

# CUTTING TOOLS AND THEIR DESIGN FEATURES: FROM THE POINT OF VIEW OF ARTIFICIAL INTELLIGENCE

**Aydın Heydarov**

Azerbaijan Technical University, Baku, Azerbaijan

## ABSTRACT

Cutting tools are fundamental components in manufacturing and engineering processes which are essential for shaping, cutting, and decided materials like metal, wood and composites. The design of these tools calls for a delicate balance between choice of materials, geometry and performance criteria whose parameters are tailored. The emergence of artificial intelligence (AI) has turned this world all upside down. AI first uses machine learning algorithms to analyze large quantities of data about material properties, wear resistance, or cutting conditions leading to new tool designs for a given material. In addition, AI also allows real-time monitoring during machining and with adaptive control. It can improve precision as well as reduce tool wear by selecting the right speed when cutting, while slow down results in prevention of damage. Furthermore, AI-driven simulations have enabled engineers to simulate and optimize tool design in virtual environments prior to physical production. AI will continue to advance in the future holds out the promise of decreasing still further the cost and improving the performance characteristics of cutting tools. It is the combination of AI and cutting tool design to gain maximum benefits of this innovation while minimizing costs for now in the future.

**Keywords:** Cutting Tools, Design Features, AI, Engineering Technology

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## INTRODUCTION

Cutting tools are at the heart of shaping materials in engineering technology. It is through these tools that precision and efficiency are achieved. Therefore, the design and selection of cutting tools determine to a great extent the quality and cost-effectiveness in production of parts. Then came the rapid development of materials science and engineering, as well as their fast iteration; under these conditions people would often rely on experience or familiar principles from other fields such as mechanics for their value judgments. But now artificial intelligence means an entirely new direction in innovation. This shows for the first time in human history that we can use technical means to improve on design objectives within all areas of life including computer applications and Web-enabling device features.

AI also brings with it a refreshing new direction for the functionality and application of cutting tools. It offers revolutionary opportunities to improve both like never before. AI has the potential to completely change how cutting tools are designed and used in engineering technology. The number of tools available for coupling with this technology grows as the intelligent machines can analyze large amounts of data, be familiar with pattern recognition and analyses complex situations to make accurate predictions. Using machine learning algorithms and neural networks, we can now anticipate tool wear, optimize cutting parameters, and even design cutting tools specific to an application.

This shift from traditional ways of doing things to an AI-driven approach not only increases the efficiency of work but also opens up new possibilities for creating cutting tools that are more durable, more precise and more versatile. AI's function in cutting tool design extends further than mere optimization. Real-time data integration via smart sensors not only allows for adaptive tool control but also makes it possible to predictively maintain tools so that they operate at peak efficiency. This is preventative, preventative maintenance: it reduces downtime, lowers costs- and helps to elongate lifespan of equipment as well. Furthermore, AI can help

to simulate highly complex cutting processes, thus allowing engineers to anticipate problems that might arise and make informed decisions before physical models are even created.

The development of this technology will undoubtedly bring huge advances across many industries where cutting and splitting materials (engineering sciences) are used extensively. The application of AI in cutting tool design is also closely related to the rise of Industry 4.0 and intelligent manufacturing. As factories become more closely intertwined and automated, there is an increasing need for highly-intelligent tools that can communicate with the machines to which they are being applied.

AI-operated cutting tools therefore represent a prerequisite for the future of manufacturing, where precision and efficiency but also agility are of paramount importance. Based on this general framework, the following sections are designed to provide a closer look at tools and tool design features from an AI perspective.

We will examine all the way in which it changes our accustomed ways of thinking about tool design and how this is reflected through improved performance and cost-effectiveness. And finally, we shall address challenges faced by those also striving to learn from robots: how to make possible the full application of such knowledge. Through our exploration, we hope to provide a comprehensive understanding of how AI is reshaping the future of cutting tools in engineering technology and what it means for industry as a whole.

