**ТОРАЙҒЫРОВ УНИВЕРСИТЕТІНІҢ**
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**НАУЧНЫЙ ЖУРНАЛ**
**ТОРАЙГЫРОВ УНИВЕРСИТЕТА**

# ҚАЗАҚСТАН ҒЫЛЫМЫ МЕН ТЕХНИКАСЫ

2001 ЖЫЛДАН БАСТАП ШЫҒАДЫ

TORAIGHYROV UNIVERSITY

# НАУКА И ТЕХНИКА КАЗАХСТАНА

ИЗДАЕТСЯ С 2001 ГОДА

ISSN 2788-8770

№ 1 (2022)

**ПАВЛОДАР**

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**СВИДЕТЕЛЬСТВО**
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информационного агенства и сетевого издания
№ KZ51VPY00036165

выдано
Министерством информации и общественного развития
Республики Казахстан

**Тематическая направленность**
Публикация научных исследований по широкому спектру проблем
в области металлургии, машиностроения, транспорта, строительства,
химической и нефтегазовой инженерии, производства продуктов питания

**Подписной индекс – 76129**

https://doi.org/10.48081/TFZY8989

**Импакт-фактор РИНЦ – 0,342**

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SRSTI 55.20.15, 55.01.77

https://doi.org/10.48081/TTBA5794

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## *NUMERICAL 3D MODELING OF THE PROCESS OF HIGH-SPEED SPRAYING*

*The article is devoted to the formation of a spray cloud after the interaction of an ultrajet with an obstacle. Variants of different mutual arrangement of the ultrajet and the surface on which the impact occurs are considered. Evaluation of the effectiveness of the choice of angle is carried out by analyzing the values of the coverage area of the target with a spray, set at a fixed distance from the impact site. It is accepted that a large contact area of the spray with the target surface is the best possible result.*

*The research was carried out within the framework of the RFBR grants 18-29-18081 and 19-38-90228\19, the grant of the President of the Russian Federation for state support of the leading scientific schools of the Russian Federation NSh-3778.2018.8 and grants from the Innovation Promotion Foundation under the UMNIK-18 program in accordance with contract No. 14727GU/2019 and No. 14549GU/2019.*

*Keywords: ultrajet treatment, suspension, mathematical modeling of the process, technological parameters.*

**Introduction**

At present, ultrajet processing (UJT) technologies are widely used both in machine building and in other industries. To date, new areas of application of ultrajet technology based on the well-known waterjet cutting of materials include the following: ultrajet diagnostics of metals, ceramics, composite materials, processing (sterilization) of liquids, and dispersion of hydrotechnological media.

The search for new areas of application is ongoing. So, the department of SM-12 Bauman Moscow State Technical University planned a series of theoretical and experimental work aimed at assessing the possibility of impregnating materials with a spray. Now the task is set on the basis of general ideas, and in this article we will not talk about concretization of technological ideas and potentially solvable practical issues. We will proceed from the fact that the impregnation should provide the maximum area of contact with the target. As a target, for example, a fabric stretched and installed in a frame can be considered, as shown in the calculation diagram (Fig. 1).

By preliminary mathematical modeling of the process, it is possible to optimize the parameters of the hydrosuspension and the conditions for the impact of the jet on the surface of the workpieces, primarily by the criterion of the maximum area of tissue coverage by the spray.

In this work, the modeling takes into account and considers such parameters as the density of the hydrosuspension, the diameter of the ultrajet, its velocity and the angle of contact with the front surface of the workpiece (Fig. 1), as well as the physical and mechanical characteristics of the surface of the processed material (fabric) [1–4].

The purpose of this work is to develop practical recommendations for increasing the efficiency of processing by ultra-jet spraying. The task was solved numerically by means of step-by-step modeling of the process using the equations of continuum mechanics in the environment of the ANSYS Autodyn software package (License Number: 339001).

**Material and methods**

To study the considered technology of ultrajet surface spraying, we will use the parametric scheme shown in Fig. 1.

