimental data;
– extrapolation of past data to future periods;
– based on Bayesian procedures.

This article describes a non-destructive strength testing method based on indentation developed with the author's participation and repeatedly tested in actual surveys. The aim of this article is to justify the author's methodology to minimize the amount of required samples during survey work by combining non-destructive testing methods and Bayesian accounting for experimental information.

Materials and Methods. The research plan involved analyzing experimental data on the mechanical properties of metals and developing an algorithm to minimize the number of samples of control objects. Before measuring, the metal of the structures was cleaned with a hand grinder. The method of non-destructive testing of the evaluation of mechanical characteristics according to the parameters of the impact insertion of the indenter into the surface under study was used. To minimize the amount of work, a Bayesian approach was used to reduce the variability of posterior values by utilizing additional experimental data on the mechanical characteristics of such steels. The material St3 of strength class KP 245 with yield strength of 245 MPa and tensile strength of 412 MPA was studied. Additional experimental data on this material's properties were available from a previously studied metal structure.

Results. The method of non-destructive testing of the strength of metal in pipe structures has been implemented. This method used prior information obtained from previous surveys of similar materials. Based on a Bayesian approach, experimental and previous information was combined, in particular, the values of time resistance to rupture. A method

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for estimating the minimum required sample size of the examined structural elements was proposed provided there was minimal risk from an estimation error. As a result of calculations, it was shown that the use of such a technique was possible with a sample size of 2–3 elements.

Discussion and Conclusion. The proposed methodology was developed based on an analysis of more than 20 surveys conducted to assess the strength of the existing metal structures. Using the non-destructive testing method, we were able to simultaneously determine the yield strength, tensile strength, elongation, and hardness. The article presents data on the values of tensile strength. It should be noted that although the duration of each measurement was 20–30 seconds, in some cases it took longer to inspect large structures, such as bridges, which could take weeks. The calculation performed using the proposed method, which combined experimental and pre-experimental information about one of the strength characteristics of steel, temporary tear resistance, showed the high efficiency and potential for further application in future surveys.

Keywords: mechanical characteristics, tensile strength, non-destructive testing, Bayesian estimation, optimal sample size during testing

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Оригинальное эмпирическое исследование

Определение оптимального объема элементов строительных и машиностроительных конструкций при неразрушающем контроле их прочности

Н.Л. Вернези

Донской государственный технический университет, г. Ростов-на-Дону, Российская Федерация

✉ vernezin@mail.ru

Аннотация

Введение. Перед ремонтом или реконструкцией стальных сооружений необходимо получить информацию о прочностных возможностях металла. Расчетные сроки службы металлоконструкций составляют десятки лет, при этом известно, что механические характеристики исходного металла за это время претерпевают изменения. Кроме того, многие объекты работают с превышением этих сроков. Как отмечают некоторые исследователи, проблема получения таких характеристик связана с тем, что, во-первых, в большинстве случаев вырезание образцов из действующих конструкций невозможно, во-вторых, применение неразрушающих методов контроля должно обеспечить достаточную точность оценки, в-третьих, неразрушающий контроль из-за конструктивных особенностей объекта физически возможен не в любой точке, в-четвертых, обследовательские работы эксплуатируемой конструкции весьма трудоёмки, дороги и требуют снижения как объёмов, так и стоимости, в-пятых, при оценке механических характеристик исследуемого металла необходимо применение подхода, позволяющего обеспечить точность результатов с минимизацией объёмов работ за счет использования ранее полученной информации о характеристиках металла подобной конструкции. Вследствие изложенного возникает задача разработки методики, объединяющей методы неразрушающего контроля и учета априорной информации.

При неразрушающем контроле конструкций на практике применяются методы качественной оценки состояния металла или сварных соединений, такие как ультразвуковой, магнитный, радиационный и др. Также имеют место количественные методы оценки механических характеристик, например, с помощью переносных твердомеров. Однако приборное обеспечение большинства методов оценки прочностных характеристик (предела текучести, временного сопротивления разрыву) громоздко или ограничено лишь лабораторными рамками.