### LITERATURE REVIEW

The prepared article by **Abdul Wahab Hashmi, Harlal Singh Mali, Anoj Meena, Irshad Ahamad Khilji, Mohammad Farukh Hashmi, Siti Nadiyah binti Mohd Saffe in 2022** discusses new trends seen over the past decade and rapid advances in AI and smart manufacturing. By pointing out thus, they suggest to focus on efficiency and cost effectiveness when manufacturing technology advances into the more forward stages. The article discusses how traditional activities such as manufacturing or processing need to be combined with AI hardware and software the latest machinery.

It is particularly interested in what interaction there might be between cutting tools and AI design tricks from this perspective. Other issues discussed in this study include AI-based manufacturing applications, how to implement them and the present state of smart manufacturing manufacturing. In summary, this paper focuses on how to optimize cutting tool design with a view to engineering technology, through AI (Hashmi, Mali, Meena, Khilji, Hashmi, Saffe, 2022).

**Wenchao Xiao, Jianghua Huang, Baoyu Wang, and Hongchao Ji's** systematic review examines the role of artificial intelligence (AI) in tool breakage detection during machining. Due to its potential in this area, however, the study points out that few AI models have been actually put to use in manufacturing environments. Review learned that 9 of the 21 articles are qualitative and 9 are quantitative model, Support Vector Machine (SVM) was used in most cases as an AI model; cutting force the signal most often used for input. The report concludes that AI can show good accuracy in detecting tool breakage. Nonetheless, more real-time experiments under various cutting conditions are needed to close the gap between research and reality (Xiao, Huang, Wang, Ji, 2022).

The main conclusion of next article by **Weam A. Al-khaleeli, Mazin Al-wswasi** is to emphasize the success of the proposed method in automating machining process, especially for rotational parts. Based on the technology of features, this study finds it both more effective and flexible to choose algorithms for Automatic Feature Recognition (AFR) than CAD/CAM. The system, by combining the stages of design and manufacturing, may indeed automatically select processes of lathe operations, decide on proper cutting tool and condition, generate G-code for machining.

The use of C# programming in building the system supported knowledge representation on 14 predefined final features as well as various intermediate features. It not only helped to produce tool paths but also reduced human intervention, mistakes and production costs in general.

The method was then verified through both simulation and practical experiment, and the results were satisfactory and came as expected, showing the potential for automation to enhance manufacturing pilgrimage (Al-khaleeli, Al-wswasi, 2024).

### METHODOLOGY

In the field of engineering technology, cutting tools act as a vital factor in manufacturing processes such as milling, turning, drilling, and grinding. They not only have a direct bearing on the efficiency, accuracy, and precision of machining operations but in some cases also determine the quality and performance of machined components. Traditionally cutting tool design rested heavily on empirical methods, pairing its development with an extensive series of experiments. But the recent application of artificial intelligence is pushing the frontiers of this area, providing greater precision more efficiently and with new innovative approaches to tool design. The article explores how AI-based methodologies are revolutionizing cutting tool research and design, chronicling Representative techniques and their implications for the industry.

### 1. AI-Enabled Design Optimization

AI's greatest contribution to the design of cutting tools lies in its capacity to optimize tool geometries as well as their choice materials. Genetic algorithms (GAs), which are inspired by natural selection, possess such features. GAs gives a population of potential tool designs a series of iterations one after another, so the best-performing individuals may be selected consistent with such criteria as tool life, cutting force or surface finish. Adopting this evolutionary strategy allows us to explore complex design spaces, providing optimal configurations to be found that otherwise might not yet even have been discovered by conventional methods.



