Comprehensive assessment of the impact of technological processes of mechanical processing on the environment and people based on the energy representation

S Pushenko, L Shvartsburg, S Ryabov, and N Ivanova

1Don State Technical University, Gagarin sq., 1, Rostov on Don, 344003, Russia
2Moscow State University of Technology "STANKIN" Vadkovsky lane 1, Moscow 127055, Russia
E-mail: slpushenko@yandex.ru

Abstract. The article considers the some indicators of quality of technological processes machining, characterizing their impact on the environment and human, which determine the competitiveness of these processes. This primarily refers to the safety performance indicators which are specific to the technological processes machining – power consumption, vibration, noise, air pollution of the working area products of thermal degradation of cutting coolant, and some others. In addition, the work also touched upon questions related to social aspects of improving occupational safety performance.

1. Introduction
Modern production is currently characterized by a large number of different indicators. These indicators can only be achieved with a high level of automation and mechanization of technological processes and auxiliary operations. All this requires the presence of modern electric motors, microprocessor control systems, Electromechanical and power converters, various types of relays, electromagnetic clutches, tables, clamping devices and other automation and mechanization tools in the process equipment. These devices require the consumption of electrical energy, which is then converted in various types of converters into other types of energy (for example, mechanical, thermal, etc.), or into electrical energy.

In many cases, technological processes are implemented with the use of cutting coolant. These fluids, falling into the cutting zone characterized by the presence of high temperatures, undergo a process of thermal degradation. As a result, the environment and air in the working area of the process equipment are polluted [1-4].

At the same time, any consumption of electrical energy, its transmission and conversion is accompanied by electromagnetic waste, which has a great impact on the environment and humans.

All these pollutants affect the technical level of equipment and the quality of technological processes. These pollutants affect such important indicators as environmental and safety indicators – electricity consumption, air pollution in the work area, and some others.[5,6] In the end, all this has a great impact on the competitiveness of automated machine-building production.

Today, a competitive manufacturer is required to produce high-quality products in accordance with European standards. Currently, the Russian engineering industry does not always meet quality requirements for all standard requirements for groups of quality indicators. This applies to the
requirements of reliability, durability, labor intensity of products, energy and resource saving, as well as to the safety and environmental friendliness of technological processes and productions.

Today, it is necessary to change the existing approaches in Russia related to the use of high-performance technologies. It is necessary to ensure that technological processes can be managed taking into account the relationships between separate groups of quality indicators. It should be noted that such important quality indicators as indicators of safety of technological processes for people and the environment, comfort of work are often not given due attention. These indicators largely determine the competitiveness of machine-building production and products. The formation of the most important directions for creating competitive forming technologies can have a great impact on the development of machine-building production.

Solving the problem of minimizing the impact on humans and the environment of machine-building forming technologies often leads to changes, and sometimes to deterioration, of the quality indicators of technological processes. This requires establishing a qualitative and quantitative interdependence between the quality indicators of technological processes, and modernization of control algorithms on this basis. These indicators include: accuracy of shape and size; properties and characteristics of the surface layer; productivity; environmental and human impact, including energy intensity of technological processes, etc.

2. Installation for studying the formation of cutting coolant thermal degradation products
Modern cutting coolant is an important part of the entire complex of tools that ensure efficient operation of metal-cutting equipment. In the process of Metalworking, the cutting conditions differ significantly. As a result, it is necessary to use different types of liquid cutting coolant, which are introduced into the cutting zone. The use of cutting coolant allows reducing the wear of the cutting tool, improving the quality and performance of the treated surface, timely removing chips and tool wear products from the cutting zone, increasing labor productivity, and reducing the temperature in the processing zone.

Water cutting coolant are concentrates from which emulsions or working solutions of various concentrations are prepared. The advantages of water-miscible cutting coolant are higher cooling capacity than oil cutting coolant, low cost of working solutions, fire safety and lower toxicity. Disadvantages - low lubricating properties, low stability of properties over time, the need for regeneration and disposal of spent cutting coolant.