Методы уточнения экспериментальной информации на основе использования априорных данных специалистами условно разделены на три группы:

– по приоритету весов априорной и опытной информации;

– экстраполирование прошлых данных на будущие периоды;

– основанных на байесовских процедурах.

В статье описан метод неразрушающего контроля прочности на основе индентирования, разработанный при участии автора и многократно апробированный в реальных обследованиях. Цель данной статьи заключается в обосновании предложенной автором методики минимизации объема необходимой выборки при обследовательских работах, основанной на объединении методов неразрушающего контроля и байесовского учета доопытной информации.

Материалы и методы. План исследования включал в себя анализ доопытной информации о механических характеристиках металлов и разработку алгоритма минимизации объема выборки объектов контроля. Перед измерением металл конструкций зачищался ручной шлифовальной машиной. Использовался метод неразрушающего контроля оценки механических характеристик по параметрам ударного внедрения индентора в исследуемую поверхность. Для минимизации объема работ применялся байесовский подход к сокращению дисперсии апостериорных значений за счет использования доопытной информации о механических характеристиках подобных сталей. Исследовался материал Ст3 класса прочности КП 245 с пределом текучести 245 МПа и временным сопротивлением разрыву 412 МПА, по характеристикам которого на ранее исследованной аналогичной металлоконструкции имелась доопытная информация.

Результаты исследования. Реализован метод неразрушающего контроля прочности металла трубной конструкции. При этом использована априорная информация, полученная при предыдущих обследовательских работах аналогичного материала. На основе байесовского подхода объединена опытная и доопытная информация, в частности, о значениях временного сопротивления разрыву. Предложена методика оценки минимально необходимого объема выборки обследуемых элементов конструкции при условии минимального риска от ошибки оценивания. В результате расчетов установлено, что применение такой методики возможно при объёме выборки в количестве двух-трех элементов.

Обсуждение и заключение. Предложенная методика явилась следствием анализа результатов более 20 проведённых обследовательских работ по оценке прочностных возможностей действующих металлических конструкций. На основе примененного метода неразрушающего контроля одномоментно определялись предел текучести, временное сопротивление разрыву, относительное удлинение и твердость. В статье приведены данные для значений временного сопротивления разрыву. Следует отметить, что даже при условии длительности одного измерения в 20–30 сек. в некоторых случаях на обследование крупных сооружений (например, мостов) требовалось значительное время, иногда измеряемое неделями. Выполненный расчет по предложенной методике, объединившей опытную и доопытную информацию об одной из прочностных характеристик стали, временном сопротивлении разрыву, показал высокую эффективность применения такого подхода и возможность дальнейшего его применения при обследовательских работах.

Ключевые слова: механические характеристики, временное сопротивление разрыву, неразрушающий контроль, байесовское оценивание, оптимальный объем выборки при испытаниях

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Introduction. The article discusses the problem of surveying steel structures prior to their repair or reconstruction. The issue arises due to several factors, including the impossibility of cutting out samples for standard tests from the existing structures, the need to ensure sufficient accuracy of the results of non-destructive testing, the impossibility of conducting non-destructive testing in all studied places of the structure due to the design features of the object, high cost and high complexity of the examination of large structures (for example, steel bridges). For this reason, it is necessary to develop an approach to the examination of structures that will ensure the accuracy of the results while minimizing the amount of work. This can be achieved by using previously obtained information about the characteristics of the metal of the structure.

When developing such an approach, three important questions need to be answered:

– how do the properties of the metal change during the operation of the structure;

– how should information be obtained;

– how to supplement it with known experimental information and minimize the amount of survey work.

The answers to these questions are extremely important, as it is known that under the influence of various factors (temperature or force in the form of cyclic loads), changes in the strength characteristics of a metal may occur.