**Figure 1:** AI-Enabled Design Optimization

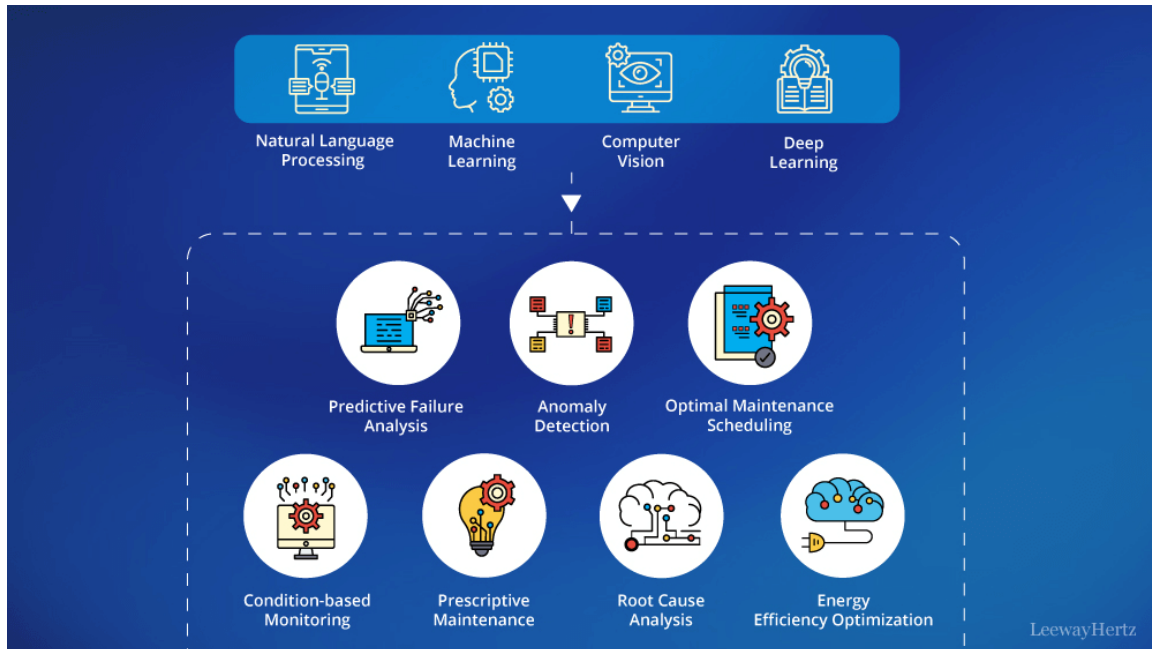
Source: Neural Concept, 2024

A further optimization technique is simulated annealing, which simulates the process of annealing in metallurgy. By exploring the design space and making probabilistic changes in those cases where exploration has lain everything fruitful for this problem can extend toward near optimal solutions, simulated annealing can help find better values for cutting tool designs. Such methods are capable of significantly upgrading tool performance by juggling tradeoffs among different design parameters like tool sharpness, durability and cost.

### 2. Predictive Maintenance and Performance Monitoring

AI can also play a vital role in predictive maintenance and performance monitoring for tools of cut. For example, machine learning algorithms may analyze large amounts of sensor data collected from machining equipment. Regression analysis, for instance, can anticipate tool wear and failure based on operating conditions plus historic materials collected over time from monitoring instruments. When one has some indication of when a particular tool is likely to fail or begin losing power, with this data in hand manufacturers can plan ahead and thereby minimize downtime costs while avoiding an expensive shutdown.

Further, a classifier on data types that come out of cuts—good or bad performance—is also needed. This new function permits precise diagnosis and helps make possible the development of tailored solutions which relate directly to specific problems. By working with AI, manufacturers are able to go from being merely exhaustive in terms of maintenance to creating entire new strategies; overall productivity is improved &, finally, operating costs are dramatically reduced.



