Comparison of diagnostic tools for cutting tools for the utilization of aerospace composite materials

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Abstract. The article discusses the comparison of diagnostics of the cutting tool for utilization of composites of aerospace engineering. The paper presents the results of classical, traditional diagnostic methods and ultra-jet method. The article concludes with the advantages of ultra-jet diagnostics.

1. Introduction
At present, polycrystalline composite materials (PCM) are increasingly used in the global industry. The leaders in their application are the aerospace technology industry. The analysis showed that by 2030 relative to 2015, the volume of PCM production will increase by 2 times or more. In the future, recycling PCM will be a hot issue. This will require the development of new methods and tools that will effectively implement the issues of PCM disposal. All existing and used methods of physical, thermal and chemical processing of PCM require preliminary processing of PCM, which consists in grinding these materials. Thus, at the first stage of PCM utilization, mainly mechanical rotary crushers are used. At present, these installations use monolithic knives made of 6XM2C steel. These knives have a number of comments from technologists of enterprises on: temporary resource, wear resistance and their value [1]. Analysis has shown that it is possible to reduce these drawbacks by switching to the manufacture of bimetallic knives. For industrial testing, four types of bimetallic knives “9HF Steel - Steel 3” were manufactured for various hardening and tempering modes.

A related issue is the choice of diagnostics of operating properties of a bimetallic tool. Ultra-jet technologies have found wide application for solving various problems [1]. An independent and significant place in the list of these technologies is taken by ultra-jet diagnostics, the main advantage of which is the prompt receipt of the necessary information about the operational and technological parameters of the state of the surface layer of material of various technical objects. In addition, the
ultra-jet effect in a technologically achievable degree is similar to the actual operating conditions of various kinds of technical objects and devices [2-5].

2. Ultra-jet diagnostics

Thus, the surface layer of the object of diagnostics will be exposed to a hydrocontact interaction that simulates real operating conditions, for example, a hydroabrasive effect.

In the implementation of ultra-jet technology, up to their time, two types of liquid jets were used: a high-speed ultra-jet with a power flux density of ~ 0.5 MW/mm² and an ultra-jet suspension consisting of a liquid (water) and an auxiliary material of a given concentration: an abrasive material.

The schematic diagram of the ultra-jet diagnostic process using the modified powder of the polymer is represented in figure 1.

![Schematic diagram of the ultra-jet diagnostic process using a water-polymer ultra-jet of liquid (water).](image)

Polyamide-12 powder used in the technology of selective laser alloying was used as a modifier.

The ultra-jet diagnostic experiment with the use of a modified ultra-jet (water-polymer ultra-jet) was carried out using a Flow System (USA) plant for waterjet cutting materials, Flow Mach 3 model at the Hydrophysical Research Center of the Physical Faculty of the Moscow State University. Lomonosov. The pressure in the system was P = 400 MPa, the distance from the cut-off focusing tube to the knife surface h = 4 mm, the feed speed of the nozzle head S = 0.41 mm/s, the concentration of polymer powder with = 0.2 kg/min. As a result of the implementation of the ultra-jet diagnostic procedure, a hydrocavity was formed on the surface of the sample (knife), the geometrical parameters of which were determined using a BV-7669 profilometer (manufactured by the Research Institute Measurements, RF).

Knives for a PM250 rotary crusher (manufactured in China), made of bimetal (steel 3 (base) - 9HF), produced at the Research Institute of Pulse Processes with a pilot production “SRI IP with OP” (Minsk, Republic of Belarus).
In figure 2 shows the studied batch of knives manufactured according to different technological conditions.

3 + B - quenching 840 C, cooling in a stream of water; 3 + B + O - quenching 840 C, cooling in a stream of water, tempering 160 C, 2 h; 3 + M - quenching 880 C, cooling in oil; 3 + M + O - hardening 880 C, cooling in oil, tempering 160 C, 2 h.

Figure 2. Bimetallic knives produced by “Scientific Research Institute of Industrial Enterprise with OP” (Minsk, Republic of Belarus).

The study of the microstructure was carried out in the Research Institute of Individual entrepreneurs with an OP (Minsk, Republic of Belarus) using a Meicher-3 microscope Reichert (Austria) with an increase of 50, 100, 500. Grain size was determined according to GOST 5939-82 “Steel and alloys. Methods for identifying and determining the size of the grain.

Microhardness was measured on a Micromet II microhardness meter with a load of 500 g according to GOST 9450-76.

3. Comparison of various diagnostic methods
At the next stage of the implementation of the methodical work plan, the task was to conduct comparative comparative studies of various diagnostic methods to assess the adequacy of the proposed method of water-polymer diagnostics. For these purposes, friction tests on a friction machine and field tests on industrial equipment were considered.