The literature offers different interpretations of the first question (how the properties of metal change during the operation of the structure). V.I. Bryushko in [1] indicates an increase in strength characteristics and a decrease in ductility of steels 20, 15X5M, 19G. In [2] G.N. Nikiforchin, O.T. Tsirulnik, O.I. Zvirko, M.I. Gredil, V.A. Voloshin provide information about an increase in strength characteristics during the first 20 years of operation of a steel 17G pipe, and a steady decrease in strength and ductility over the next 10 years. In their work of I.V. Gorynin and B.T. Timofeeva [3] note the stability of mechanical characteristics of the metal in nuclear power structures and 17G1C pipe steel over 25–40 years of operation. The author of work [4] V.V. Kiselev draws attention to the fact that the nature of changes in the strength and plastic characteristics of steels mainly depends on the temperature influence and loading parameters, primarily cyclic. As a result, it is not entirely correct to focus on the values of the characteristics of the source material specified in the technical documentation. Moreover, such documentation may simply be lost over a long period of operation. Therefore, in order to obtain an objective assessment of changes in material characteristics, it is necessary to periodically or continuously monitor the condition of structures. Today, this practice is extremely rare.

The solution to the problem of obtaining information about the current design, especially if monitoring is taken into account, is exclusively related to non-destructive testing. Currently, non-destructive testing of structures uses methods of qualitative assessment of the state of metal based on the use of ultrasound, acoustic emission, radiation flaw detection for metal [5, 6], welded joints [7, 8] or in hard-to-reach places [9]. These techniques allow us to determine the presence of defects in metal, but they do not provide a quantitative measure of the material's ability to resist external forces.

There are techniques and portable devices available to assess the hardness of materials. One method for determining mechanical characteristics involves constructing stretching diagrams based on indentation results, such as by using an indenter [10]. The article [11] considers the issue of evaluating the mechanical characteristics of plastic materials by the ball indentation method based on the application of a finite element model. In [12], the problem of indentation of plastic materials with ball indenters is considered using numerical modeling. The sensitivity of the numerical results to the elasticity of the indenter is investigated. However, the instrumentation used in these methods is often cumbersome and is only used in laboratory settings, making it impractical for survey work.

Often, the controlled sites within a structure that need to be monitored are difficult to reach, and therefore, it is essential to have a tool that enables you to minimize the number of samples collected during survey work. At present, the range of techniques that allow for the joint processing of prior and experimental data is rather limited. In fact, there are three main categories: methods for assigning weights to prior and experimental information in posterior estimates, methods for extending past data into the future, and methods based on Bayesian procedures.

The authors of the article, V.N. Arsenev and P.V. Labetskii, [13] note that the issue of selecting a criterion for determining the significance coefficient of a priori information remains unsolved.

Bayesian procedures make it possible to reduce the a posteriori variance of the random variable under study by combining experimental and pre-experimental information. Experimental information can be expressed, for example, in the knowledge about the type of distribution of a random variable or one of its parameters.

Techniques based on the use of Bayesian procedures are widely applied today. These techniques are used to describe a systematic approach to decision-making, based on a large number of examples developed by the authors of the work [14]. The authors of the article [15] apply Bayesian analysis to assess economic uncertainty in investor behavior prediction. It is noted in [16], that the use of Bayesian parametric models for assessing survival in medicine is not inferior to traditional approaches, but requires less parameter tuning and increases the possibilities of statistical conclusions and forecasts. In [17], a methodology for developing a classifier of common dental diseases based on Bayesian statistical procedures is proposed.

In general, it is worth noting that methods of non-destructive testing, as well as methods of accounting for a priori information, have been highlighted and described in detail by many authors. However, it is obvious that the development of a methodological approach to solving the problem of minimizing the sample size of the examined elements has not been fully worked out, especially with regard to the method based on the synthesis of non-destructive testing of mechanical characteristics by indentation and Bayesian accounting of a priori information.

It is therefore essential to develop systems for monitoring the condition of metal structures based on non-destructive testing of mechanical characteristics by the indentation method. At the same time, in order to reduce material and time costs, such monitoring should be carried out using the possibilities of taking into account additional information about other similar objects.

The aim of this article is to substantiate the methodology proposed by the author, which combines the use of the original non-destructive testing method with the Bayesian approach for calculating the minimum necessary volume of examined elements, carried out on a specific example.