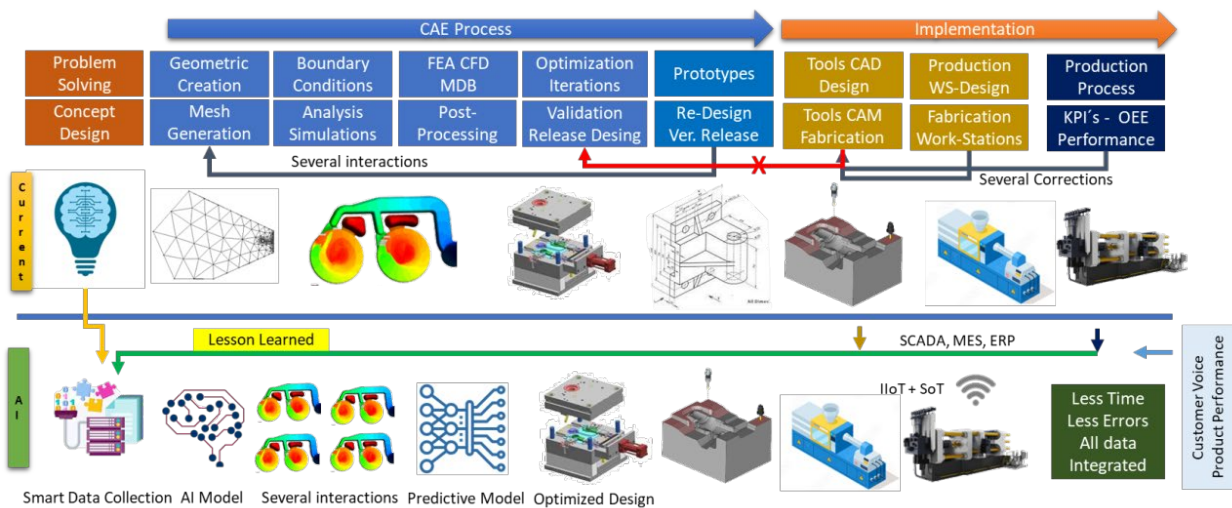
**Figure 2:** Predictive Maintenance and Performance Monitoring