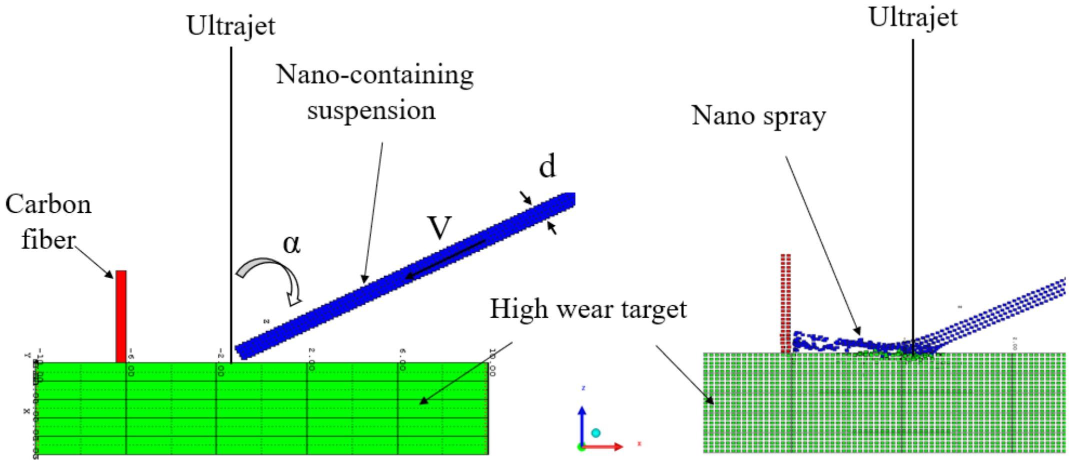


Figure 1 – Parametric diagram of the surface UJF process
d – diameter, v – jet velocity, α – angle (0º, 30 º, 45 º, 60 º), t = time

The parametric scheme of the process under study is shown in fig. 1 and includes an ultrajet with a diameter d flowing out of a focusing nozzle with a velocity V at an angle α to a solid target. After the impact of the ultrajet on the target surface, a spray cloud is formed, which is directed towards the impregnated sample. During the study, the jet encounter angle with the workpiece was varied $\alpha = 0^\circ, 30^\circ, 45^\circ, 60^\circ$ and the ultrajet velocity v = 0.6, 0.8, 1 km/s, $\rho0 = 1.0$ g/cm$^3$ [5-7]

The process of UJF can be described by the following system of differential equations, presented in tensor form:

Law of conservation of mass:

$$\frac{d\rho}{dt} + \rho \nabla_i V^i = 0 \qquad (1)$$

Law of conservation of momentum:

$$\rho \frac{dV_i}{dt} = \nabla_i \sigma^i_j = 0 \qquad (2)$$

Law of energy conservation:

$$\frac{dE}{dt} = \sigma_{ij} \varepsilon^{ij} \qquad (3)$$

Equation of state of interacting media:

$$p = p(\rho, E); \qquad (4)$$

Kinematic relations:

$$\dot{\varepsilon}_{ij} = \left(\nabla_i V_j + \nabla_j V_i\right) / 2 \qquad (5)$$

Physical relationships in the form of Hooke's law:

$$D_{ij} D^{ij} \leq 2Y^2 / 3 \qquad (6)$$

Stress tensor components:

$$\sigma_{ij} = -pg_{ij} + D_{ij} \qquad (7)$$

Where ρ – density, p – pressure, E – specific internal energy, t – current time, i; j = x; y; z – the coordinates of the metric coordinate system, vi – he components of the velocity vector, gij – the metric coefficients of the main basis of the chosen coordinate system, gij = 1 for i = j and gij = 0 otherwise, σij – the components of the stress tensor, Dij – the components of the stress deviator, Ɛ*ij – the strain rate tensor components.

The following relations were used as equations of state for interacting materials. For water

$$p = A_1\mu + A_2\mu^2 + A_3\mu^3 + (B_0 + B_1\mu)\rho_0 e \quad \text{at} \quad \mu = (\rho/\rho_0 - 1) \geq 0 \quad \text{and}$$
$$p = T_1\mu + T_2\mu^2 + B_0\rho_0 e \quad \text{at} \quad \mu \leq 0,$$

where are the initial and current density, as well as the compressibility of water, respectively; A1 = 2.2 GPa, A2 = 9.54 GPa, A3 = 14.57 GPa, B0 = 0.28, B1 = 0.28, T1 = 2.2 GPa, T2 = 0 GPa are empirical coefficients.

