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PROMISING METHODS OF HARDENING AND RESTORATION OF PARTS OF MODERN MECHANICAL ENGINEERING

A. KHABAY
K.I. Satpayev Kazakh
National Technical
University
Almaty, Kazakhstan
E-mail: anar.kh@mail.ru

Abstract. The article assessed the effectiveness of laser surfacing technology designed to restore metal parts subject to high wear, dynamic loads and mechanical influences during operation. Laser surfacing, as a new technology based on the use of lasers and nanomaterials to harden alloys, is an effective method of restoring worn parts or improving the strength characteristics of new mechanisms and machines. This technology allows the material to be precisely applied to the surface of the parts, which ensures high accuracy and quality of restoration. As a result of the use of laser surfacing, it is possible to significantly increase the service life of parts and ensure their reliable operation under conditions of increased operational load. This makes this technology in demand in various industries where high wear resistance and strength of parts and mechanisms are required.

Additionally, laser surfacing is characterized by high efficiency and cost-effectiveness of the parts restoration process. Due to the possibility of using a variety of materials and precise control of the application of a layer of material to the surface, this technology minimizes waste and reduces production costs. Moreover, laser surfacing is capable of restoring not only surface defects, but also improving the mechanical properties of the material, which increases its strength and durability. Thus, the use of laser surfacing in production promises significant benefits, including increased resource efficiency, reduced maintenance costs and improved quality of the final product.

Keywords: strength characteristics of parts, laser surfacing, thermal effects, laser installations, lasers, nanomaterials, life of parts.

Introduction. In modern machine–building production, laser surfacing of metal surfaces using highly concentrated energy sources is a unique and most effective method of surfacing wear-resistant coatings of parts, which allows improving strength characteristics and increasing the life of new parts of mechanisms and machines in the manufacture of parts.

The transience of processes in the affected area, which contributes to the formation of coatings with high physical and mechanical characteristics, the possibility of local processing and other parameters characterizing the methods of laser surfacing of parts, also make it possible to use them in the restoration of critical highly loaded parts laser surfacing technology is a new technology that uses lasers and nanomaterials to harden alloys in various parts.

The process involves modern laser systems equipped with powerful diodes and specialized nozzles. Processing can significantly increase the hardness and wear resistance of the surface and extend the service life of the parts [1].

Materials and methods. With traditional surfacing methods, the base metal is subjected to significant melting and thermal effects, which is a significant disadvantage, because the technology must ensure minimal thermal effect on the part and mixing of the filler material with the alloy of the product. These flaws are almost completely absent from laser treatment – the heating is localized and corresponds to the shape and size of the supplied radiation, and the depth of thermal exposure is limited by an insignificant surface layer, so that the probability of warping (distortion of the shape) of the part is minimized.

Laser surfacing has a number of advantages. The high concentration of energy in the heating spot makes it possible to carry out the process at increased processing speeds.

This, in turn, causes:

- formation of a deposited layer with a low mixing coefficient (0.05 ... 0.15) as a result of slight melting of the substrate;
- minimal thermal effect on the base metal, which is especially important for materials undergoing structural and phase transformations;
- small residual deformations of the deposited parts.

Small deformations, on the one hand, and high performance properties, on the other, create prerequisites for the use of this method not only to obtain special surface properties of products, but also in the manufacture of machine parts. Laser light sources have a number of significant advantages over other light sources:

- lasers are capable of producing beams of light with a very small angle of divergence (about 10-5 rad);
- laser light has exceptional monochromaticity, unlike conventional light sources, the atoms of which emit light independently of each other, in lasers the atoms emit light in concert and the phase of the wave does not experience irregular changes;
- lasers are the most powerful light sources.

In a narrow range of the spectrum, for a short time (during a time interval of about 10-13 seconds), some types of lasers achieve a radiation power of 1017 W/cm^2.

The technology of laser surfacing of parts of mechanisms and machines is produced using a new generation of laser systems, the operation of which is based on the use of powerful fiber-optic lasers and special nozzles. Their main difference is the presence of auxiliary devices that ensure the supply and distribution of additive materials over the surface of the processed product. Welding devices are often used as universal surfacing equipment, which, if necessary, are supplemented with special equipment and devices.

Specialized surfacing equipment is usually classified according to the shape of the surfaced surfaces: for flat parts, for bodies of rotation and for complex profiles.

Additive materials in such installations are applied not only by traditional methods (wire, rods, nozzle spraying), but also using special technologies: spiral laying of the tape, centrifugal distribution of the additive material, etc. In addition, any surfacing unit for massive parts is equipped with a device for preheating the product to a temperature of +500...+700°C [2].