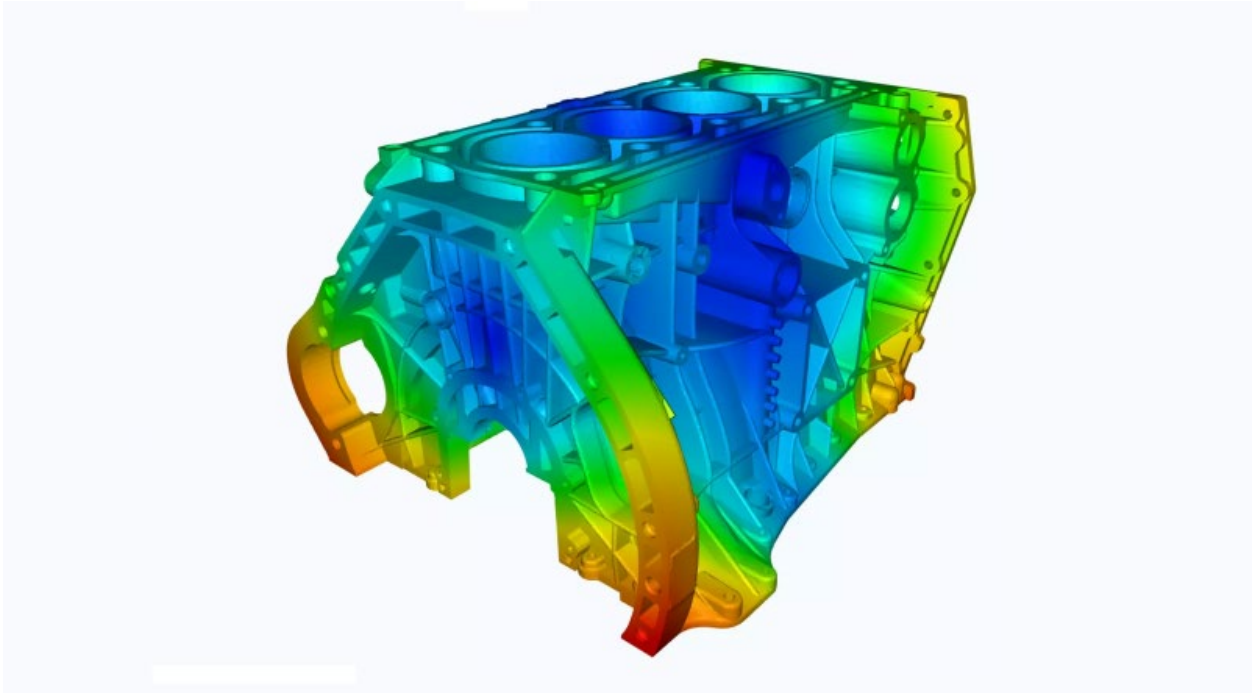
Source: LeewayHertz. 2024

### 3. Enhancing Tool Design through Simulation and AI

Machine learning can also improve product simulation and arrange tests about the best pre- design of cutting tools using artificial intelligence. The techniques of correlative machine revolutionizing AI—neural networks and deep learning in particular—can now permit models to consider the extremely intricate relations between cutting parameters (Rampur, 2017).

#### AI-Powered Role: Concept, Design, Simulation, and Manufacturing Product for Time-to-Market Success."





**Figure 3:** Enhancing Tool Design through Simulation and AI

Source: Octavio, 2024

These models will simulate many different cutting scenarios, allowing us to see in exact detail how various designs perform under each condition. By simulating these processes ahead of time, the process of fine-opening designs before any physical prototypes have been made also lowers expenditures and leads to quicker results.

### DISCUSSION

Above figures show how AI can improve the design and production of cutting tools—which are key for engineering technology. Here is an Ai-driven process broken down by steps:

With Ai, tool designs can be generated from specific requirements such as material, cutting speed and finish desired. Tool geometries, rake angles and dropout clearances can all be optimized to improve tool life and cutting efficiency by Ai algorithms (Ismail, 2005).

Ai can automate FEA simulations to predict and demonstrate tool performance under various conditions of stress, strain temperature etc.

Coolant flowing around the tool can be simulated by Ai, so as to optimize cooling and get rid of chips.

Artificial Intelligence can optimize CAM (Computer-Aided Manufacturing) programs for minimal machining time and tool wear. AI can analyze sensor data to predict tool wear and failure, enabling proactive maintenance and reducing downtime.

Artificial Intelligence can look for the optimal tool configuration in a vast design space. Artificial Intelligence can iterate designs quickly based on simulation results and feedback from manufacturing.

Artificial Intelligence can control CNC machines (Computer Numeric Control) to get tool paths and tolerances right on the button. Artificial Intelligence can manage tool use, conditions in which it is not functioning correctly and the entire maintenance history to keep inventory at an optimized level and reduce costs.

Artificial Intelligence can gather and analyze data from various sources. Sensors, machines and manufacturing processes all provide useful cues to AI. Artificial Intelligence works out future trends such as tool wear or process variations by using historic data.

Key Benefits of Ai in Cutting Tool Design and Manufacturing:

Artificial Intelligence can optimize tool design, manufacturing processes, and maintenance to boost productivity. Artificial Intelligence can help create tools with outstanding cutting performance, longer life and better surface finish. Artificial Intelligence can help reduce costs by optimizing material usage, minimizing downtime, and improving the efficiency of processes.

By automating design, simulation, and manufacturing processes, AI can trim the development cycle. In conclusion, AI is revolutionizing the design and manufacture of cutting tools by achieving more efficient and effective seductions. With AI, the engineer may produce tools that are better tailored to specific applications, cut back on manufacturing costs and he has a greatly improved product to sell as well (Yusof, Latif, 2014).

As a conclusion, the melding of artificial intelligence into the invention and design of cutting tools is a major advance made possible by engineering science. Using AI methods such as genetic algorithms, simulated annealing, machine learning and networks, manufactures can both optimize tool designs and anticipate maintenance requirements at once. This should give them a significant edge over the competition. As AI continues to mature, the influence of cutting tool technology is bound to expand also. Responding to these changes means more imaginative & efficient manufacturing options in the future. How to seize these opportunities will be crucial to survival in an increasingly challenging business world.