Table 1 – Physical and mechanical characteristics of the processed material

| Number | Material | Density $\rho_{m0}$, g/cm$^3$ | Volume modulus K, GPa | Shear modulus G, GPa | Yield strength Y, GPa |
|---|---|---|---|---|---|
| 1 | Hard alloy | 3,47-3,55 | 550 | 330 | 0.02 |

To solve the problem, it is also necessary to set the initial and boundary conditions. For this, we will assume that the jet velocity at the initial moment of time is determined by the value V = 0.8 km/s, which is assumed to be a constant value in the calculations. The boundary conditions for the problem under consideration within the framework of the parametric scheme (Fig. 1) can be divided into two groups. Namely: at the interface between two interacting media (water-workpiece), in the presence of contact, the equality of normal stresses and the impermeability condition are always satisfied, i.e.

$$\sigma_{ij}^{(1)} \cdot n_j = p = \sigma_{ij}^{(2)} \cdot n_j \text{ and } V_i^{(1)} \cdot n^i = V_i^{(2)} \cdot n^i. \quad (9)$$

The set spatial problem was solved numerically by the SPH (Smoothed Particle Hydrodynamics) method in the ANSYS/AUTODYN.

**Results and discussion**

The results of the calculation according to the scheme of Fig. 1 are presented in fig. 2 for different interaction angles. The images are presented for the same time t=30 s.

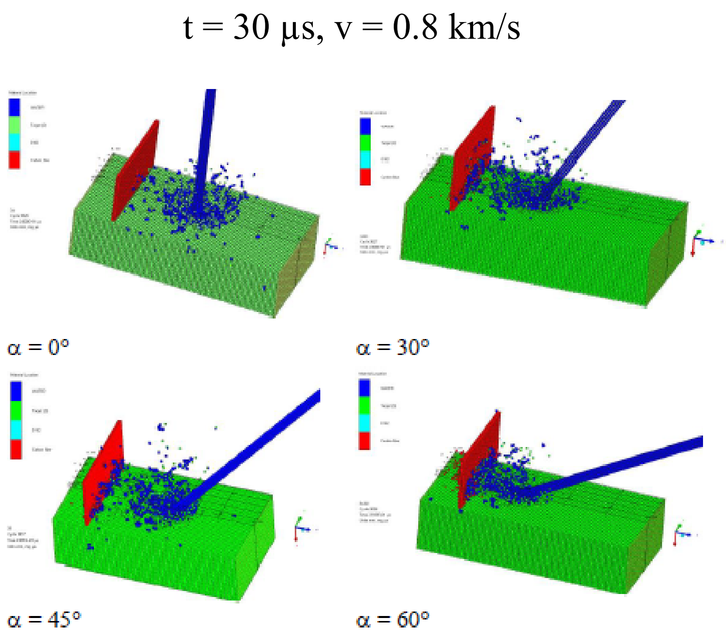


Figure 2 – The nature of ultrajet motion in the direction of the barrier (target), its impact, decay and spray formation

The interest is not the process of interaction between the ultrajet and the target surface, but the result – impregnation of the fabric material of the barrier with a spray.

On fig. 3 shows images where the hatching indicates the area of contact S of the spray and the fabric. Table 2 shows the numerical values of the areas for the considered interaction angles [6–11].

