Laser processing systems in machines with numerical control

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Abstract. The paper considers one of the ways to expand the technological capabilities of numerically controlled metal-processing machines, in particular vertical machining centers, by integrating a fiber laser system into their body. The combination of laser and machining technology will complement the traditional processes of milling materials with engraving and microstructuring of material surfaces. The use of a concentrated energy flow - laser radiation - as a working tool will not only reduce the costs associated with the wear of a mechanical contact tool, but also move to fundamentally new microprocessing that is used for various products.

1. Introduction
In the modern age the tendency to an increase of the assortment and quality of manufactured metal products is becoming more noticeable, as well as the improvement of the structural, operational and other technical characteristics of products and their surfaces. In this regard, the tasks are to replace obsolete production equipment with modern high-performance machines, in particular with computer numerical control (CNC), which can ensure production competitiveness of many enterprises by improving the quality of products and the production pace. The combination of various integrated systems and standard traditional metal processing equipment opens up the opportunities not only to expand production technological functions, but also to reduce production time, as well as to improve the technological, precision and functional characteristics of a product. An example is a regular micro- and macrorelief, regulation of roughness and microtopology formation on metal surface using a laser after a workpiece processing on the CNC machines.

One of the most promising examples of integrated systems is pulsed fiber laser sources equipped with a scanning beam guidance system. The use of laser systems makes it possible to efficiently perform additional macro- and micro-processing of material surfaces directly at the stage of manufacturing parts, as well as to refine these surfaces to the necessary technological requirements.

2. Methods and materials
On the issue of integrating a laser system into a machining center.
It is known that one of the tools for metal surface treatment is laser radiation. However, the laser systems, as well as the CNC cutting machines, in particular multi-operation machining centers, are not universal equipment for processing materials. This is due to the fact that the machining centers are limited by their own technical characteristics, such as a moving speed of a milling table, a rotation speed of a spindle, etc., as well as the geometric characteristics of a tool. Moreover, the expansion of the technological capabilities of the CNC machines is possible, both by improving their control systems [1], and by
introducing new technological laser blocks, units and entire systems into their body. In turn, one of the
drawbacks of the laser systems is the locality of their impact on material, which requires much time
when large areas are under processing. However, at the same time, the size of a laser radiation waist is
on average 30 ... 50 microns. (according to the data presented on the manufacturer's website), which in
turn allows to complement the traditional technological process of processing workpieces with cutting
on the CNC machines with surface microprocessing.

In fact, at the same machining center, along with the traditional methods applied to processing
workpieces made from various materials by a cutting method, there will be available such types of laser
processing as marking, surface finishing, creating a gradient surface structure through laser radiation,
creating various complex contour regular surface microtopology, 3D engraving-reliefs, ceramic
processing [2,3], macro- and microstructuring of a surface layer, carbon fiber cutting [4], surface local
oxidation (decorating), perforation, local thermostrengthening welding steel sheet [5], metallization,
providing storage information on the workpiece surfaces due to the application of micro-dot-and QR-
codes used in information technology, digital production and others [6, 7, 8, 9, 10, 11]. The laser head
can be used to apply local physical effects [12, 13], which greatly facilitates the removal of metal from
a workpiece with a tool equipped with cutting ceramics [14, 15, 16]. In the future, it is possible to use
the laser system for microstructuring complex surfaces, excluding the process of preliminary preparation
of a tool for finishing transitions [17].

The combination of the laser system and the machining center (MC) with the CNC will contribute to
the emergence of single-stage multi-operational processes.

