ANALYSIS OF THE USE OF COMPOSITE MATERIALS IN AVIATION AND THEIR CONTACT DAMAGE UNDER VIBRATION CONDITIONS

Khimko Andrii
Candidate of Technical Sciences
Associate Professor of the Air Transport Department
National University "Kyiv Aviation Institute"
https://orcid.org/0009-0009-8059-880X
andreykhimko@ukr.net
Mikosianchik Oksana
Doctor of technical sciences
Head of the Department of Applied Mechanics and Materials Engineering
National University "Kyiv Aviation Institute"
https://orcid.org/0000-0002-2438-1333
oksana.mikos@ukr.net

Annotation. *The article analyzes the use of composite materials in the structures of modern aircraft. It is established that the latest generation of aircraft is characterized by the use of ultralight and high-strength materials, in particular carbon fiber, fiberglass and titanium alloys. The widespread introduction of such materials necessitates the creation of a significant number of joints between composite materials and titanium parts. Given that vibration loads are an integral factor in the normal operation of aircraft, damage to contact zones due to fretting wear is increasingly recorded in modern aircraft. The most vulnerable are joints of titanium alloys with composite materials, where vibration microdisplacements lead to destruction of surface layers and a decrease in the durability of the structure due to the appearance of cracks in the metal parts of the structure. The formation of microcracks leads to damage to surfaces and, as a result, without proper* *maintenance, to a sharp loss of joint strength, which in turn leads to the destruction of structures and the emergence of catastrophic situations with consequences. The article analyzes the mechanisms of damage to contact pairs "titanium alloy - composite material" under the influence of vibration loads. It is determined that a promising direction for increasing the wear resistance of assemblies is the implementation of technological measures to strengthen titanium parts and the use of intermediate materials in contact zones. In particular, the use of gas-thermal coating methods provides a multiple (tens of times) increase in the wear resistance of contacts and changes the nature of wear: from the destruction of titanium elements to the controlled wear of composite materials. This approach contributes to increasing the reliability and service life of connections in the structures of modern aircraft without maintenance and transferring equipment to maintenance according to the actual condition.*

Keywords: *aviation, titanium alloys, carbon fiber, fiberglass, vibration, damage, analysis, durability.*

Problem statement. Composite materials are among the most sought-after resources in modern aircraft engineering. One of the key problems in the industry is to reduce the mass of an aircraft structure while ensuring the necessary strength and rigidity. The use of composite materials, along with titanium alloys, allows for a significant reduction in the mass of aircraft, which directly affects fuel consumption. The specific strength of such materials significantly exceeds the characteristics of traditional metal alloys [1].

In modern aircraft engineering, composite materials are used in the structures of many aircraft. A prime example is the Boeing 787 Dreamliner, the first commercial aircraft in which the main structural elements are made of composite materials [2], rather than aluminum alloys. This aircraft has implemented a transition from fiberglass composite materials to more modern carbon laminates and sandwich composites. According to calculations [3], the use of composite materials in the Boeing 787 Dreamliner provides a 20% reduction in the mass of structural elements.

For comparison, reducing the weight of the Airbus A340-300 aircraft structure by 20 % allows for a reduction in fuel consumption by 8,660 kg during a flight of 10,000 km, which corresponds to a saving of about 9–10,000 euros depending on the region.

However, the widespread use of composite materials in combination with titanium alloys under operational loads and engine vibrations leads to damage and loss of service life even in units that are nominally considered stationary. The number of such connections in modern aircraft reaches thousands of contact points, which makes the problem of ensuring their durability and reliability urgent.

The purpose of this work is a comprehensive analysis of the use of composite materials in the structures of modern aircraft and the study of characteristic damage in contact pairs "composite material - titanium alloy". Special attention is paid to units where titanium alloys are widely used in connections with composite materials, which is due to their widespread use in modern aircraft construction.

Analysis of the use and damage of composite materials in aviation. Composite materials occupy a leading position in modern aircraft construction due to the combination of high specific strength and low density. The most common among them are fiberglass and carbon fiber, which provide a significant reduction in the mass of aircraft structures while maintaining the necessary operational characteristics.