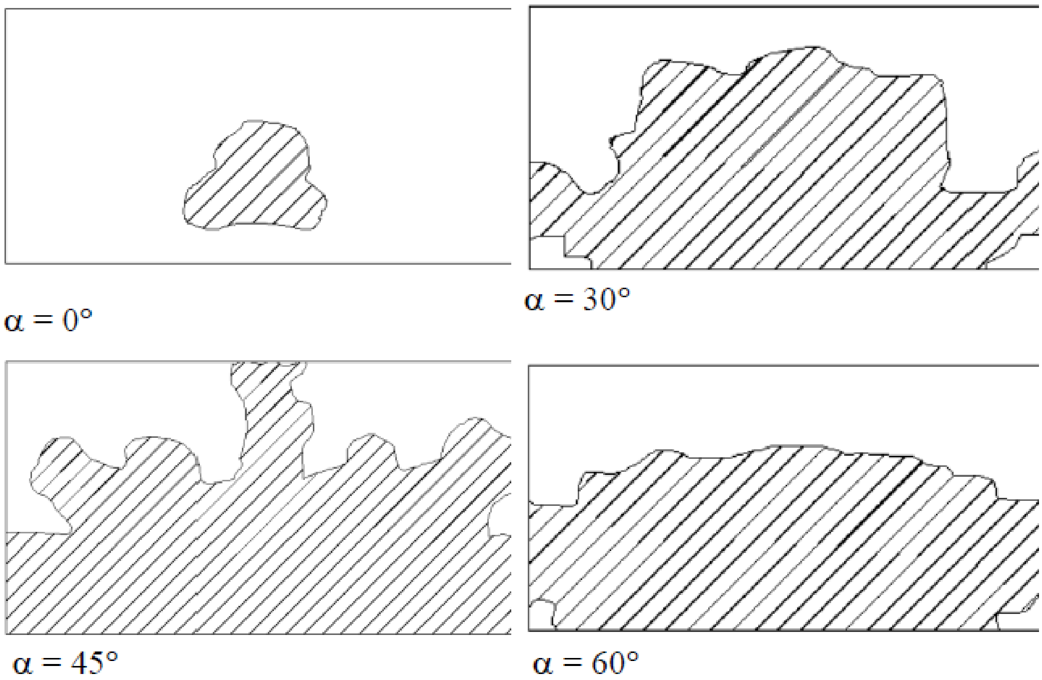

Figure 3 – Results of modeling the area of interaction between the spray and the tissue barrier

Table 2 – Simulation results - area of spray coverage of the tissue target surface

| Angle | The number of particles on the surface of carbon fiber | Area |
|---|---|---|
| 0° | 123 | 95,667 |
| 30° | 765 | 676,823 |
| 45° | 889 | 817,543 |
| 60° | 470 | 688, 791 |

It should be noted that the simulation results make it possible to identify both the contact area and calculate the number of particles that interacted with the tissue target (Fig. 4, 5).

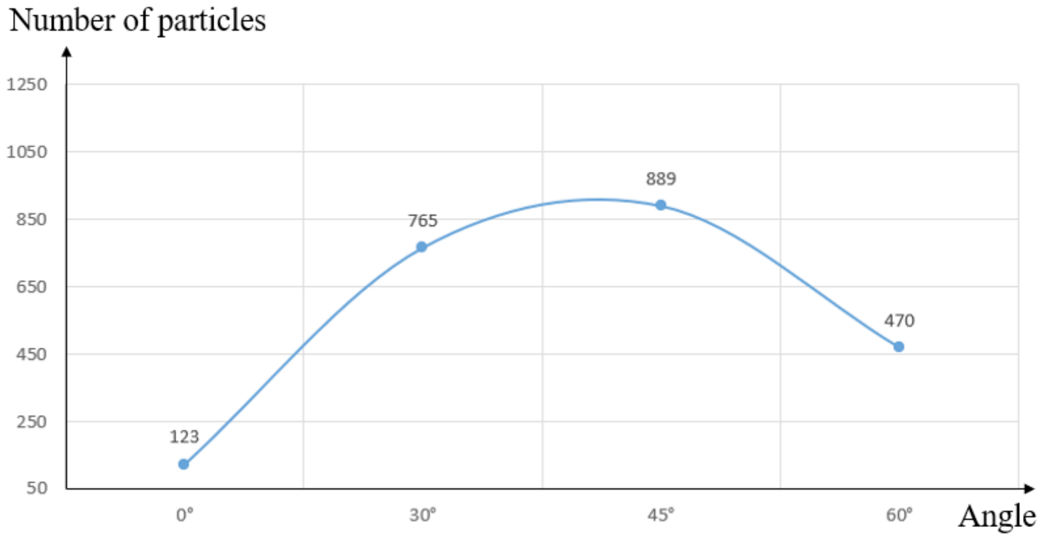


Figure 4 – Comparative results of modeling the number of particles on the surface of carbon fabric at angles of 0°, 30°, 45°, 60°

