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ANALYSIS OF THE DEGREE OF DAMAGE FROM EXPLOSIVE IMPACT ON STRUCTURES USING DISTRIBUTION FUNCTIONS AND THE LAGRANGE INTERPOLATION METHOD

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Abstract: This article employs statistical methods to assess and analyze the degree of damage to structures and buildings under the influence of external and internal forces. Using Gaussian and Laplace distributions, the probability of structural failure and the state of resources under explosive impact were analyzed. Additionally, functional relationship models were developed using the Lagrange interpolation method, and their accuracy was confirmed by experimental results. The obtained results are of significant importance for evaluating the stability of structures and determining safety measures.

Keywords: Gaussian distribution, Laplace function, Lagrange interpolation, structural analysis, statistical modeling, blast effect, damage degree, resource assessment, structural strength.

Аннотация: В данной статье используются статистические методы для оценки и анализа степени повреждения конструкций и зданий под воздействием внешних и внутренних сил. Используя распределения Гаусса и Лапласа, были проанализированы вероятность разрушения конструкций и состояние ресурсов при взрывном воздействии. Кроме того, были разработаны модели функциональных взаимосвязей с использованием метода интерполяции Лагранжа, и их точность была подтверждена экспериментальными результатами. Полученные результаты имеют существенное значение для оценки устойчивости сооружений и определения мер безопасности.

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Ключевые слова: гауссово распределение, функция Лапласа, интерполяция Лагранжа, структурный анализ, статистическое моделирование, взрывной эффект, степень повреждения, оценка ресурса, прочность конструкции.

Annotatsiya: ushbu maqolada tashqi va ichki kuchlar ta'sirida inshootlar va binolarga etkazilgan zarar darajasini baholash va tahlil qilish uchun statistik usullar qo'llaniladi. Gauss va Laplas taqsimotlaridan foydalanib, tarkibiy nosozlik ehtimoli va portlovchi ta'sir ostida bo'lgan resurslarning holati tahlil qilindi. Bundan tashqari, Lagranj interpolatsiyasi usuli yordamida funktsional munosabatlar modellari ishlab chiqilgan va ularning aniqligi eksperimental natijalar bilan tasdiqlangan. Olingan natijalar tuzilmalarning barqarorligini baholash va xavfsizlik choralarini aniqlash uchun muhim ahamiyatga ega.

Kalit so'zlar: Gauss taqsimoti, Laplas funktsiyasi, Lagranj interpolatsiyasi, tarkibiy tahlil, statistik modellashtirish, portlash effekti, zarar darajasi, resurslarni baholash, strukturaviy quvvat.

Introduction

The assessment of the condition of structures and buildings under the influence of external factors, as well as the determination of their service life, requires complex computational and analytical methods. In this process, the use of statistical models and distribution laws is important. Using distribution laws such as those of Gauss, Laplace, Weibull-Gnedenko, and others, the probabilities of structural failure and the extent of their damage are analyzed.

This article examines methods for analyzing experimental results while accounting for external impacts on structures, using the Gaussian normal distribution and Lagrange interpolation method. The study assesses the extent of structural damage based on a statistical analysis of the consequences of random explosions. Additionally, various mathematical modeling methods are used to analyze the dynamics of damage points, ensuring the accuracy of the obtained results.

When determining the resources of structures based on experimental results, an analysis is conducted of their mathematical expectation $M(x)$, arithmetic mean $\bar{x}$, as well as the displacements of structures or buildings under the influence of external and internal forces (earthquake, explosion, weight or pressure, etc.), their vibrations, or partial destruction. In other words, the variance $D(x)$ of deviations from the center of gravity is analyzed, along with the standard deviation $\sigma(x)$.

In all statistical distributions (Gaussian, Rayleigh, Student's t, Fisher–Snedecor, Weibull–Gnedenko, etc.), three main parameters must be defined: the expected value $M(x) = a_m$, the variance of the random variable $D(x)$, and the standard deviation $\sigma(x)$. Among them, the Gaussian normal distribution stands out

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for its high accuracy in diagnosing the degree of damage to structures and buildings, as well as in scientific studies of their physical and mechanical properties [1–3].

Methodology and Results of the Scientific Research

Various experiments were conducted, with pressure recorded at different distances from the explosion epicenter, and a statistical analysis of the explosion's impact was performed using a numerical model [4]. The study scientifically analyzes the conformity of building damage points to the normal (Gaussian) distribution in cases of random TNT (trinitrotoluene) charges with a mass of $m = (10 \dots 30)$ kg. During the calculations, the coefficient of variation $V_v = 0{,}2$, and in a number of random explosions, its value was kept constant.