Laser surfacing works on the same principle as powder plasma and flame gas. It also creates a flow of filler material from a powder with metal and flux compounds, only its melting is performed using a focused laser beam.

The main element of laser installations is a special head with a nozzle in which a gas stream heated by a laser is formed, and a powder injector injecting additive powder into this stream (Figure 1). Compared with other types of surfacing technologies, laser surfacing is characterized by high accuracy and stability of technological modes.

The process of laser surfacing of parts consists in applying molten material to the processed product, the surface of which is heated to the melting point, or reliably wetting with a coated liquid metal.

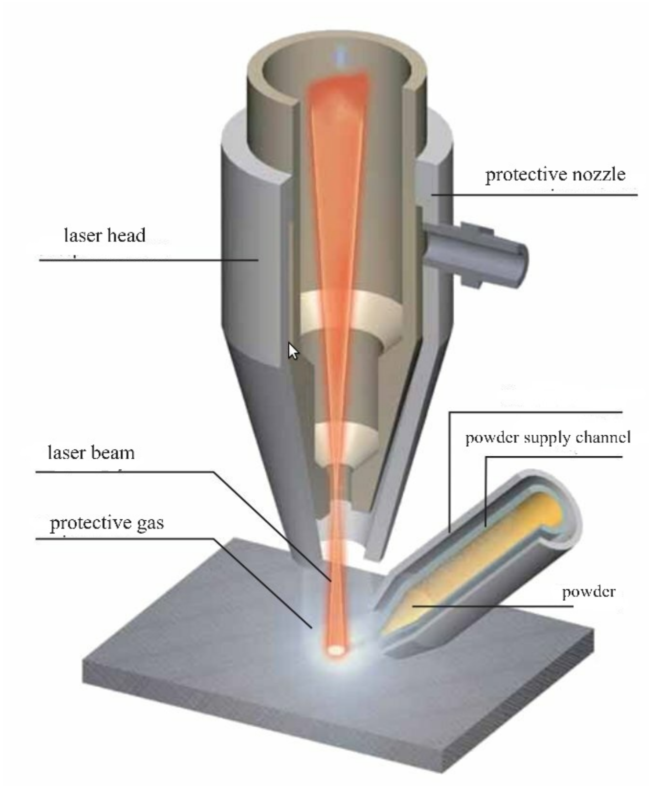

Figure 1-Technology of laser surfacing of a part

A high-power laser beam focuses on the surface of the part, creating a small bath of melt. A metal powder is fed into this area, which melts and creates a new layer. The robot manipulator, which performs surfacing according to a pre-written program, ensures the highest accuracy and speed of the process.

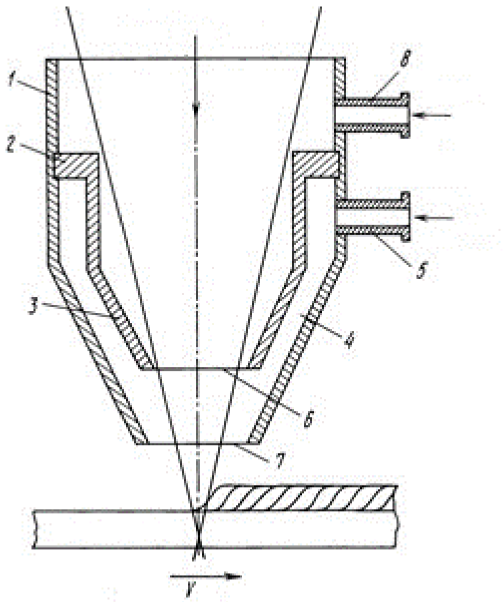

Figure 2 - The nozzle of the laser installation
1 - housing 2 - insert 3 - central opening of the housing
4 - annular gap 5 - pipe , 6 - insert 7 - body section 8 additional pipe

The use of a nozzle (Figure 2) will allow for a uniform supply of powder to the processing zone; improve the quality of coating formation by reducing the variation in the height and width of the rollers along their length; eliminate the ingress of alloying elements onto the external optical system of the laser; shorten the technological cycle by simultaneously feeding the deposited material and melting it [3].

Research results. Practically all the fundamental technical differences between the technology of electric arc surfacing and pulsed laser surfacing are the result of the fact that the arc is a concentrated welding energy source, and the laser beam is a highly concentrated energy source.

The concentration coefficient of an electric arc is approximately 1.0 x 101 cm^2, the effective radius of its heat source is 3.0 x 10-1 cm, and the laser beam is 3.0 x 106 cm^2 and 6.0 x 10^{-4} cm, respectively.