Fiberglass has been widely used due to its high corrosion resistance and ability to withstand alternating loads. They are easily machined, which contributed to their use in the first power structures of aircraft. In particular, fiberglass was used to make fuselage and wing elements, as well as high-pressure cylinders. The main disadvantage of fiberglass is the decrease in mechanical properties in an aqueous environment, which is associated with the weakening of the bond between glass fibers and the polymer matrix. In modern conditions, fiberglass is considered to be a previous generation material, although it is still used in a number of aircraft structures.

Carbon fiber composites are gradually replacing fiberglass due to the combination of lower weight and high strength. Carbon laminates and sandwich composites are characterized by increased stiffness, fatigue resistance and better performance properties. Their use allows for a significant reduction in the weight of aircraft structures, which directly affects fuel economy and flight efficiency.

At the same time, the use of composite materials in combination with titanium alloys creates new challenges for the aviation industry. Under operational loads and vibrations from engines, damage occurs in the contact zones, leading to loss of service life even in units that are nominally considered stationary. The number of such joints in modern aircraft reaches thousands, which makes the problem of ensuring their durability and reliability urgent.

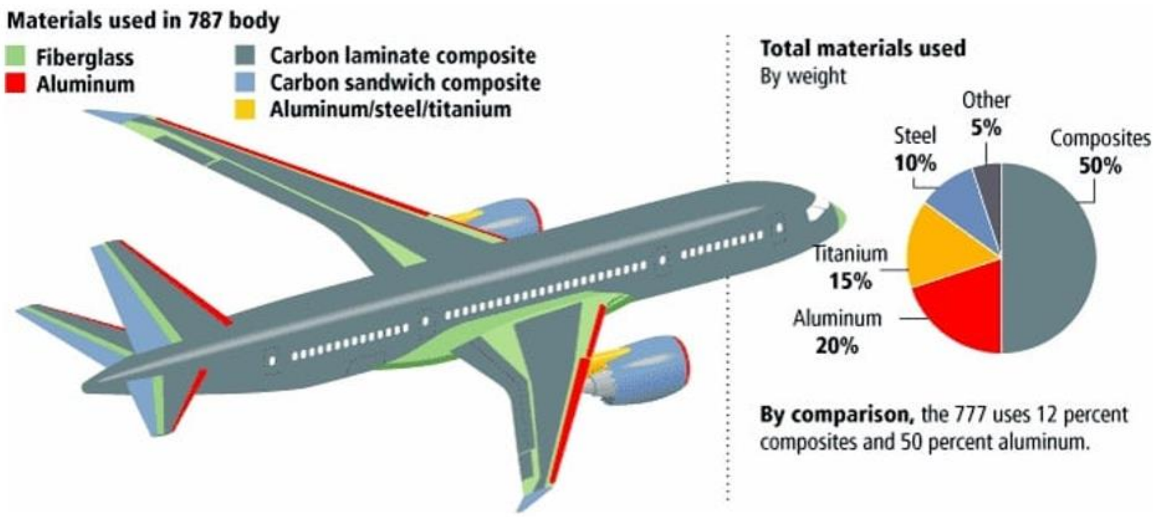

Fig. 1. Use of materials in the Boeing 787 Dreamliner [2]

Carbon fiber composites are the most promising type of composite materials for aviation and space technology. Their key advantages are determined by high specific strength and stiffness, heat resistance, and corrosion resistance. Composite materials based on epoxy binders are capable of operating for a long time at temperatures up to 200 °C, and materials based on organosilicon resins - up to 300 °C. Due to the high electrical conductivity of carbon fiber, carbon fiber composites can perform antistatic protection functions, which expands their functional capabilities.

The combination of these properties has led to the widespread use of carbon fiber composites in aircraft structures. Their exceptional rigidity makes the material ideal for the manufacture of large-sized parts, in particular wing elements. In addition, the technology for forming carbon fiber structures allows you to reduce the number of connections made using screws or rivets, which reduces the need for regular technical control and maintenance. An important advantage is also resistance to moisture and corrosion, which distinguishes carbon plastics from traditional metal materials. Thus, carbon plastics combine lightness, strength, heat resistance and functionality, which makes them one of the key materials for the new generation of aviation industry. Fig. 2 shows examples of aviation parts made of composite materials [4].