3. Some features of fiber laser system integration into machining center

To integrate a fiber laser system into a machining center, a CNC vertical milling machine is preferred
since the laser beam control system is designed for vertical positioning. The steady tendency, which has
been observed at the Russian market, relating to decreasing of serial production towards small-scale and
single-unit types has led to the fact that most industrial enterprises purchase the CNC machines when
upgrading the equipment fleet, the adjustment and direct maintenance of which are carried out by a certain
amount of specialists. Enterprises with these types of production do not use robotic lines or sections in
which industrial robots would automatically change workpieces or additionally process the surfaces of
workpieces with a tool mounted on the robot's arm. That is, under these conditions, in order to realize
the possibility of using a laser head on a CNC machine, it is necessary to partially or completely
modernize the laser head frame and adapt it for manual installation in the machine spindle by an operator
or a preset person.

Fig. 1 shows an example on how to use a tool cone to install the laser head in a CNC machine. A
diagram of the laser head integration into the machining center, developed with using a circuit diagram
of a fiber laser setup, presented in [8], is shown in Fig. 2.
When solving the problem of integrating the laser head into the machining center, it is necessary to determine the installation location of the main system unit. Since the control unit of the laser system has a large number of components sensitive to electromagnetic effects, it can not be installed directly into the control cabinet of the CNC system. It can only be placed directly next to the CNC cabinet.

In turn, the laser head should be redesigned so that it can be easily disconnected from the collimator after the work completion. At present due to its design and overall size, the laser head can not be removed to the general tool magazine on a CNC machine, even if the collimator is disconnected. To store the
laser head, it must be removed manually, close the lens and the hole for the collimator with protective covers to prevent industrial dust and cutting fluid. Then, it must be removed to a special for it place.

Fig. 3 and 4 show the examples on how the topology of the lower part of the laser head can be optimized and the collimator fastening and the back wall can be modernized.

**Figure 3.** Example of optimization towards the topology of the lower part of the laser head

**Figure 4.** An example on how the collimator fastening and the back wall can be modernized: before (a) and after (b) modernization
Dividing the entire laser system into two main components (control unit and laser head), you can not only integrate it into most machining centers, but also increase its maintainability. In order to replace some element of the system, it will not need to be completely disassembled. For example, if the laser head fails, you can easily install a similar head without disassembling the collimator.

4. Collimator quick fastening system
To ensure the operational efficiency with the laser system and creation of greater clutch stiffness of the collimator and the laser head, a fundamentally new quick-fastening system was developed, a Bayonet-type system. A similar working principle is used in professional photographic equipment to adjoin a photo lens to a camera. Such a system will make it possible, without an auxiliary tool, to ensure quick coupling and opening of the collimator with the laser head and to preserve the alignment of the laser optical circuit [18]. Also, in the place where the collimator is fixed to the laser head corpse, two groups with electrical contact platforms are placed, which allows removing connectors and plugs from the structure. The system has a safety mechanical button, which will not allow to arbitrarily disconnect the collimator and the laser head without fully pressing it.

5. Further development and research
For the most convenient use of the laser system in the machining center, it is necessary to completely change the system of fastening the collimator to the laser head, since the use of the system with an existing fastening is unfeasible. The development of a new fastening will be made directly with the modernization of the laser head corpse.

After completion of the design and manufacturing stages a laser beam control system will be installed into the corpse, whereas the system operates from an external control unit. For the sequential operation of two systems (a laser control system and a CNC machine control system), it will be necessary to combine them by using an additional software shell. Thus, the laser control system will be waiting for a command to start from the CNC control system, while the machine is operating some tasks (for example, moving to the next position). When the start command is transmitted to the laser control system, the CNC system will be waiting for a return command from the laser to complete its operation.

Next, it will be necessary to carry out testing and exploring, for example, the possibility of putting some marking on conical and cylindrical surfaces, as well as on surfaces of a complex shape.

6. Conclusion
Thus, the integration of the laser system into the existing machining center will expand its functionality and reduce the number of equipment, thereby reducing the cost of electricity and maintenance. Along with this, the spectrum of work in technological processes will grow, in which a laser can be used at the stage of doing the mechanical processing. To achieve a positive result, it is necessary to solve a number of problems considered in this paper.

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