The power densities created in the processing zone during arc surfacing are ~ 102 W/cm^2, and with pulsed laser surfacing, in thermal conductivity mode, 104-105 W/cm^2, such a large difference leads to a heating rate in the melting zone with a laser beam of 104-105 degrees/sec, which minimizes the zones of thermal influence. Thus, pulsed laser surfacing, in comparison with electric arc surfacing, is characterized by minimal melt volumes, zones of thermal influence and, accordingly, significantly smaller transverse and longitudinal shrinkages [4].

A comparative analysis of the surfacing by an electric arc and a solid-state pulsed laser with a wavelength of l = 1.06 microns is presented in Table 1.

Table 1 - Comparative analysis of welding by an electric arc and a solid-state pulsed laser with a wavelength l = 1.06 microns

№	Technical characteristics of the gifts method	Electric arc	The laser beam (l = 1,06 microns)
1.	Effective radius of the heat source of heating	2-3 mm	0,2; 0,3 mm
2.	Zones of thermal influence	Up to several mm	Several tens of microns
3.	Transverse and longitudinal deformations	+	-
4.	Undercuts	+	-
5.	Preheating and accompanying heating	+	-
6.	Subsequent heat treatment	+ -	-

Thermal deformation and mixing with the base material are reduced to an absolute minimum as a result of a strictly limited heating area and controlled laser beam power. A high level of automation of workflow control ensures the regulation of the size of melting zones and thermal cycles. The accuracy of the laser radiation guarantees the formation of a completely dense surfacing layer with a dilution (mixing with the base metal) of less than 5%, and also provides excellent metallurgical adhesion. It is possible to apply several protective layers, which increases resistance to destruction mechanisms.

As a result, a completely dense surfacing layer with excellent metallurgical adhesion is formed, which cannot be achieved with other coating methods (chrome plating, thermal spraying, etc.). The surface layer created in this way forms a single whole with the main alloy [5,6].

The control of the deposited surfaces on the valve plates showed the absence of defects, the appearance of the coatings is similar to that of the simulator samples. The hardness value for the cobalt alloy (Table 2) after laser surfacing exceeds the values given in for the B3K type alloy formed by traditional methods, which must be taken into account in the case of restoration of worn surfaces using laser surfacing. In the case of processing new parts, laser surfacing allows you to significantly save on material, since there is no need to manufacture the product entirely from an expensive alloy. Also, in all cases of using this technology, the service life of the processed components and parts is significantly extended [7,8].

Table 2 - Comparative analysis of the hardness HRC of the surface of the deposited metal

Name of the composition	Surfacing method	Hardness after surfacing, HRC	Release temperature	Hardness after heat treatment, HRC
Powder material based on iron, fraction 63-150 microns	Laser surfacing	38-41	730 °C	51-52
Cobalt-based powder material, fraction 53-150 microns	Laser surfacing	43-45	730 °C	52-54
Bars of the B3K brand	Gas	-	-	41,5-51,5

Discussion. Thus, highly efficient laser technologies have been developed to protect new parts from wear and corrosion, as well as to restore worn and damaged parts. This technology makes it possible to modify, repair and extend the service life of critical frequently worn components of machines and mechanisms that operate in highly abrasive and corrosive environments.

The main advantages of laser surfacing technology:

- controlled small penetration;
- the ability to create thin surfacing layers (up to 0.3 mm);
- high-strength adhesion to the base;
- metered energy;
- possibility of local surface treatment;
- absence of thermal leashes, minimization of the zone of thermal influence;
- the ability to process large-sized parts with a high consumption of surfactant;
- fast heating and cooling of the deposited material;
- possibility of surface modification;
- high degree of adhesion of the deposited material with slight mixing with the substrate.

Conclusion. In conclusion, the conducted research allowed us to conclude about the high efficiency and prospects of laser surfacing technology in the field of restoration and improvement of metal parts subject to wear and mechanical influences. Laser surfacing using lasers and nanomaterials demonstrates significant advantages over traditional recovery methods, providing high accuracy, efficiency and cost-effectiveness of the process. This technology is a promising solution for various industries where it is important to ensure the durability and reliability of equipment. Further development and implementation of laser surfacing in industrial production will reduce maintenance costs, increase the service life of equipment and improve the quality of products, which will make this technology an important element of modern production.