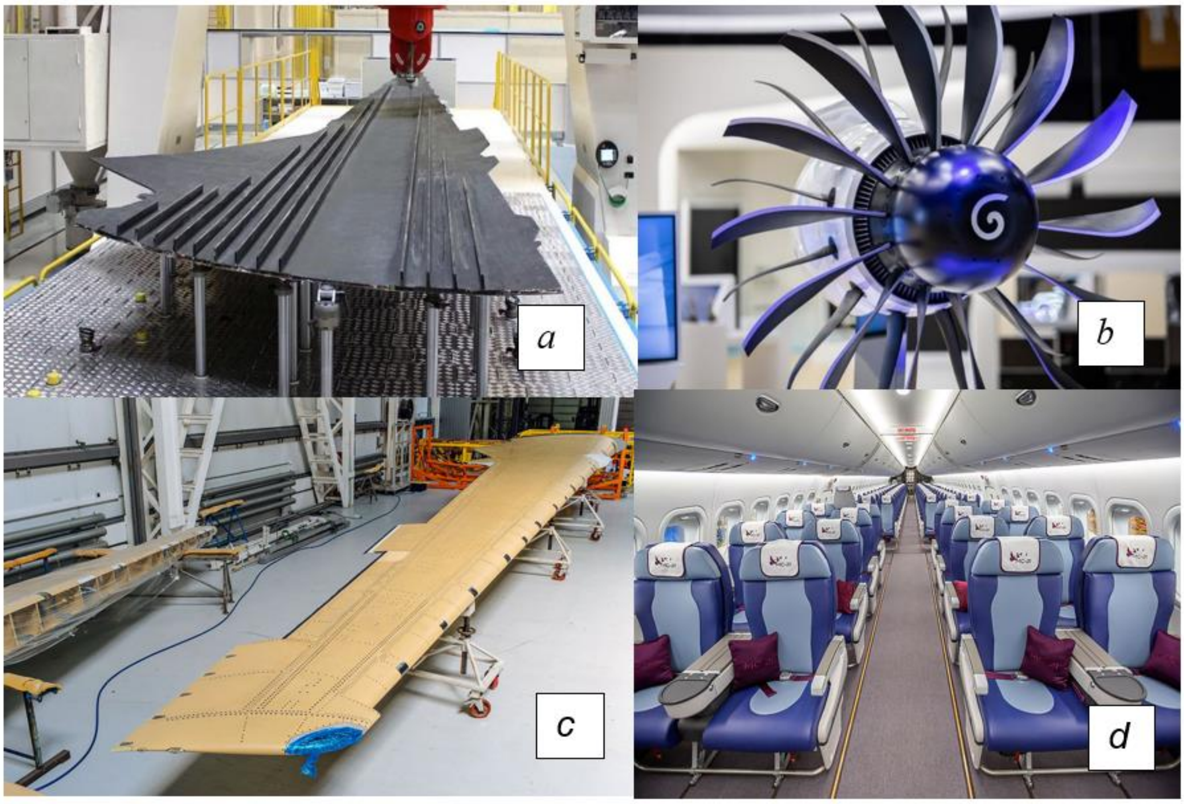

Fig. 2. Examples of manufacturing parts from composite materials for aviation: a – aircraft wing panel (carbon fiber), b – aircraft engine propeller (carbon fiber), c – aircraft wing (fiberglass), d – aircraft interior (PAEK, PEEK, PEI, PTFE) [4]

The moving elements of the tail and ailerons of modern aircraft have a multilayer structure, which provides increased torsional resistance. Such structures are formed on the basis of a cellular filler made of Kevlar aramid fiber, located between layers of carbon fiber. The areas of connection of the wings with the fuselage are traditionally made of fiberglass, which are characterized by high strength.

Airbus airline uses aramid fiber to strengthen the wings of the A320 aircraft, which provides resistance to various operational factors. Boeing in the 777X series uses composite wings with a span of 72 m, which, thanks to a system of titanium hinges, can be folded in the parking lot, reducing the span by 7 m. This is an example of an effective combination of the properties of titanium alloys and composites.

Modern polymer technologies are also actively introduced into aviation. Solvay has developed a polymer film with a copper mesh to dissipate electrostatic charges and improve aerodynamics. In collaboration with Lufthansa and BASF, a polymer coating with a microprismatic structure has been created that reduces air resistance. Applying such a film with an area of 950 m^2 allows saving up to 400 tons of fuel annually and reducing CO_2 emissions by 1,200 tons. If implemented globally, this technology could save about 5 million tons of fuel per year.