![Special stand for the study of the selection of thermal degradation products of the cutting coolant](image)

**Figure 1.** Special stand for the study of the selection of thermal degradation products of the cutting coolant.

The oil cutting coolant is a complex mixture containing mineral oils and special additives. Organic components of oil cutting coolant have a low working temperature (approximately 130-200°C). This
temperature is lower than the average temperature in the cutting zone. As a result of exceeding the working temperature, the components of the cutting coolant are destroyed and gaseous compounds are released into the air of the working zone.

When working on machines in the cutting zone, temperatures are formed in the range from 300 to 700 °C. These temperatures significantly exceed the working temperature of the cutting coolant components. This leads to the decomposition of the organic component of the coolant and the entry of chemical pollutants into the air of the working area [7, 8].

The Department of Engineering ecology and life safety of MSTU "STANKIN has developed a special installation, the block diagram of which is shown in figure 1.

The installation allows you to simulate the process of thermal destruction and includes a power source-1; a voltage regulator (laboratory transformer) - 2 ; a heating element - 3 (temperature range from 0 to 750°C), a dispenser - 4 to provide a metered cutting coolant supply (the liquid used is Rossoil-500), including a system of pipes; a container 5 and a control valve.

In the work, studies were conducted on the concentration of hexane, which is formed as a result of thermal degradation of the cutting coolant.

Research results (Figure 2) showed that when the temperature increases in the range from 40 to 330 °C, there is a slight increase in the concentration (C) of hexane in the air, except for the temperature range of 154-218 °C. there is a significant release of the chemical substance into the air of the working area (chemical resonance).

This is due to the fact that the organic component of the coolant has a low working temperature (130 °C). When this value is exceeded, the decomposition of the cutting coolant and the selection of saturated hydrocarbons. In the range from 218 to 234 °C, the concentration drops. At a temperature of 234°C or higher, saturation mode occurs, and in the future there is a slight increase in concentration.

As follows from figure 3, the highest sensitivity value is provided when controlling the cutting speed, which can be used in the construction of automatic control systems.

![Figure 2](image2.png)

**Figure 2.** Dependence of the formation of hexane C concentration (mg / m³) on the temperature in the cutting zone.

![Figure 3](image3.png)

**Figure 3.** Dependence of hexane concentration on cutting parameters.
The research results also showed that with increasing concentration of cutting coolant solutions there is a gradual increase in the concentration of hexane at different temperatures.

3. Energy analysis of technological processes of mechanical processing

Problems of energy consumption are the most important economic indicator of the quality of technological processes. They characterize quality indicators that determine the impact of these processes on humans and the environment. The parameters included in the models of energy conversion and transmission systems determine various groups of quality indicators – metrological, economic, environmental, and ergonomic [9,10].

Any equipment for implementing machine-building forming technologies can be represented as a system for converting and transmitting energy. The energy conversion system is an electric motor that converts electrical energy into mechanical energy, and the mechanical energy transfer system is the kinematics of the machine. In each energy system, the conversion and transfer of energy occurs with losses. Loss values determine the efficiency of the machine and characterize various types of waste (heat, vibration, noise, etc.). The presence of these wastes determines the safety and quality of the process.[11,12]

Energy losses during its conversion and transmission characterize the impact of technological processes of mechanical processing on the environment and humans. These losses lead to a large energy consumption in the implementation of technological processes [13].

The essence of energy analysis (Figure 4) is that any technological process of mechanical processing can be represented as two processes. The first is the process of converting electrical energy into mechanical energy, the second is the process of transferring mechanical energy to the processing zone.

Figure 4. Energy representation of the technological process. Where S – power, P – active component of power consumption, Q – the reactive component of power consumption, ∆P – power losses at each stage of conversion and transmission.

The relationship of energy losses with the negative impact of technological processes on the environment and humans allows us to form a comprehensive safety indicator.

It is the loss of energy during transmission to the processing zone that forms electromagnetic waste – the conversion of electrical energy into electromagnetic energy; thermal waste is the conversion of mechanical energy into thermal energy; chemical contamination-conversion of mechanical energy into chemical contamination; noise and vibration waste-converting mechanical energy into noise, etc. (Figure 5) All this leads to contamination of the working area, the emergence of dangerous and harmful production factors.
Figure 5. Formation of production waste during the implementation of technological processes.