Materials and Methods. By order of a construction company, the metal pipe sheet piling structures were inspected during the construction of a building at 51 Gorsovetskaya Street in Rostov-on-Don. Most of the pipe structures had already been put in the ground, while a small number that had not been put yet had to be inspected to assess their mechanical properties. At the same time, it was important to use the minimum number necessary from the standpoint of minimizing the error in the results of such an inspection.

For this purpose, additional experimental data was used on the strength of 11 low-carbon steel pipe elements obtained by non-destructive testing during the construction of a building at 23 Suvorova Street in Rostov-on-Don, Additionally, we used a Bayesian estimate of the optimal number of elements required for this experimental examination of pipe elements of a similar strength class.

The article describes an original method of non-destructive testing, developed with the participation of the author, which allows you to simultaneously obtain values of temporary tear resistance, yield strength, hardness and elongation at a local site of any operated metal structure. The method is especially effective when examining metal of the same strength class of similar machine structural elements (sections of a tower crane), for example, when it is necessary to conduct an examination of the condition of a lifting crane[1], that has served its service life, or here are doubts about the deformations. At the same time, it is often very difficult to inspect the elements of a metal structure, even by non-destructive methods, due to technical difficulties in accessing certain areas. Therefore, the question arises about how to minimize sample size while maximizing information content based on a priori knowledge.

The non-destructive testing method used is based on the impact insertion of a conical indenter into the tested metal [18]. This method is implemented in the "Strength" system, which include a spring-loaded impact mechanism with an induction sensor for recording the speed of movement of the indenter, an analog-to-digital converter and a laptop. The velocity graph obtained during impact is differentiated and integrated to plot acceleration and displacement graphs, respectively. The extreme values of the three graphs represent an image of the metal. Previously conducted experiments with various grades of steel allowed us to establish and enter into a computer the correlations between standard yield strength and temporary tear resistance, hardness, elongation, on the one hand, and maximum and minimum values of velocity and acceleration, the depth of indenter insertion, on the other. Measurement using the repeatedly tested "Strength" system is possible for a section of an element with a diameter greater than 3 centimeters. The total error of the instrument is ±4%.

With the help of the "Strength" system, dozens of structures were examined according to orders from manufacturing enterprises. These included booms, running wheels, frames of construction and road vehicles, various construction metal structures of stadium stands, roof trusses, power transmission poles, bridges, pipes, etc. [19]. In three-dimensional structures with a large number of similar elements, it is recommended, in accordance, for example, with SP 13–102–2003[2], to examine at least 10% of these elements from their total number. This can amount to several dozen elements for a building structure, determining a significant amount of labor and cost for the work performed.

When examining, for example, a lifting crane boom, which may have up to 100 or more identical parts, the volume of the sample that is acceptable is also important.

However, when it is difficult to take even a few measurements in hard-to-reach areas, the issue of reducing the number of elements examined becomes relevant.

To address this issue, we apply the Bayesian method, which takes into account a priori information.

Let us assume that it is necessary to obtain information about the mechanical properties of the metal in the structure that has been operating for a long time (for diagnosis, monitoring or subsequent reconstruction in conditions of limited access to controlled elements of the same type) when the examination is carried out by non-destructive testing. Additional experimental data is used to justify the required sample size of n surveyed elements of the same type. In this case, we have average value $\sigma_{вт\ ср}$ of the measured value of the characteristic, variance S^2 of its experimental values and a priori information about this characteristic of the metal of a similar strength class.

In the pre-experimental (a priori) knowledge of distribution $\sigma_в$, there is parameter μ expressing the mathematical expectation of the value of tensile strength $\sigma_в$. From previous experience, density $H(\mu)$ of the distribution of this parameter is known. Let $(\sigma_{вт} \mid \mu)$ be the density of the distribution of values $\sigma_{вт}$ obtained as a result of this measurement, provided that mathematical expectation $\sigma_{вт}$ is μ. Then a posteriori density $K(\mu \mid \sigma_{вт})$ of the distribution of parameter μ of the measured random variable of characteristic $\sigma_в$, in accordance with Bayes' theorem, will be expressed as follows:

$$K(\mu \mid \sigma_{вт}) \sim H(\mu)\, g(\sigma_{вт} \mid \mu), \qquad (1)$$

where $K(\mu \mid \sigma_{вт})$ — density of the a posteriori distribution of parameter μ, synthesizing experimental and a priori information, provided that experimental values $\sigma_{вт}$ are realized. In the expression for this density, parameter μ will be understood as the mathematical expectation of the value of tensile strength $\sigma_в$ after the implementation of the measured current values $\sigma_{вт}$.