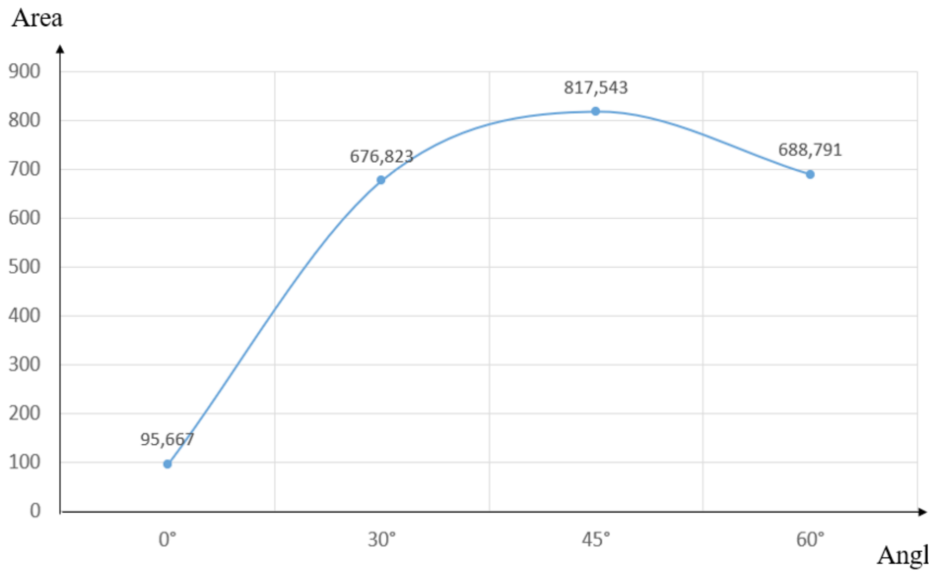


Figure 5 – Comparative results of modeling the coverage area with a nano-containing spray on the surface of carbon fabric at angles of 0°, 30°, 45°, 60°

**Financing**

The research was carried out within the framework of the RFBR grants 18-29-18081 and 19-38-90228\19, the grant of the President of the Russian Federation for state support of the leading scientific schools of the Russian Federation NSh-3778.2018.8 and grants from the Innovation Promotion Foundation under the UMNIK-18 program in accordance with contract No. 14727GU/2019 and No. 14549GU/2019.

**Conclusion**

The results of 3D modeling showed images where the hatching indicates the area of contact S of the spray and the fabric and the nature of ultrajet motion in the direction of the barrier (target), its impact, decay and spray formation. The comparative analysis results of modeling the number of particles on the surface of carbon fabric and area of spray on the surface of carbon fabric at angles of 0°, 30°, 45°, 60° are considered. The results show the maximum area and maximum number of particles on the surface of carbon fabric found at angle 45°.

REFERENCES

1 **Galinovsky, A. L.** Studying the parameters of hydrosuspensions obtained by ultrajet processing [Text] // Science and education. Electronic journal. – 2012. – No. 10.

2 **Babkin, A. V.** Numerical Methods in Problems of the Physics of Fast Processes : A Textbook for Technical Colleges. T.3. [Text] . – Moscow : Publishing house of MSTU im. N. E. Bauman. – 2006. – 520 p.

3 **Grigorieva, I. S. Meilikhova, E. Z.** Physical Quantities : Handbook [Text] // Ed.– Moscow : ENERGOIZDAT. – 1991. –1232 p.

4 **Bazenov, G. M.** On the issue of the use of waterjet treatment in modern mechanical engineering / G. M. Bazenov // Science and Technology of Kazakhstan. – 2021. – No 2. – P. 39–47. – DOI 10.48081/BDFH9117. – EDN GPTGIM.

5 **Kolpakov, V. I. Ilyukhin, A. A.** Features of mathematical modeling of the destruction of structures made of different materials under the action of a high-speed hydroabrasive jet [Text] // Engineering Journal : Science and Innovation. – 2019. – P. 1–8.

6 **Barzov, A. A. Galinovsky, A. L. Puzakov, V. S.** Ultrajet technology for processing liquids [Text]. – A - M. : MSTU im. N. E. Bauman, 2009. – P. 258.