The probability density function (differential form) of the normal distribution is expressed as follows.:

$$f(m) = \frac{1}{\sigma(m)\sqrt{2\pi}} \cdot \exp - \frac{(m-a_m)^2}{2\sigma^2(m)} \qquad (1)$$

The function $f(m)$ is a differential or mass distribution density function by Gaussian, where $\sigma_m(x) = mV_m$ is the standard deviation, a_m is the unknown expected value; $e = 2.71\dots$

It should be noted that the obtained results can be compared with the probabilities of a random value falling within a given interval and are calculated using the following formula:

$$P(2 < x < 6) = \frac{1}{2}[\varphi \frac{b-m}{\tau\sqrt{2}} - \varphi \frac{a-m}{\tau\sqrt{2}}]$$

where $f(x) = \frac{2}{\sqrt{\tau}} \int_0^x e^{-t^2\delta t}$ is the Laplace function, the values of which are provided in Table 1.

Table-1

x_{kg}	0-10	10-14	14-18	18-22	22-26	26-30
$n_{variants}$	1	2	4	5	6	2
$W_{probability}$	0,05	0,10	0,20	0,25	0,30	0,10

Using the Laplace distribution, we used the statistical data provided in Table 1 to analyze the TNT data.

$$P(0 < x < 10) = \frac{1}{2}\left[\varphi \frac{10-2\ ,2}{5{,}2\cdot 1{,}41} - \varphi \frac{0-21{,}2}{7{,}33}\right] = \frac{1}{2}[\varphi(-1{,}53) + \varphi(2{,}89)] = \frac{1}{2}[+0{,}9684 + 0{,}999] = 0{,}0153$$

$$P(10 < x < 14) = \frac{1}{2}\left[\varphi \frac{14-21{,}2}{7{,}33} - \varphi \frac{10-21{,}2}{7{,}33}\right] = \frac{1}{2}[\varphi(-0{,}98) + \varphi(1{,}53)] = \frac{1}{2}[-0{,}8342 + 0{,}9684] = 0{,}067$$

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$$P(14 < x < 18) = \frac{1}{2}\left[\varphi\frac{18-21,2}{7,33} - \varphi\frac{14-21,2}{7,33}\right] = \frac{1}{2}[\varphi(-0,44) + \varphi(0,98)] = \frac{1}{2}[-0,4662 + 0,8342] = 0,184$$

$$P(18 < x < 22) = \frac{1}{2}\left[\varphi\frac{22-21,2}{7,33} - \varphi\frac{18-2\ ,2}{7,33}\right] = \frac{1}{2}[\varphi(0,11) + \varphi(0,44)] = \frac{1}{2}[0,1125 + 0,4662] = 0,289$$

$$P(22 < x < 26) = \frac{1}{2}\left[\varphi\frac{26-\ \ ,2}{7,33} - \varphi\frac{22-21,2}{7,33}\right] = \frac{1}{2}[\varphi(0,65) + \varphi(0,11)] = \frac{1}{2}[0,6346 - 0,1125] = 0,261$$

$$P(26 < x < 30) = \frac{1}{2}\left[\varphi\frac{30-21,2}{7,33} - \varphi\frac{26-21,2}{7,33}\right] = \frac{1}{2}[\varphi(1,2) + \varphi(0,65)] = \frac{1}{2}[0,9103 - 0,6346] = 0,1392$$

The research results on the Laplace distribution are presented in Table 2.

Table-2

Ikg	0-10	10-14	14-18	18-22	22-26	26-30
$P_{probability}$	0,015	0,057	0,184	0,289	0,261	0,1392

To improve the accuracy and reliability of research results, we will use the Lagrange polynomial for continuous interpolation.

Scientific research and literature analysis show that, despite the availability of a sufficient number of scientific works dedicated to analyzing the degree of damage to buildings and structures under the influence of external forces using Gaussian and Laplace distributions, methods that allow for continuous determination of building destruction have not been sufficiently studied. Therefore, we believe it is appropriate to analyze the practical results of our scientific research using the Lagrange interpolation method.

The polynomial interpolation method requires constructing a polynomial of degree $m \leq n-1$ that satisfies the condition $y_i = f(x_i)$ where ($i = 1, 2, \dots, n$) for given values of x_i. In other words, the graph of this polynomial must pass through the (n) points $M_i(x_i;\ y_i)$.

$f(x) = (x - x_1)\ (x - x_2)\ (x - x_3) \dots (x - x_n)$ is a polynomial of degree n, (where $\varphi(x) = f(x)$, and $x_i -$ are continuous values of the argument specified in the table. In this case, the Lagrange formula will be correct:

$$f(x) = \sum_{k=1}^{n} \frac{y_k \cdot \varphi(x)}{\varphi^1(x_k)\ (x - x_n)}$$

and its extended form:

$$f(x) = \frac{y_1 \cdot \varphi(x)}{(x - x_1)\ (x_1 - x_2)\ (x_1 - x_3) \dots (x_1 - x_n)} + \frac{y_2 \cdot \varphi(x)}{(x - x_2)\ (x_2 - x_1)\ (x_2 - x_3) \dots (x_2 - x_n)} + \cdots$$

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$$\frac{y_n \cdot \varphi(x)}{(x-x_n)\,(x_n-x_1)\,(x_n-x_2)\ldots(x_n-x_{n-1})},$$

This is the Lagrange interpolation polynomial.