Composite materials based on epoxy resins are used in the front parts of jet engines to reduce fuel consumption. The use of polymers (PEEK, carbon fiber) in the blades of CFM's LEAP engine has allowed for a weight reduction of 450 kg compared to the previous generation, which resulted in a 30% reduction in fuel consumption.

Polymers also play an important role in creating aircraft interiors: overhead compartments, bulkheads, service carts and seats. PEI-based materials are used for large parts due to their fire safety, and polyamides with flame retardants are used for small fasteners. Replacing aluminum parts with PEI and carbon fiber products allows you to reduce the weight of the structure by tens of kilograms.

Airbus has developed a seat with a titanium and carbon fiber frame weighing only 4 kg, which is almost half the weight of traditional seats. This is the first CAA-certified carbon fiber seat, which is already used in A320 and Boeing 737 aircraft.

Safran has created a new type of propeller for aircraft gas turbine engines with a diameter of 4 m, made of carbon fiber. Thanks to the flexibility of the blades, it was possible to reduce noise levels to the level of the LEAP engine and provide an additional reduction in fuel consumption by 15-25%.

Analysis of damage to composite materials with titanium alloys during vibrations. The aviation industry is constantly improving, and contacts between composite materials and titanium alloys are becoming increasingly common in the structures of modern aircraft. Since the structural elements are in the field of vibration loads, even nominally fixed connections undergo microdisplacements, which leads to damage. This is especially relevant given the low antifriction properties of titanium alloys and the high strength of reinforced fibers of composite materials. A review of the literature [10–15] shows that under vibration conditions, microdisplacements occur in contact pairs, which cause damage to both titanium parts and composite materials. Works [16–20] show that the wear resistance of titanium alloys in such contacts can be up to 10 times lower compared to reinforced glass fiber and carbon composites. The main problem is the formation of fatigue cracks in titanium alloys due to fretting corrosion, which can lead to a sharp loss of strength and structural failure.

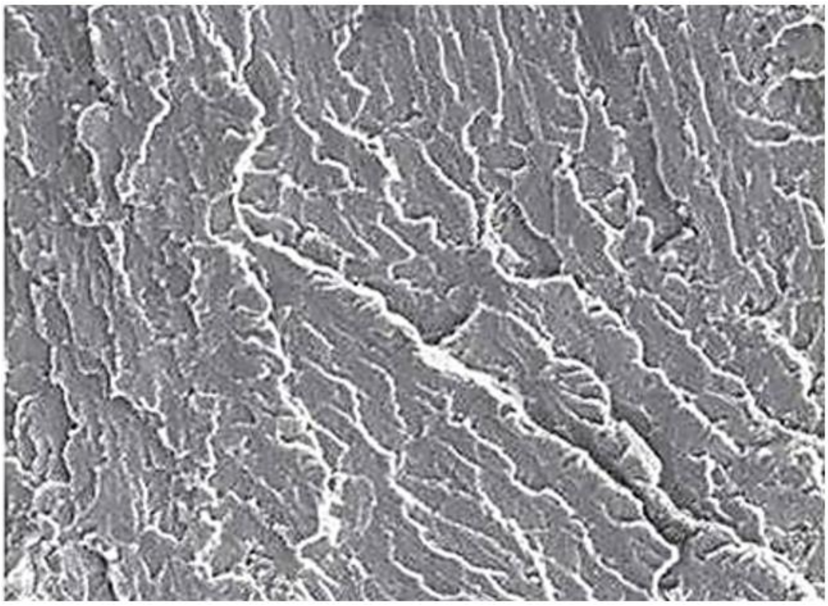

Fig. 3. Shows examples of damage to titanium alloys in contact with composite materials during fretting corrosion

Ways to increase the durability of contact pairs:

- application of technological methods for strengthening titanium parts [21–24], which allows increasing their wear resistance to the level of composites;
- use of antifriction intermediate materials [21, 22];
- application of special wear-resistant coatings [23–33].

In particular, gas-thermal and galvanic coatings based on chromium or molybdenum can increase the wear resistance of titanium parts in contact with composite materials by up to 20 times, ensuring the balance and durability of the assembly.

Conclusions. Thus, the use of composite materials in modern aircraft tends to grow steadily, which is accompanied by an increase in the number of their contacts with titanium alloys. Under operational and vibration loads, such joints are inevitably damaged, even if they are nominally considered immobile. The main risk is the formation of fretting corrosion and fatigue cracks in titanium parts, which can lead to loss of strength and structural failure.