The main condition for practical application of formula (1) is the conjugacy of distribution densities $H(\mu)$ and $g(\sigma_{вт} \mid \mu)$ (i.e., the possibility of obtaining a convenient result).

The densities of two normally distributed random variables are best conjugated. However, numerous studies have found that the distribution of mechanical characteristics is most reliably described by Weibull's law, since it has a distribution shift parameter or a minimum characteristic value hat is not in the sample but in the general population. This inconvenience can be eliminated if we take as $\sigma_{вт}$ not the instantaneous, but its average value $\sigma_{вт\_ср}$. Then in

[1] RD 10–112–2–09. *General Purpose Boom Cranes and Lifting Cranes, Part 2.* (In Russ.) URL: https://meganorm.ru/Data2/1/4293828/4293828984.pdf (accessed: 15.05.2024).

[2] SP 13–102–2003. *Rules for Inspection of Load-Bearing Building Structures of Buildings and Structures.* (In Russ.) URL: https://docs.cntd.ru/document/1200034118 (accessed: 15.05.2024).

accordance with central limit theorem $H(\mu)$ and $g(\sigma_{\text{вт\_ср}} \mid \mu)$ can be assumed to be normally distributed, and the a posteriori distribution density of parameter μ is expressed as:

$$P\left(\mu \mid \sigma_{\text{вт\_ср}}, S\right) \sim P(\mu)\cdot g\left(\sigma_{\text{вт\_ср}} \mid \mu, S\right), \tag{2}$$

where $\sigma_{\text{вт\_ср}}$ — not current, but average values of measured experimental value $\sigma_{\text{вт}}$, and μ, S — their mathematical expectation and standard deviation, respectively.

In this case, $P(\mu \mid \sigma_{\text{вт\_ср}}, S)$ will also have a normal form, and the a posteriori estimate of variance $D[\mu]$ will take the form [20]:

$$D[\mu] = \frac{\dfrac{S_a^2 S_t^2}{n}}{S_a^2 + \dfrac{S_t^2}{n}}, \tag{3}$$

where S^2_a — respectively, the standard deviations of the average value of a random measured value from μ and μ from μ_a; μ_a — mathematical expectation μ; n — required number of experimental data or a sufficient number of experimental S^2_t measurements from the condition of minimal risk from estimation error. Therefore

$$n = \frac{S_t^2\left(S_a^2 - D[\mu]\right)}{S_a^2 \cdot D[\mu]}. \tag{4}$$

Let us note that in formula S^2_t and S^2_a, have a priori information, the a posteriori information is expressed in a posteriori variance $D[\mu]$ and the number of necessary experimental measurements n.

The work investigated the material of tube steel, which was intended for the construction of sheet pile screen for a construction pit.

Research Results. The procedure proposed above was based on the use of similar information about the mechanical properties of sheet pile pipes obtained during the examination of similar steel piles-pipes of the screen. During the initial examination, it was found that the tensile resistance of a sheet pile screen material was 418 MPa at 51 Gorsovetskaya Street.

The average value of the tensile strength of the metal of the batch of pipes examined earlier (at 23 Suvorov Street) was 405 MPa, which indicated that both batches of pipes belonged to approximately the same strength class. This information was used as a priori. Table 1 shows the values of tensile strength of the metal of the 11 pipes previously examined, ranked in ascending order.