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Анар Хабай

Қ.И. Сәтбаев атындағы Қазақ ұлттық техникалық университеті

Алматы, Казахстан

ЗАМАНАУИ МАШИНА ЖАСАУ БӨЛШЕКТЕРІН НЫҒАЙТУ МЕН ҚАЛПЫНА КЕЛТІРУДІҢ ПЕРСПЕКТИВАЛЫҚ ӘДІСТЕРІ

Аңдатпа. Мақалада жұмыс кезінде жоғары тозуға, динамикалық жүктемелерге және механикалық кернеулерге ұшыраған металл бөлшектерін қалпына келтіруге арналған лазерлік балқыту технологиясының тиімділігі бағаланды. Лазерлік қаптау, қорытпаларды қатайту үшін лазерлер мен наноматериалдарды қолдануға негізделген жаңа технология ретінде, Тозған бөлшектерді қалпына келтірудің немесе жаңа механизмдер мен машиналардың беріктік өнімділігін жақсартудың тиімді әдісі болып табылады. Бұл технология материалды бөлшектердің бетіне дәл жағуға мүмкіндік береді, бұл жоғары дәлдік пен қалпына келтіру сапасын қамтамасыз етеді. Лазерлік балқытуды қолдану нәтижесінде бөлшектердің қызмет ету мерзімін едәуір ұзартуға және жоғары жұмыс жүктемесі жағдайында олардың сенімді жұмысын қамтамасыз етуге болады. Бұл бұл технологияны әртүрлі салаларда сұранысқа ие етеді, мұнда бөлшектер мен механизмдердің жоғары тозуға төзімділігі мен беріктігін қамтамасыз ету қажет.

Сонымен қатар, лазерлік қаптау бөлшектерді қалпына келтіру процесінің тиімділігі мен үнемділігімен ерекшеленеді. Әр түрлі материалдарды қолдану мүмкіндігі және материалдың бетіне жағылуын дәл бақылау арқылы бұл технология қалдықтарды азайтуға және өндіріс шығындарын азайтуға мүмкіндік береді. Сонымен қатар, лазерлік қаптау тек беткі ақауларды қалпына келтіріп қана қоймай, сонымен қатар материалдың механикалық қасиеттерін жақсарта алады, бұл оның беріктігі мен беріктігін арттырады. Осылайша, өндірісте лазерлік қаптауды қолдану айтарлықтай пайда әкеледі, соның ішінде ресурстарды пайдалану тиімділігін арттыру, техникалық қызмет көрсету шығындарын азайту және соңғы өнімнің сапасын жақсарту.

Кілт сөздер: бөлшектердің беріктік сипаттамалары, лазерлік қаптау, термиялық әсер, лазерлік қондырғылар, лазерлер, наноматериалдар, бөлшектер ресурсы.

Анар Хабай
Казахский национальный технический университет имени К.И. Сатпаева
Алматы, Казахстан

ПЕРСПЕКТИВНЫЕ МЕТОДЫ УПРОЧНЕНИЯ И ВОССТАНОВЛЕНИЯ ДЕТАЛЕЙ СОВРЕМЕННОГО МАШИНОСТРОЕНИЯ

Аннотация. В статье была проведена оценка эффективности технологии лазерной наплавки, предназначенной для восстановления металлических деталей, подверженных высокому износу, динамическим нагрузкам и механическим воздействиям в процессе эксплуатации. Лазерная наплавка, как новая технология, основанная на использовании лазеров и наноматериалов для упрочнения сплавов, представляет собой эффективный метод восстановления изношенных деталей или улучшения прочностных характеристик новых механизмов и машин. Эта технология позволяет точно наносить материал на поверхность деталей, что обеспечивает высокую точность и качество восстановления. В результате использования лазерной наплавки удается значительно увеличить срок службы деталей и обеспечить их надежную работу в условиях повышенной эксплуатационной нагрузки. Это делает данную технологию востребованной в различных отраслях промышленности, где требуется обеспечение высокой износостойкости и прочности деталей и механизмов.

Дополнительно, лазерная наплавка отличается высокой эффективностью и экономичностью процесса восстановления деталей. За счет возможности использования разнообразных материалов и точного контроля нанесения слоя материала на поверхность, эта технология позволяет минимизировать отходы и снизить затраты на производство. Более того, лазерная наплавка способна восстанавливать не только поверхностные дефекты, но и улучшать механические свойства материала, что повышает его прочность и долговечность. Таким образом, применение лазерной наплавки в производстве обещает значительные выгоды, включая увеличение эффективности использования ресурсов, снижение затрат на обслуживание и улучшение качества конечной продукции.

Ключевые слова: прочностные характеристики деталей, лазерная наплавка, термическое воздействие, лазерные установки, лазеры, наноматериалы, ресурс деталей.