ВЕСТНИК
ДОНБАССКОЙ НАЦИОНАЛЬНОЙ АКАДЕМИИ СТРОИТЕЛЬСТВА И АРХИТЕКТУРЫ

ISSN 2519-2817 online
Научно-технические достижения студентов строительно-архитектурной отрасли
Выпуск 2024-4(168)

EDN: JBIYBS
UDC 678.026.34

NIKITA BACHURIN, VYACHESLAV STEPAKIN, EKATERINA BURYAK
FSBEI HE «Donbas National Academy of Civil Engineering and Architecture»,
Russian Federation, Donetsk People's Republic, Makeevka

GAS-DYNAMIC SPRAYING IN THE RESTORATION OF MACHINE PARTS

Abstract. The method of cold gas dynamic spraying (CGS) makes it possible to apply coatings with a wide range of functional properties to almost any substrate material, restore the geometric dimensions of parts damaged during operation, and restore protective anti-corrosion coatings without labor-intensive dismantling of the structure. The simplicity and manufacturability of the process, the mobility of installations for applying coatings using the CGN method make it possible to use this method both in industrial conditions using robotic systems and in «field» conditions. Methods for restoring metal surfaces of parts are considered. The method of cold gas dynamic spraying (CGS) of metals allows not only to apply various protective and functional coatings, but also, when using plastic materials, to effectively eliminate defects in parts and assemblies for various purposes.

Keywords: reliability, repair, cold gas-dynamic spraying, powder materials, gas-dynamic spraying, methods, restoration.

PROBLEM STATEMENT

Improving the reliability of automotive equipment can be carried out in two main areas:

1) increasing the reliability of manufactured vehicles in mass production conditions;

2) increasing the reliability of operating vehicles through the use of promising methods for restoring automobile parts in conditions of single and mass production. Reliability, as it is known, is a complex property, which, depending on the purpose of the product and its operating conditions, may include failure-free operation, durability, storability and maintainability of the product and its components [1].

THE PRIMARY PURPOSE

Today, quite high demands are placed on the materials necessary for the manufacture of machine parts and structures to increase the service life of products. The most promising is to improve the characteristics of parts by applying functional coatings that increase corrosion resistance, wear resistance, and protection from the mechanical damage. It is important to note that preference is given to methods and technologies that do not negatively affect the applied surface. The most dynamically developing method of coating today is the technology of cold gas dynamic spraying [2].

STATEMENT OF BASIC MATERIALS

Methods for restoring metal surfaces of parts [3] are the following:

– detonation spraying;
– arc;
– high frequency;
– cold gas dynamic spraying.

welding and surfacing methods:

– submerged arc;
– arc in carbon dioxide;
– arc with gas-flame protection;
– vibrating arc;
– arc cored wire or tape;

– arc in argon;
– contact;
– gas;
– plasma;
– multi-electrode submerged arc;
– lying electrode;
– electropulse;
– electroslag;
– liquid metal;
– with simultaneous deformation;
– with simultaneous cutting;
– high frequency;
– high frequency in fireproof environment.
electrophysical methods:
– laser processing;
– electric spark machining in a gas environment or vacuum;
– ion-plasma sputtering reactive electron beam – RAP;
– activated reactive sputtering CIB bombing.

All methods have their own advantages and limiting factors, which determine the appropriateness of their use in various cases. The most promising direction is cold gas-dynamic spraying. The essence of gas dynamic spraying (GDS) is that small metal particles in the solid state are accelerated by a supersonic gas flow to speeds of several hundred meters per second and directed to the surface of the part being repaired. During a high-speed impact, particles are fixed to the surface and a continuous coating is formed. In this case, the temperature of the powder particles is usually significantly lower than their melting point. The scheme for forming a coating using the cold gas-dynamic spraying method is shown in Figure [4].

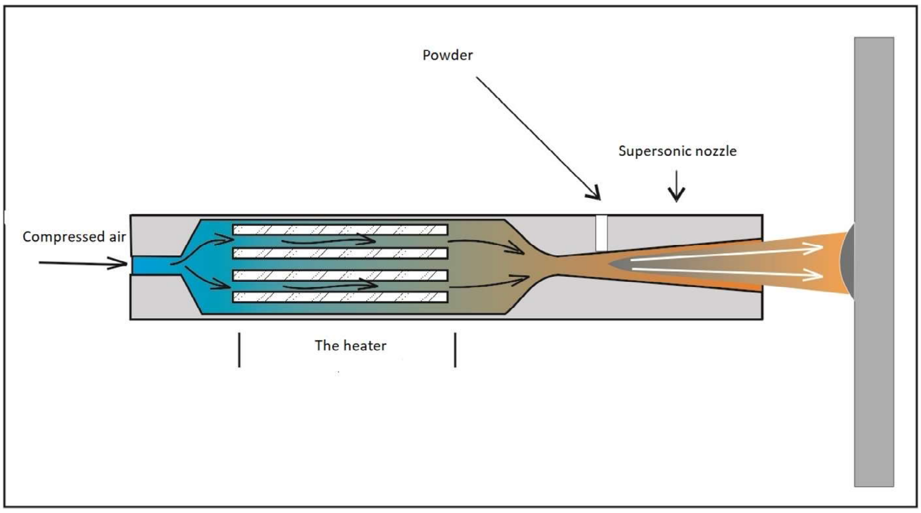

Figure – Scheme of coating formation using HDN method.

