UDC 656.2

ANALYSIS OF LIMITATIONS ON THE DESIGN OF A SMALL-DIMENSIONAL ROBOT FOR INVESTIGATING DAMAGE TO PANEL BUILDINGS

Illya Karpenko
Municipal Institution “Kharkiv Lyceum 178 Kharkiv City Council”
Ukraine, 61105, Kharkiv, Monyushka street, 1
E-mail: sch178@kharkivosvita.net.ua

Annotation. The article analyzes the design limitations of a compact robot designed to investigate damage to panel houses. The requirements for size, maneuverability, energy efficiency, load capacity and the use of sensors to detect defects in hard-to-reach areas are considered. An approach to design optimization is proposed, taking into account operating conditions in a limited space, which allows to increase the efficiency of inspection and reduce the risks of destruction.

Keywords: compact robot, panel houses, damage, structural limitations, inspection, optimization.

АНАЛІЗ ОБМЕЖЕНЬ НА КОНСТРУКЦІЮ МАЛОГАБАРИТНОГО РОБОТА ДЛЯ ДОСЛІДЖЕННЯ ПОШКОДЖЕНЬ ПАНЕЛЬНИХ БУДИНКІВ

Ілля Карпенко
Комунальний заклад «Харківський ліцей № 178 Харківської міської ради»
Україна, 61105, м. Харків, вул. Монюшка, 1
E-mail: sch178@kharkivosvita.net.ua

Анотація. У статті проведено аналіз конструктивних обмежень малогабаритного робота, призначеного для дослідження пошкоджень панельних будинків. Розглянуто вимоги до розмірів, маневровості, енергоефективності, вантажопідйомності та використання сенсорів для виявлення дефектів у важкодоступних зонах. Запропоновано підхід до оптимізації конструкції з урахуванням умов експлуатації в обмеженому просторі, що дозволяє підвищити ефективність інспекції та зменшити ризики руйнувань..

Ключові слова: малогабаритний робот, панельні будинки, пошкодження, конструктивні обмеження, інспекція, оптимізація..

The development of compact robots for investigating panel houses damaged as a result of Russia's aggression against Ukraine is an important and relevant task in the context of the restoration of affected regions. These robots enable the safe inspection of structures in areas where human presence is hazardous due to the risk of collapses or toxic substances. They provide access to hard-to-reach zones, such as cracks, basements, and inter-floor ceilings, for a detailed analysis of the buildings' condition. This technology will allow for the prompt assessment of damage levels, the identification of critical defects, and decision-making regarding reconstruction or demolition. The use of robots will contribute to resource savings and reduce risks for engineers and rescuers. It is also a significant step toward integrating innovative technologies into Ukraine’s civil security system and supporting post-war reconstruction efforts.

The analysis of existing mobile robots that can be used for the inspection of damaged buildings is presented in Figure 1, while a comparison of their technical characteristics is provided in Table 1.

а) б)

а) GPK-32 Tracked Inspection Robot
б) GPK-32 4-Wheel Drive (4WD) Inspection Robot
Figure 1. Existing mobile robots that can be used for the inspection of damaged buildings.

Table 1. Comparison of technical characteristics of mobile robots GPK-32 Tracked Inspection Robot та GPK-32 4-Wheel Drive (4WD) Inspection Robot.