Table 1

Values of tensile strength obtained by measurement on 11 pipes, MPa

393	399	402	408	417
394	399	402	408	418
394	399	402	409	418
394	399	402	411	418
395	400	403	411	419
396	400	403	411	420
396	400	404	412	420
396	400	405	412	421
396	400	405	412	425
396	400	405	412	426
396	400	405	412	426
396	400	405	412	427
397	400	406	413	427
397	401	406	413	430
397	401	406	414	430
397	401	407	414	435
398	401	407	415	436
398	401	407	416	436
398	402	407	416	
398	402	407	416	

Figure 1 shows the frequency of $n_{зн}$ values of tensile strength with standard deviation $S\sigma_в$ = 11.3 MPa and dispersion $S^2\sigma_в$ = 110 MPa^2.

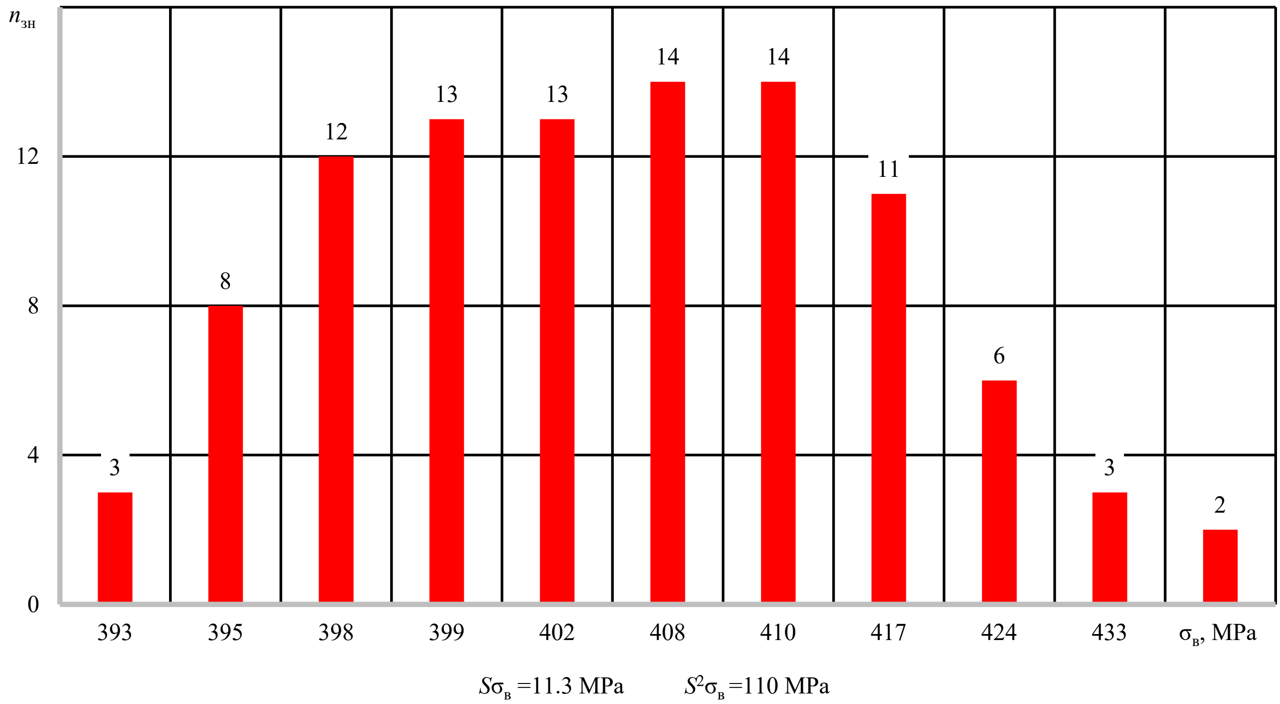

Fig. 1. Distribution of tensile strength values of metal pile pipes of sheet pile screen at Suvorov Street, 23 in Rostov-on-Don

Average values of tensile strength $\sigma_{Вср\_тр}$ for each of $m_{тр}$ pipes are shown in Figure 2 and Figure 3 — their distribution with average value $\sigma_{Вср}$ = 405 MPa, standard deviation $S\sigma_в$ = 3.6 MPa and dispersion $S^2\sigma_в$ = 14 MPa^2.