To carry out industrial (full-scale) tests, four sets of bimetallic knives "9HF steel - steel 30" (figure 2) manufactured according to various technological conditions were transferred to "Astreati" LLC. The work was carried out on the processing (grinding) of defective polypropylene structures. Bimetallic knives were installed in a PM250 rotary crusher (manufactured in the PRC) together with standard knives of 6XВ2С alloy. The operating time of the cutting tool was 160 hours. (figure 3).

As informative parameters of wear of the cutting edge of the knives were selected: the change (increase) of the radius of rounding, the change of the rake angle, and the number and area (ablation of the material) of the chips to the length of the cutting edge of the tool. All of these parameters undergo noticeable changes during the operation of the tool, first of all it is about shedding and chipping the cutting edge of the knives.

The calculation of the area of chips along the cutting edge of the tool was carried out using the Gwidion modular data analysis program.
Figure 3. Impact crusher (a) model PM250 (manufactured in China) and a cutting tool mounted in the rotor of the installation (b).

Friction tests were carried out using developed at the department SM-12 "Technology of rocket and space engineering" BMSTU installation for friction testing (figure 4).

Figure 4. Schematic diagram of the installation for friction testing.

The impact on the surface of the material of the knife was carried out using a carbide ball mounted on a cylindrical shaft. Contact load was 0.2 kg and was determined by the mass of the rod. The absence of additional mass is associated with the need to ensure sufficiently free relative movement of the indenter (ball) and tool.

As a result of the diagnostics of each cutting tool sample, the profiles and depths of the cavity were determined. To measure the microgeometry of the cavity profile, a KEYENCE VHX6000 digital optical microscope was used, with a KEYENCE VH-Z500R high resolution lens installed. X500 increase.
All the obtained informative parameters of full-scale and friction tests, ultra-jet water-polymer diagnostics are presented in table 1. In table 2 presents the pairwise correlation values of all considered in table 1 informative parameters

**Table 1.** Results of processing the results of all tests of the cutting tool.

| Option technology manufacturing knife (marking) | 3+B | 3+B+O | 3+M | 3+M+O |
|-------------------------------------------------|-----|-------|-----|-------|
| Radius of cutting edge rounding, mm             | 0.19| 0.29  | 0.25| 0.21  |
| Change in rake angle, degree                    | 0.70| 7.37  | 7.30| 2.84  |
| The number of chips per unit length of the cutting edge | 0.05| 0.22  | 0.19| 0.16  |
| The ratio of the area of ablation of the cutting edge to the length, mm | 0.31| 0.48  | 0.47| 0.42  |
| Hydrocaval depth                                | 21.95| 98.57 | 81.66| 67.24 |
| The depth of the cavern of the friction test, micron | 2.80| 8.23  | 4.84| 3.73  |
| Microhardness, MPa                              | 8379.50| 5978.50| 5649.40| 6216.60|

**Table 2.** Correlations of processing the results of all diagnostics of the cutting tool.

| Correlations | Radius of cutting edge rounding, mm | Change in rake angle, degree | The number of chips per unit length of the cutting edge | The ratio of the area of ablation of the cutting edge to the length, mm | Hydrocaval depth, mm | The depth of the cavern of the friction test, micron | Microhardness, MPa |
|--------------|-------------------------------------|-----------------------------|--------------------------------------------------------|--------------------------------------------------------------------|---------------------|-----------------------------------------------|-------------------|
| Edge rounding radius, mm                        | -                                  | 0.93                        | 0.88                                                   | 0.87                                                              | 0.91                | 0.97                                           | -0.74             |
| Change in rake angle, degree                     | 0.93                               | -                           | 0.91                                                   | 0.94                                                              | 0.92                | 0.81                                           | -0.79             |
| The number of chips per unit length of the cutting edge | 0.88| 0.91  | -                          | 0.99                                                   | 0.99                | 0.81                                           | -0.95             |
| The ratio of the area of ablation of the cutting edge to the length, mm | 0.87| 0.94  | 0.99                       | -                                                      | 0.99                | 0.77                                           | -0.95             |
| Hydrocaval depth, mm                            | 0.91                               | 0.92                        | 0.99                                                   | 0.99                                                              | -                   | 0.85                                           | -0.95             |
| The depth of the cavern of the friction test, micron | 0.97| 0.81  | 0.81                       | 0.77                                                   | 0.85                | -                                              | -0.68             |
| Microhardness, MPa                              | -0.74                              | -0.79                       | -0.95                                                  | -0.95                                                             | -0.95               | -0.68                                          | -                 |
4. Conclusion

On the basis of the data obtained (table 1, table 2), it can be noted that the ultra-jet diagnostic method is highly informative, and its efficiency is higher than the traditional method of friction testing. The effectiveness of the method is proved by the compliance of the results of field tests and ultra-jet diagnostic. In comparison with the method of friction testing, water-polymer ultra-jet diagnostic has several advantages, such as express speed of the diagnostic process.

It can be argued that the water-polymer ultra-jet diagnostic can be effectively used to assess the performance properties of the cutting tool.

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