Based on the results of the conducted experiment, Table 3 was compiled to obtain the multidimensional Lagrange multiplier.

Table-3

x Mass of charge *(kg)*	20	24	28	32	…	x_n
y number of charges	1	2	6	3	…	y_n

Auxiliary polynomial:

$$f(x) = (x-20)\,(x-24)\,(x-28)\,(x-32);$$

The first derivative of the obtained polynomial is found.

Calculating $f'(x)$:

$$f'(x) = (x-24)(x-28)(x-32) + (x-20)(x-28)(x-32) + (x-20)(x-24)(x-32) + (x-20)(x-24)(x-28)$$

As a result of simplifying the obtained polynomial and calculating the derivative values, we get:

$$f'(20) = (20-24)(20-28)(20-32) + 0 = -4 \cdot -8 \cdot -12 = -384$$

$$f'(24) = (24-20)(24-28)(24-32) = 4 \cdot -4 \cdot -8 = 128$$

$$f'(28) = (28-20)(28-24)(28-32) = 8 \cdot 4 \cdot -4 = -128$$

$$f'(32) = (32-20)(32-24)(32-28) = 12 \cdot 8 \cdot 4 = 384$$

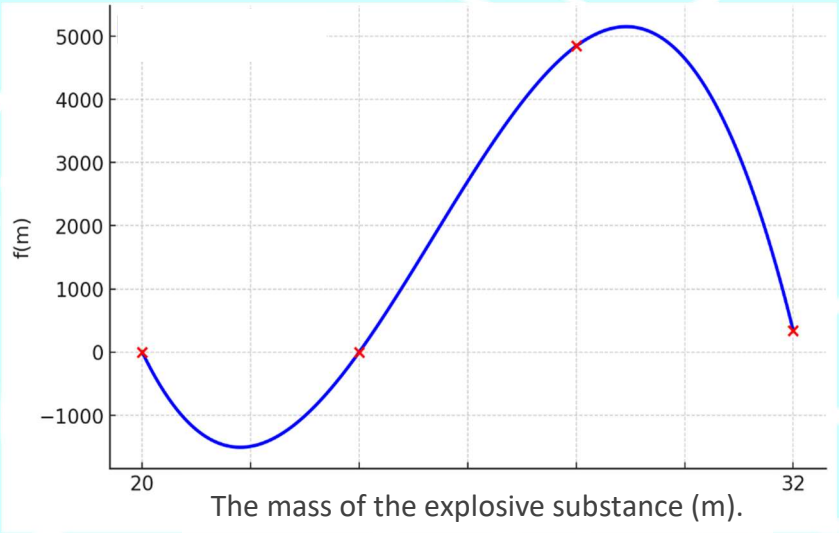
The expression of the Lagrange set then looks as follows:

$$f(x) = \frac{1}{-384}(x-24)(x-28)(x-32) + \frac{2}{128}(x-20)(x-28)(x-32) + \frac{6}{-128}(x-20)(x-24)(x-32) + \frac{3}{384}(x-20)(x-24)(x-28)$$

After expanding the parentheses and simplifying the terms for x^3, x^2, x and the constant terms, we obtain the following Lagrange polynomial (Fig. 1). By substituting $x = m$ (i.e., $f(m)$), we form the third-degree Lagrange polynomial with one unknown.

$$f(m) = 0{,}026x^3 - 1{,}969x^2 + 48{,}46x + 340{,}48$$

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1-Fig. Analysis of the mass of port substance in the Lagrange polynomial model

Conclusion

The results obtained from the Lagrange function and the correlation curve with catalytic substances have also been confirmed by data presented in scientific studies by leading foreign scientists and publications by the authors [5].

The Lagrange function is a functional that expresses the continuous action of forces acting on a building at different values of ***m***, and it theoretically confirmed the results of a practical experiment, presented as a third-degree polynomial with one unknown.

In this study, statistical and analytical methods were used to assess the degree of damage to structures and buildings under the influence of external forces. Gaussian and Laplace distributions were utilized to create the possibility of evaluating the impact of an explosion. The application of the Lagrange interpolation method enabled continuous functional analysis of the explosion's effect. This method provided the opportunity to develop an accurate analytical approach that meets modern requirements. Future research using this methodology will focus on creating models adapted to real-world objects, which aligns with the established goal.

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