Ensuring the safety of the production environment is implemented by a security specialist or environmental engineer in close contact with specialists of other profiles (designer, technologist, automation specialist, and others). It is their joint work that allows us to implement the basic principle of ensuring safety – to eliminate dangers to humans and the environment directly at the source of occurrence. This is ensured through designing, technology, automation and environmental safety.

Energy consumption in the implementation of technological processes determines their energy efficiency and is an important component in the formation of a comprehensive safety indicator [14].

Thus, the problem of comprehensive assessment of the impact of technological processes of mechanical processing on the environment and humans can be solved. Using the energy representation of these processes allows you to compare the cutting power with the power consumed by the process equipment. This makes it possible to create a comprehensive safety indicator.

The complex impact of technological processes on the environment and humans is caused by energy losses and overestimated values of consumed currents. An urgent problem is the formation of sound technical solutions aimed at improving the safety indicators of technological processes of mechanical processing [15]. Solving this problem can have great social and economic effects.

References

[1] Ivanova N A, Ryabov S A, Shvartsburg L E 2015 The reduction of energy consumption of technological processes with application of the liquid lubricant-cooling technological substances. Life safety No 6 (174) pp 47-49

[2] Egorov S, Kapitanov A, Kozlova A 2020 Application problems of process capability evaluation methods in modern quality assurance systems. IOP Conference Series: Materials Science and Engineering, Vol 709(3), 033054

[3] Kostenko A, Mikhaylov A, Pichko N 2019 Technological process structure of parts manufacturing of ship diesels in using function-oriented methods of finishing and hardening treatment. Materials Today: Proceedings, Vol 19, Part 5, pp 2213-2217

[4] Kapitanov A, Mitrofanov V 2019 Book Chapter. General principles and design strategy of optimal reconfigurable manufacturing systems Lecture Notes in Mechanical Engineering, 0(9783319956299), pp1347-1353

[5] Huang Z, Yu Q 2019 Surveillance efficiency evaluation of air quality monitoring networks for air pollution episodes in industrial parks: Pollution detection and source identification. Atmospheric Environment Vol 215, 116874

[6] Ivanova N A, Ryabov S A, Shvartsburg L E 2015 Environmental compatibility assessment of manufacturing processes on the base of their integral ecological parameter. Bulletin of
mechanical engineering, Vol 9 pp 36-38

[7] Shvartsburg L E, Ivanova N A, Ryabov S A 2014 Zaborowski T Chemical contaminations in a process of polishing with an implementation of liquid LCTS. Life Science Journal Vol 11(10s) pp 228-230

[8] Kuznetsov V A, Cherepakhin A A, Volkov R B 2020 Wear and Microcrack Formation in the Machining of Medium-Carbon Bearing Steels Russian Engineering Research, Vol 40(9), pp 789-792

[9] Chester L, Elliot A 2019 Energy problem representation: The historical and contemporary framing of Australian electricity policy. Energy Policy, Vol 128, pp102-113

[10] Liang J, Wang Y 2019 Energy efficient production planning and scheduling problem with processing technology selection. Computers & Industrial Engineering, Vol 132, pp 260-270.

[11] Acar C, Dincer I 2018 4.30 District Energy Conversion Systems. Comprehensive Energy Systems, Vol 4, pp 1159-1233

[12] Dunlop T 2019 Mind the gap: A social sciences review of energy efficiency. Energy Research & Social Science, Vol 56, 101216

[13] Zaborowski T, Shvartsburg L, Ivanova N, Ryabov S 2018 Ecoenergetics cutting techniques. Management and Production Engineering Review. Vol 9, Number 4, pp 70-75

[14] Maiorano J 2019 Towards an uncertainty theory for organizations: Energy efficiency in Canada’s public sector. Energy Research & Social Science, Vol 54, pp185-198

[15] Ivanova N A, Ryabov S A, Shvartsburg L E, Zaborowski T 2019 Selection of Best Available Machining Technologies in Terms of Energy Efficiency. Russian Engineering Research, Vol 39, pages 1093–1095