The use of a controlled approach to the design and operation of contact zones, as well as the use of technological methods for preparing the surfaces of titanium alloys and composite materials, allows you to significantly increase the durability of such units. The implementation of these measures ensures the possibility of operating joints without frequent maintenance, which reduces the cost of maintaining aviation equipment and at the same time increases the service life and reliability of structures.

References:

1. Filik K. (2024) Study of new composite materials for aviation with the use of lightning current pulses. Przegląd Elektrotechniczny, 1(11), 188–191. https://doi.org/10.15199/48.2024.11.36

2. Appropedia. (n.d.). Kompozytuvaty v aviabuduvanni. Retrieved June 13, 2026, from https://www.appropedia.org/Composites_in_the_Aircraft_Industry/ru

3. Shi, X.-H., Chen, L., Liu, B.-W., Long, J.-W., Xu, Y.-J., & Wang, Y.-Z. (2018). Carbon fibers decorated by polyelectrolyte complexes toward their epoxy

resin composites with high fire safety. Chinese Journal of Polymer Science, 36(12), 1375–1384. https://doi.org/10.1007/s10118-018-2134-7

4. Plastinfo. (n.d.). Aviatsiya: polimery ta kompozyty dlya vysokykh poletiv. Retrieved June 13, 2026, from https://plastinfo.ru/information/articles/798

5. National Institute for Aviation Research (U.S.). (2012). Composite materials handbook. Warrendale, PA: SAE International on behalf of CMH-17, Wichita State University.

6. Du, Y., Yan, N., & Kortschot, M. T. (2015). The use of ramie fibers as reinforcements in composites. In Biofiber reinforcements in composite materials (pp. 104–137). https://doi.org/10.1533/9781782421276.1.104

7. Chauhan, A. K., et al. (2020). Properties of composite materials. In Composite materials (pp. 61–78). Boca Raton, FL: CRC Press. https://doi.org/10.1201/9781003080633-3

8. June, R., & Lager, J. (n.d.). Commercial aircraft: Applications of composite materials. ASTM International. https://doi.org/10.1520/stp34128s

9. Khayrnasov, K. Z. (2021). Composite materials in aircraft engine blades. PNRPU Mechanics Bulletin, 4, 13–18. https://doi.org/10.15593/perm.mech/2021.4.02

10. Khimko, A., Popov, O., & Khimko, M. (2026). Effect of temperature on the wear resistance Ti6Al4V-CFRP/GFRP contact under vibration conditions. Problems of Friction and Wear, 1(110), 4–12. https://doi.org/10.18372/0370-2197.1(110).20915

11. Khimko, A. (2025). The influence of corrosive and aggressive environments on the contact of aluminum and titanium alloys with CFRP under vibration loading conditions. Problems of Friction and Wear, 4(109), 95–104. https://doi.org/10.18372/0370-2197.4(109).20757

12. Khimko, A., Mikosianchik, O., Khimko, M., & Filonenko, O. (2025). Wear resistance of contact of titanium alloys with composite materials depending on the technology of their manufacturing under conditions of nominally fixed contact.

Problems of Friction and Wear, 3(108), 28–37. https://doi.org/10.18372/0370-2197.3(108).20445

13. Khimko, A. (2025). Analysis of the use and damage of titanium alloy parts in aircraft. In Proceedings of the Eighteenth International Scientific and Practical Conference “Integrated Intelligent Robotic Complexes” (IIRTK-2025) (pp. 65–68). Kyiv: KAI.

14. Khimko, M., et al. (2024). Influence of thermophysical properties of metal-polymer composite materials on wear resistance. Problems of Friction and Wear, 3(104), 91–100. https://doi.org/10.18372/0370-2197.3(104).18984

15. Khimko, M., et al. (2024). Wear resistance of polymer composite materials for spherical bearings. Problems of Friction and Wear, 2(103), 29–42. https://doi.org/10.18372/0370-2197.2(103).18670

16. Khimko, M., Khimko, A., Mnatsakanov, R., & Mikosyanchyk, O. (2024). Resource testing of modified plain bearings for the aviation industry. Problems of Tribology, 29(2/112), 16–22. https://doi.org/10.31891/2079-1372-2024-112-2-16-22