To calculate a sufficient sample size using formula (4), a posteriori variance $D[\mu]$ is determined as follows. For St3 steel of strength classes C255–C275, from which the pipe is made, a range of possible values of tensile strength[3] from 380 to 400 MPa is provided, i.e. based on the rule of three sigma of a normally distributed random variable, the permissible range of 20 MPa approximately corresponds to six standard deviations

Then a posteriori standard deviation will be expressed as (20/6) = 3.33 (MPa).

Since the reasoning concerns the average values of tensile strength, we can use the ratio of a priori standard deviations of current (110 MPa) and average (14 MPa) values of tensile strength, assuming that their ratio in the a posteriori estimate will remain approximately the same.

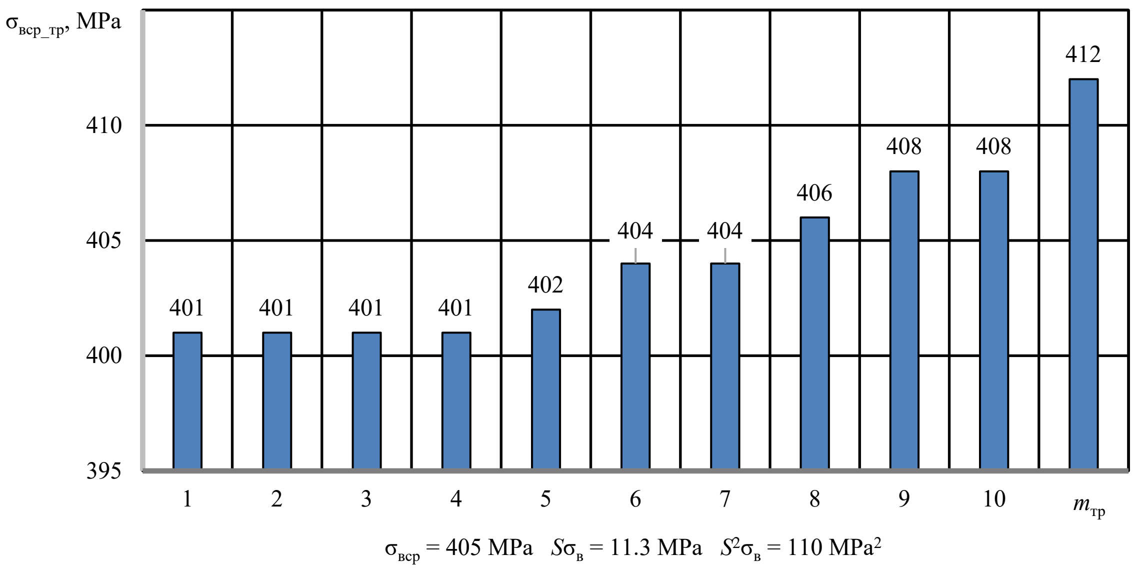

Fig. 2. Average values of tensile strength of metal of 11 pile pipes of sheet pile screen at Suvorov Street, 23 in Rostov-on-Don

[3] GOST 27772–88. *Rolled Products for Structural Steel Constructions. General Specifications*. (In Russ.) URL: https://docs.cntd.ru/document/1200003192 (accessed: 15.05.2024).