Powders containing metal or ceramic particles are introduced into the flow. The particles are accelerated by the gas flow and directed to the surface of the product in an unmelted state. When hitting the surface of a product, metal particles are plastically deformed. The kinetic energy of particles is spent on their deformation and the energy of adhesion to the surface of the product. As a result of the high-speed impact, metal particles are fixed on the surface of the product and form a dense coating. Ceramic particles clean the surface, compact the growing coating and help fix the metal particles. The gas-dynamic method for restoring defects in parts is based on the plastic deformation of particles upon impact with the metal substrate of the part and the creation of an adhesive bond due to the kinetic energy of the sprayed particles. In the Dimet-405 installation, compressed air is used as a working medium to accelerate particles, which is supplied under pressure to the inlet of a supersonic Laval nozzle. To increase the spraying efficiency by increasing the air flow speed, heating elements are installed in the spraying unit up to temperatures within 300 °C. Passing through them, the air flow is heated to temperatures of ~(80...130) °C.

Near the exit from the nozzle there is a hole for supplying powder material, which, as a result of the created vacuum, rises into the nozzle and is captured by the air flow. The flow rate imparts significant kinetic energy to the powder particles, despite their small size. Thanks to this energy, not only plastic deformation of metal powder materials occurs, but also their introduction into the structure of the part takes place. With CGN, a local effect is observed on a certain area of the surface, which allows visual control of the geometric dimensions of the part and helps preserve the structure of the material [5].

Properties of the resulting coatings are as follow:

– high adhesion (30...80 MPa);
– high cohesion (30...80 MPa);
– uniformity of coatings;
– low porosity (1...3 %);
– high electrical conductivity between the coating and the base;
– the surface roughness of the coatings is Rz = 20...40.

The advantages of the technology include the following [6]:

– coating application occurs in the atmosphere at atmospheric pressure, regardless of the temperature and humidity;
– during the coating process, there is practically no thermal effect on the coating object, which means that there is no development of internal stresses and deformation of the product, and there is no oxidation of the coating object or components;
– applying a multi-component coating is possible, and the content of the components can be varied depending on their thickness;
– a simple change of technological mode allows further polishing the surface for coating or decorative effects;
– different types of coatings possible in one installation.

CONCLUSIONS

The method of cold gas-dynamic spraying is of great interest due to a colossal number of problems that can be solved thanks to its use. Such as, for example, filling caverns, cracks, chips, holes, restoring geometric shapes and sizes of parts of almost any complexity. It has been established that the main parameters influencing the structure, microhardness and conditional utilization rate of the material are the compressed air heating mode, spraying angle and powder consumption mode. Thus, with increasing powder consumption, plasticity increases, and the particle size of electrocorundum becomes larger. If there is a large amount of powder, overheating occurs. The metallographic analysis performed have showed that the sprayed coatings have a two-phase structure, which consists of a metal matrix and a dark phase. The dark phase consists of electrocorundum particles and pores. As a rule, large dark phases have edges and are particles of electrocorundum. With increasing heating mode, the particle size decreases and plasticity increases. In the structure of the samples, as the deposition angle decreases, the number of electrocorundum particles decreases, but their size becomes larger. Spraying samples using a special nozzle turned out to be impossible, since particles are deposited on the nozzle with subsequent filling of the nozzle [7].

This technology can be successfully implemented when restoring seating surfaces for bearings of housing parts, sealing cracks in engine blocks, auto air conditioner radiators, heat exchangers and restoring power plant parts, etc.