### CONCLUSION AND RECOMMENDATION

There is a potential beyond the elementary in the interface of machine tools and artificial intelligence hand represents an entirely new stage engineering process. As AI technologies continue to mature, the addition of intelligent capabilities into the design and use of cutting tools can bring huge benefits such as well efficiency improvements and greatly enhanced precision. This makes for a silk-stocking conclusion through the combination of looking into cutting tools' design features with AI perspective. It shows how they are altering this discipline afresh.

Machine learning algorithms based on AI and data mining have fundamentally changed the way cutting tools are designed, produced and used. Utilizing large datasets and predictive models, AI can offer real-time understanding of tool wear, cutting conditions and material interactions. Consequently, tools with optimized geometries and materials increase precision significantly while waste declines markedly. For example, AI systems can predict tool failure in advance and suggest preventive measures to take. In this way they sharpen overall efficiency and reduce downtime in manufacturing processes.

A significant achievement of AI technology for cutting tool manufacturing is the creation of a series adaptive tooling systems. Making use of immediate data, these systems adjust cutting parameters continuously so they can function well under different circumstances. AI algorithms interpret feedback from sensors on the cutting tools and make instant adjustments, raising product quality and extending the useful life of these machines as well. This flexibility means not only an increase in output per hour -; it also allows for handling more work at different times and in diverse ways.

By following the conditions and points of wear of tools, AI can predict possible problems before they occur. This allows for proactive maintenance and reduces the risk of unexpected failure. This predictive approach helps to oversee the life cycle of cutting tools much better, adjust their use but realize the minimum cost of maintenance. The introduction of AI into life cycle management systems also means that tools will take full advantage of its capacity, thus improving overall operational efficiency.

Generative design algorithms, driven by AI, can create complex tool shapes that would be difficult to conceive on one's own. These algorithms consider many factors such as material properties, cutting conditions and production constraints to come out with the optimum design. Additionally, AI allows increasingly personalized cutting tools for specific applications, so that highly specialized tools tailored to unique operational requirements are possible.

Machine vision systems driven by AI can accurately check cutting tools and discover any defects or deviations from the design drawing requirements. This level of accuracy in quality assurance means that only tools which meet strict standards got through to production operations, thus enhancing the overall reliability and performance of the entire manufacturing enterprise.

We expect that AI will be integrated into cutting tool technology further in the future. Overcoming difficulties and taking advantage of new trends – autonomous manufacturing systems, advanced robotics. Since these have yet to gain common acceptance that is an uphill struggle. Ensuring that each stage of machine control

from the acquisition and processing of data to job scheduling and process monitoring can stand scrutiny is another issue. The problems that will have to be considered include data security and the need for large quantities of high-quality data — as well as difficulties integrating AI with existing manufacturing facilities.

In conclusion, the introduction of AI into cutting tool production and manufacturing represents a great leap forward for engineering technology. Artificial intelligence, by raising the level of accuracy and efficiency in general and in specific will open up new possibilities in cutting tools. It is changing the whole field of cutting tools, contributing to greater convenience precisely machines can be adjusted conveniently in production processes. As AI technology continues to develop the scope of its impact on cutting tools and engineering will expand even further, offering new possibilities for advancing results in these areas.

### Recommendations

1. Based on the integration of artificial intelligence (AI) into the investigation and design of cutting tools, several recommendations can be made to further enhance the application and benefits of these technologies:

2. Organizations should invest in training programs for engineers and designers to understand and effectively utilize AI tools and methodologies.

3. Foster interdisciplinary collaboration between AI experts and cutting tool engineers must address complex design challenges.

4. Regularly it must be updated AI models and algorithms based on new data and emerging technologies.

By adopting these recommendations, organizations can enhance their cutting tool design and investigation processes, leveraging AI to achieve superior performance, efficiency, and innovation in manufacturing technology.

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#### ABOUT THE AUTHORS

Aydın Heydarov, email: [aydinheydarov7@gmail.com](mailto:aydinheydarov7@gmail.com)

**PhD candidate Aydın Heydarov** Doctoral student of Azerbaijan Technical University. He is currently working as a Quality Control Inspector at the Baku Food and Oil Factory (AZERSUN Holding).