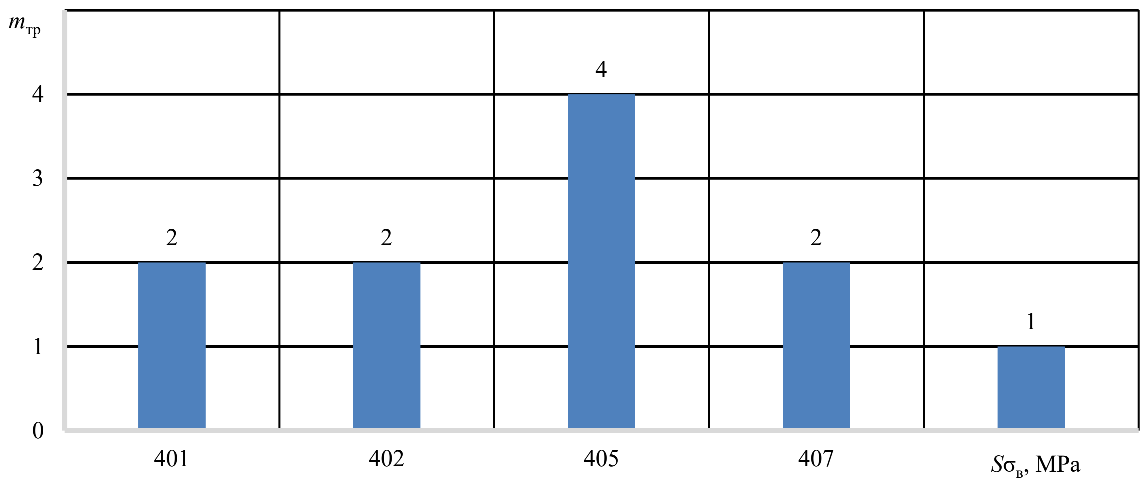

Fig. 3. Distribution of pipes with average value $\sigma_{Всp}$ = 405 MPa, standard deviation $S\sigma_В$ = 3.6 MPa and dispersion $S^2\sigma_В$ = 14 MPa^2

Thus, a posteriori variance of the average value of tensile strength can be determined:

$$D[\mu]=\frac{11\cdot 14}{110}=\frac{11}{7.86}=1.4\ \text{MPa}^2.$$

A priori variance of the average value of tensile strength:

$$S^2_t = S^2\sigma_{Всp} = 14\ \text{MPa}.$$

The a priori variance of parameter μ of the distribution of the average value of tensile strength S^2_a is also assumed under the assumption that the ratio of S^2_t to S^2_a will remain the same (7.86). As a result of our research, we have determined the minimum number of elements that need to be examined — two or three pipe piles.

$$S_a^2=\frac{14}{7.86}=1.78\ \text{MPa},$$

$$n=\frac{S_t^2\left(S_a^2-D[\mu]\right)}{S_a^2\cdot D[\mu]}=\frac{14(1.78-1.4)}{1.78\cdot 1.4}=2.13.$$

Discussion and Conclusion. When solving the problem of minimizing the sample size for an experimental batch of pipe piles, a novel method of non-destructive testing based on indentation was employed. At the same time, mechanical characteristics obtained during the previous examination of 11 similar pile pipes were used as prior information. Due to the limited number of pile pipes available in the experimental batch for inspection, the use of Bayesian techniques made it possible to reduce the required sample size significantly to three, while minimizing the risk of error in the assessment.

The steels considered in the article for pipe manufacturing belong to the strength class KP 245. According to GOST 54157–10[4] they have a yield strength of 245 MPa and a temporary tensile strength of 412 MPa. These steels are mainly made from 3sp and 3ps steel. The same steels are widely used in the manufacturing of machine-building structures in lifting cranes, in the frames of tractors, trailers, semi-trailers, etc. For these structures, the approach described in the article also applies and is feasible. Thus, the use of a priori information based on Bayesian procedures for non-destructive testing of mechanical characteristics of low-carbon steels used in construction and machine-building structures allows us to justify the minimum required number of elements of the object of inspection, significantly reduce the volume, time, labor intensity, and cost of work.

[4] GOST 54157–10. *Profile Steel Pipes for Metal Constructions. Specifications.* (In Russ.) URL: https://docs.cntd.ru/document/1200084959 (accessed: 15.05.2024).

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About the Author:

Nikos L. Vernezi, Cand. Sci. (Eng.), Associate Professor of the Transport Systems and Logistics Department, Don State Technical University (1, Gagarin Sq., Rostov-on-Don, 344003, Russian Federation), SPIN-code, ORCID, vernezin@mail.ru

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Об авторе:

Никос Леонидович Вернези, кандидат технических наук, доцент кафедры эксплуатации транспортных систем и логистики Донского государственного технического университета (344003, Российская Федерация, г. Ростов-на-Дону, пл. Гагарина, 1), SPIN-код, ORCID, vernezin@mail.ru

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