REFERENCES

1. Малышев, А. Н. Повышение надежности автомобильных деталей при их изготовлении и восстановлении / А. Н. Малышев, О. Л. Пирозерская. – Текст : непосредственный // Электронный журнал: наука, техника и образование. – 2015. – № 2(2). – С. 60–65.
2. Крикунов, Е. Д. К вопросу о холодном газодинамическом напылении / Е. Д. Крикунов. – Текст : непосредственный // Современные проблемы и направления развития агроинженерии в России : сборник научных статей 3-й Международной научно-технической конференции, Курск, 20 октября 2023 г. – Курск : Курский государственный аграрный университет имени И. И. Иванова, 2023. – С. 79–81.
3. Толмачева, И. И. Методы восстановления деталей машин / И. И. Толмачева, М. А. Дючкова, В. Е. Устимова. – Текст : непосредственный // Современные проблемы лингвистики и методики преподавания русского языка в ВУЗе и школе. – 2022. – № 40. – С. 629–634.
4. Кузнецов, Ю. А. Восстановление деталей машин сверхзвуковым газодинамическим напылением / Ю. А. Кузнецов, А. В. Добычин. – Текст : непосредственный // Мир транспорта и технологических машин. – 2009. – № 4(27). – С. 7–10.
5. Использование металлопорошковых композиций для устранения дефектов деталей из сплава ВАС-1 методом холодного газодинамического напыления / И. А. Козлов, М. А. Фомина, С. А. Демин [и др.]. – Текст : непосредственный // Труды ВИАМ. – 2022. – № 12(118). – С. 96–106.

6. Лушина, М. В. Технология газодинамического напыления покрытий ДИМЕТ и перспективы применения её в производстве АО «Концерн "НПО "Аврора"» / М. В. Лушина. – Текст : непосредственный // Системы управления и обработки информации. – 2020. – № 3(50). – С. 77–80.
7. Павлов, И. С. Определение влияния технологических параметров режимов напыления на структуру и свойства функциональных покрытий на основе AL_2O_3 и Cu, полученных методом холодного газодинамического напыления низкого давления / И. С. Павлов. – Текст : непосредственный // Международный научно-исследовательский журнал. – 2023. – № 4(130). – С. 1–15.

Получена 08.05.2024
Принята 24.05.2024

Н. Д. БАЧУРИН, В. Р. СТЕПАКИН, Е. С. БУРЯК

ГАЗОДИНАМИЧЕСКОЕ НАПЫЛЕНИЕ В ВОССТАНОВЛЕНИИ ДЕТАЛЕЙ МАШИН

ФГБОУ ВО «Донбасская национальная академия строительства и архитектуры», Российская Федерация, Донецкая Народная Республика, г. о. Макеевка, г. Макеевка

Аннотация. Метод холодного газодинамического напыления (ХГН) позволяет наносить покрытия с широким набором функциональных свойств практически на любой материал подложки, восстанавливать геометрические размеры деталей, поврежденных в процессе эксплуатации, и проводить восстановление защитных противокоррозионных покрытий без трудоемкого демонтажа конструкции. Простота и технологичность процесса, мобильность установок для нанесения покрытий методом ХГН дают возможность применять данный метод как в промышленных условиях с использованием роботизированных систем, так и в «полевых» условиях. Рассматриваются методы восстановления металлических поверхностей деталей. Метод холодного газодинамического напыления (ХГН) металлов позволяет не только наносить различные защитные и функциональные покрытия, но и при использовании пластичных материалов эффективно устранять дефекты деталей и узлов различного назначения.
Ключевые слова: надежность, ремонт, холодное газодинамическое напыление, порошковые материалы, напыление газодинамическим методом, методы, восстановление.

Бачурин Никита Дмитриевич – аспирант; ассистент кафедры автомобильного транспорта, сервиса и эксплуатации ФГБОУ ВО «Донбасская национальная академия строительства и архитектуры». Научные интересы: совершенствование способов ремонта и восстановления деталей силовых установок.

Степакин Вячеслав Романович – аспирант; ассистент кафедры автомобильного транспорта, сервиса и эксплуатации ФГБОУ ВО «Донбасская национальная академия строительства и архитектуры». Научные интересы: совершенствование конструкций автомобильных гибридных силовых установок.

Буряк Екатерина Сергеевна – старший преподаватель кафедры иностранных языков и педагогики высшей школы ФГБОУ ВО «Донбасская национальная академия строительства и архитектуры». Научные интересы: методика преподавания иностранного языка, лингвокультурологический подход в обучении иностранным языкам, межкультурная коммуникация.

Bachurin Nikita – graduate student; Assistant at the Department of Automotive Transport, Service and Operation of the FSBEI HE «Donbas National Academy of Civil Engineering and Architecture». Scientific interests: improving methods for repairing and restoring power plant parts.

Stepakin Vyacheslav – graduate student; Assistant at the Department of Automotive Transport, Service and Operation of the FSBEI HE «Donbas National Academy of Civil Engineering and Architecture». Scientific interests: improving the designs of automotive hybrid power plants.

Buryak Ekaterina – a senior lecturer, at the Department of Foreign Languages and Pedagogy of Higher School of the FSBEI HE «Donbas National Academy of Civil Engineering and Architecture». Scientific interests: methods of teaching a foreign language, linguocultural approach to teaching foreign languages, intercultural communication.