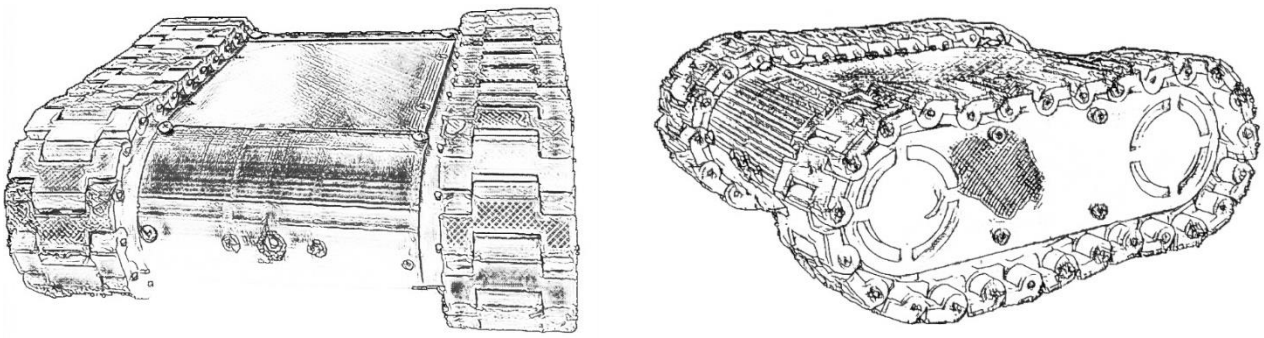
Characteristics	GPK-32 Tracked Inspection Robot	GPK-32 4-Wheel Drive (4WD) Inspection Robot.
Drive type	Tracked drive	Four-wheel drive
Size (LxWxH), mm	445 x 340 x 180	445 x 340 x 180
Weight, kg	6.8	6.5
Maximum speed, m/s	0.2	0.5
Terrain capability	High (effective movement on uneven surfaces)	Medium (effective movement on flat surfaces)
Turning radius, mm	0 (ability to turn on the spot)	~450 (depends on platform width)
Payload capacity, kg	Up to 3 kg	Up to 3 kg
Sensor type (standard set)	Cameras, thermal imagers, laser scanners	
Intended use	Rubble, rough terrain	Flat floors, tunnels

GPK-32 Tracked Inspection Robot has a drawback in terms of lower speed and energy efficiency, which may limit its operational duration in conditions with limited power supply, although it is better suited for uneven surfaces. On the other hand, the GPK-32 4-Wheel Drive (4WD) Inspection Robot has limited mobility on rubble and uneven terrain, as well as a larger turning radius, making it more challenging to maneuver in confined spaces. Both robots have a payload capacity that may be insufficient for integrating complex equipment, such as combined sensors, required for a comprehensive analysis of the damage in panel buildings.

The analysis of the necessary constraints for the development of a compact mobile robot includes consideration of size, maneuverability, energy efficiency, payload capacity, and sensor equipment. The robot's dimensions are determined by the space constraints in which it will operate. For inspecting cracks, ventilation shafts, or areas between floors, its dimensions should not exceed 200-300 mm in width and height, ensuring accessibility to hard-to-reach areas. Maneuverability is a critical parameter in the context of narrow corridors and complex movement trajectories, so it is

important to consider a minimum turning radius, which should not exceed 150 mm. Energy efficiency depends on the weight of the structure, the type of drive, and the mode of movement. Lighter robots with tracked drives consume less energy than multi-wheeled platforms, yet tracks provide better mobility in rubble. Payload capacity is limited by the ability of the structure to transport not only its own weight but also sensors and equipment, such as cameras, laser scanners, or ultrasonic sensors, with a total weight of up to 1-2 kg. When using sensors, it is important to account for the need to combine different types to achieve comprehensive analysis, particularly thermal imagers for detecting cracks and cameras for identifying structural damage. A comparative analysis of existing solutions shows that the most effective robots are those with an optimized balance between size and equipment. As a result, the technical requirements should include parameters of compactness and adaptability, ensuring efficient operation in challenging conditions, minimizing energy consumption, and improving data collection quality.

As a result of the analysis of constraints, the following concept of a compact robot for the inspection of damaged panel buildings is proposed, as shown in Figure 2.



а) б)

а) Front view; б) Side view.

Figure 2. Developed concept of a compact robot for the inspection of damaged panel buildings.

As a result of the conducted analysis, key constraints affecting the design of a compact robot for inspecting damage to panel buildings have been identified, including requirements for its dimensions, maneuverability, energy efficiency, payload capacity, and sensor equipment. It has been determined that the robot must have compact dimensions for operation in narrow spaces, a high level of maneuverability for efficient movement in challenging conditions of destruction, and an energy-efficient design to ensure prolonged autonomous operation. The payload capacity and the ability to integrate advanced sensor equipment must meet the demands of precise damage assessment and real-time data collection. Based on these findings, a robot concept with a tracked drive has been proposed. This design ensures high terrain capability, the ability to turn on the spot, and the use of combined sensors, such as thermal imagers, cameras, and laser scanners. This approach will enable the creation of an effective platform for damage diagnostics, contributing to the safe and rapid reconstruction of panel buildings.

REFERENCES

1. Qiu, Z., Wu, Q., Liu, Z., Fang, Y., & Sun, N. (2024). A New Three-Dimensional Deformation Pneumatic Soft Actuator With Mutually Vertical PneuNets. *IEEE Transactions on Industrial Electronics*.