17. Mikosyanchyk, O., et al. (2023). Analysis of models and methods for assessing the strength characteristics of polymer composite materials. Problems of Friction and Wear, 3(100), 15–29. https://doi.org/10.18372/0370-2197.3(100).17891

18. Kralya, V. O., Molyar, O. H., Trofimov, V. A., & Khimko, A. M. (2010). Defects of steel units of the high-lift devices of aircraft wings caused by fretting corrosion. Materials Science, 46, 108–114. https://doi.org/10.1007/s11003-010-9270-8

19. Khimko, A., Hrechukha, A., & Khimko, M. (2024). Research of the impact of ambient temperature on the wear resistance of metal-polymer composite materials used in aviation plain bearings. In Aviation in the XXI-st century: Safety in Aviation and Space Technologies (pp. 1.3.60–1.3.63). Kyiv: NAU.

20. Khimko, A., Mikosyanchyk, O., Khimko, M., & Klipachenko, V. (2026). Increasing the durability of the Ti-GFRP/CFRP contact with a layer of wear-resistant polymer composite coatings under vibration load conditions. Problems of Tribology, 31(2/120), 16–22. https://doi.org/10.31891/2079-1372-2026-120-2-16-22

21. Mikosyanchyk, O., et al. (2023). Analysis of models and methods for assessing the strength characteristics of polymer composite materials. Problems of Friction and Wear, 3(100), 15–29. https://doi.org/10.18372/0370-2197.3(100).17891

22. Umanskyi, O. P., et al. (2009). Development of technology for applying new wear-resistant composite coatings to strengthen aircraft engine parts. Aerospace Engineering and Technology, 9, 38–44. http://nbuv.gov.ua/UJRN/aktit_2009_9_7

23. Kralya, V., et al. (2007). Wear resistance of plasma coatings for a constant work of friction. Strength of Materials, 39(5), 523–528. https://doi.org/10.1007/s11223-007-0058-5

24. Kralya, V., et al. (2006). Wear hot-gas plasma coatings under fretting-corrosion. Proceedings of National Aviation University, 30(4). https://doi.org/10.18372/2306-1472.30.1410

25. Khimko, A., Khimko, M., Makarenko, R., & Tokaruk, V. (2026). Effectiveness evaluation of the conversion coatings application on titanium alloys in contact with GFRP under nominally stationary contact conditions. Problems of Friction and Wear, 2(111), 31–39. https://doi.org/10.18372/0370-2197.2(111).21334

26. Tareq, M. A. Al-Quraan, et al. (2026). Increasing the wear resistance of titanium alloys in plain bearings with galvanic and vacuum-arc coatings. Tribology in Industry, 48(1), 72–82. https://doi.org/10.24874/ti.2043.10.25.11

27. Khimko, A., et al. (2009). Fretynhostiykist composite materials. Proceedings of National Aviation University, 38(1). https://doi.org/10.18372/2306-1472.38.1655

28. Mikosianchyk, O., et al. (2021). Evaluation of operational properties of aviation oils by tribological parameters. Problems of Tribology, 99(1), 43–50. https://doi.org/10.31891/2079-1372-2021-99-1-43-50

29. Tokaruk, V., et al. (2022). Estimation of the stress-strain state of a tribocontact by changing the average acoustic emission power. Problems of Friction and Wear, 3(96), 30–40. https://doi.org/10.18372/0370-2197.3(96).16833

30. Svyryd, M., et al. (2009). Monitoring of tribological parameters of a friction unit under mass transfer conditions. Problems of Friction and Wear, 51. https://doi.org/10.18372/0370-2197.51.3561

31. Mnatsakanov, R. G., Mikosyanchyk, O. O., & Khimko, A. M. (2020). The influence of the gas environment on the quality of running-in of friction pairs. In Proceedings of the VIII International Scientific and Practical Conference "Information, Its Impact on Social and Technical Processes" (pp. 102–105). Haifa, Israel.

32. Svirid, M. M., et al. (2009). Methods of research of materials under conditions of reversible friction in a magnetic field. Problems of Friction and Wear, 52. https://doi.org/10.18372/0370-2197.52.3109

33. Khimko, A. (2007). The efficiency of plasma coatings under fretting-corrosion. Proceedings of National Aviation University, 33(3–4). https://doi.org/10.18372/2306-1472.33.1506