7 **Galinovsky, A. L. Kyaw Myo Htet.** Prospects for the Development of Ultra-Jet Dispersion Technology for Nanocontaining Suspensions [Text] // IOP Conference Series : Materials Science and Engineering. – V. 709. – Issue 4.

8 **Galinovsky, A. L. Kyaw Myo Htet.** To the Question of Efficiency of Different Methods of Dispersion of Nanosecuring Suspensions [Text] // Materials Science Forum. – V. 990. – P. 139 – 143.

9 **Galinovsky, A. L. Kyaw Myo Htet.** Patent - Method for processing inhomogeneous hydraulic media (liquids) [Text] // Patent holders: Limited Liability Company «NanoTechCenter». – 2022 – Patent no: RU 2 767 096 C2.

10 **Kyaw Myo Htet.** Ultra-Jet as a Tool for Dispersing Nanosuspensions [Text] // Polymer Science, Series D. – V. 13. 2020 – P. 209–213.

11 **Abashin M. I.** Ultrajet hydrodynamics [Text] . – Moscow : Moscow State University M.V. Lomonosov Faculty of Physics. – 2015. – P. 308.

Material received on 17.03.22.

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Материал баспаға түсті 11.13.22.

## ЖОҒАРЫ ЖЫЛДАМДЫҚТЫ БҮРКУ ПРОЦЕСІН САНДЫҚ 3D МОДЕЛЬДЕУ

*Мақала ультраструидің кедергімен әрекеттесуінен кейін шашырау бұлтының пайда болуына арналған. Ультраструмның және соққы пайда болатын беттің әртүрлі өзара орналасуының нұсқалары қарастырылады. Бұрышты таңдау тиімділігін бағалау әсер ету орнынан белгіленген қашықтықта белгіленген Нысананы бүріккішпен қамту аймағының мәндерін талдау арқылы жүзеге асырылады. Бүріккіш пистолеттің мақсатты бетімен үлкен байланыс аймағы ең жақсы нәтиже болып табылады.*

*Зерттеу РФФИ 18-29-18081 және 19-38-90228\19 гранттары, Ресей Федерациясы Президентінің, Ресей Федерациясының жетекші ғылыми мектептерін мемлекеттік қолдауға арналған НШ–3778.2018.8 гранты және № 14727ГУ/2019 және № 14549ГУи/2019 келісімшартына сәйкес «УМНИК-18» бағдарламасы бойынша инновацияларға жәрдемдесу қорының гранттары шеңберінде орындалды.*

*Кілтті сөздер: ультра ағынды өңдеу, суспензия, процесті математикалық модельдеу, технологиялық параметрлер.*

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Российская Федерация, г. Москва.
Материал поступил в редакцию 17.03.22.

## ЧИСЛЕННОЕ 3D-МОДЕЛИРОВАНИЕ ПРОЦЕССА ВЫСОКОСКОРОСТНОГО РАСПЫЛЕНИЯ

*Статья посвящена образованию облака брызг после взаимодействия ультраструи с препятствием. Рассмотрены варианты различного взаимного расположения ультраструи и поверхности, на которую происходит удар. Оценка эффективности выбора угла осуществляется путем анализа значений зоны охвата цели распылителем, установленной на фиксированном расстоянии от места удара. Принято считать, что большая площадь контакта распылителя с целевой поверхностью является наилучшим возможным результатом.*

*Исследование выполнено в рамках грантов РФФИ 18-29-18081 и 19-38-90228\19, гранта Президента Российской Федерации на государственную поддержку ведущих научных школ Российской Федерации НШ-3778.2018.8 и грантов Фонда содействия инновациям по программе «УМНИК-18» в соответствии с контрактом № 14727ГУ/2019 и № 14549ГУ/2019.*

*Ключевые слова: ультраструйная обработка, суспензия, математическое моделирование процесса, технологические параметры.*

Теруге 17.03.22 ж. жіберілді. Басуға 27.03.22 ж. қол қойылды.
Электрондық баспа
15 Mb RAM
Шартты баспа табағы 14,5. Таралымы 300 дана.
Бағасы келісім бойынша.
Компьютерде беттеген: Е. Е. Калихан
Корректор: А. Р. Омарова

Тапсырыс № 3952

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