2. Wang, Y., Wu, S., Fu, H., Fu, Q., Zhang, T., Chang, Y., & Wang, X. (2023). Curriculum-based co-design of morphology and control of voxel-based soft robots. In *The Eleventh International*

Conference on Learning Representations.

3. Yevsieiev V. Ecosystem Model of the Concept of Industry 5.0 / V. Yevsieiev // Digital innovation & sustainable development 2024 : Proceedings of I-st International Conference, November 15, 2024. - Kharkiv, 2024. - P. 12-13.

4. Moiseev, M., Maksymova, S., Yevsieiev, V., & Alkhalaileh, A. (2024). Program Algorithm for Monitoring System Development. *Journal of universal science research*, *2*(7), 33-43.

5. Abu-Jassar, A. T., Attar, H., Yevsieiev, V., Amer, A., Demska, N., Luhach, A. K., & Lyashenko, V. (2022). Electronic User Authentication Key for Access to HMI/SCADA via Unsecured Internet Networks. Computational Intelligence and Neuroscience, 2022, Article ID 5866922. https://doi.org/10.1155/2022/5866922.

6. Lyashenko, V., Abu-Jassar, A.T., Yevsieiev, V., Maksymova, S. Automated Monitoring and Visualization System in Production, Int. Res. J. Multidiscip. Technovation, 5(6) 2023 09-18. https://doi.org/10.54392/irjmt2362

7. Amer Abu-Jassar, Vladyslav Yevsieiev, & Svitlana Maksymova. (2024). The Optical Flow Method and Graham's Algorithm Implementation Features for Searching for the Object Contour in the Mobile Robot's Workspace. Journal of Universal Science Research, 2(3), 64–75.

8. Vladyslav Yevsieiev, Samariddin, S. M., Nikolay Starodubtsev, & Amer Abu-Jassar. (2024). ACTIVE CONTOURS METHOD IMPLEMENTATION FOR OBJECTS SELECTION IN THE MOBILE ROBOT'S WORKSPACE. Journal of Universal Science Research, 2(2), 135–145.

9. Svitlana Maksymova, Vladyslav Yevsieiev, & Ahmad Alkhalaileh. (2024). The Monitoring System Architecture Development. Journal of Universal Science Research, 2(1), 69–79.

10. Andrii Bondariev, Svitlana Maksymova, & Vladyslav Yevsieiev. (2023). Automated Monitoring System Development for Equipment Modernization. Journal of Universal Science Research, 1(11), 6–16. Retrieved from https://universalpublishings.com/index.php/jusr/article/view/2484

11. Yevsieiev, V. Comparative Analysis of the Characteristics of Mobile Robots and Collaboration Robots Within INDUSTRY 5.0. / V. Yevsieiev, D. Gurin // In the VI International Scientific and Theoretical Conference, September 8, 2023. Chicago, USA. P.92-94

12. Yevsieiev, V., & et al. (2024). Object Recognition and Tracking Method in the Mobile Robot's Workspace in Real Time. Technical science research in Uzbekistan, 2(2), 115- 124.

13. Gurin, D., & et al. (2024). Effect of Frame Processing Frequency on Object Identification Using MobileNetV2 Neural Network for a Mobile Robot. Multidisciplinary Journal of Science and Technology, 4(8), 36-44.

14. Yevsieiev, V., & et al. (2024). Building a traffic route taking into account obstacles based on the A-star algorithm using the python language. Technical Science Research In Uzbekistan, 2(3), 103-112

15. Gurin, D., & et al. (2024). MobileNetv2 Neural Network Model for Human Recognition and Identification in the Working Area of a Collaborative Robot. Multidisciplinary Journal of Science and Technology, 4(8), 5-12.

16. Yevsieiev, V., & Uskov, S. (2024). *Development of the Layout Concept of a Small-Dimensioned Mobile Robot With Increased Accessibility* (Doctoral dissertation, International Scientific Unity).

17. Yevsieiev V. New Concepts of Human Interactions and Collaborative Robot-Manipulators in the Concepts of Industry 5.0 / V. Yevsieiev, D. Gurin // Proceedings of the VII International Scientific and Theoretical Conference, October 4, 2024. - Sydney, Australia. - P. 76-79.

Scientific advisor: *Starykova Svitlana Olegivna, Math teacher*