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AUTOMATION OF SELECTIVE LASER MELTING (SLM) PARAMETERS CONTROL BASED ON COMPUTER ANALYSIS OF THE GRANULOMETRIC COMPOSITION OF METAL POWDERS

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The development of the 3D printing industry requires new approaches in terms of choosing materials for the production of products. A special place in this issue is occupied by the choice of metal powders. If at the initial stage of development, it was mainly about plastic as the main type of material for 3D printing, then recently metal powder printing has become more relevant. This is especially true in cases of small-scale production. As you know, there are consumer goods and in such cases their production is carried out in large factories and factories. However, there are areas of production where it is necessary to establish the production of products in small quantities and for special purposes.

There is also the problem of producing metal powders. Currently, our country does not produce metal powders. Metal powders are purchased in foreign countries. The price of 1 kilogram of metal powder reaches 200,000 tenge. At the same time, our country has huge reserves of raw materials in the form of man-made waste from the mining and metallurgical industries. These wastes can be used to produce metal powders with various compositions and properties. In the process of manufacturing parts and assemblies, it is possible to replace expensive imported metal powders with inexpensive metal powder of domestic production.

In the article, the aim of the research is to identify the optimal powder composition by automating the process of conducting scientific experiments with different powder compositions.

At the same time, the following tasks were solved:

- based on the results obtained, conducting a comparative analysis of the qualitative composition of the powder;

- automate technologies for producing metal powder with pre-defined properties to obtain the required parameters of parts and assemblies.

Keywords: algorithm, additive technologies, software codes, computer modeling, neural network, layer-by-layer synthesis.

МЕТАЛЛ ҰНТАҚТАРЫНЫҢ ГРАНУЛОМЕТРИЯЛЫҚ ҚҰРАМЫН КОМПЬЮТЕРЛІК ТАЛДАУ НЕГІЗІНДЕ ТАҢДАУЛЫ ЛАЗЕРЛІК БАЛҚЫТУДЫҢ (SLM) ПАРАМЕТРЛЕРІН БАСҚАРУДЫ АВТОМАТТАНДЫРУ

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3D басып шығару индустриясын дамыту өнімдерді өндіру үшін материалдарды таңдау тұрғысынан жаңа тәсілдерді қажет етеді. Бұл мәселеде металл ұнтақтарын таңдау ерекше орын алады. Егер дамудың бастапқы кезеңінде негізінен 3D басып шығаруға арналған материалдың негізгі түрі ретінде пластик туралы болса, онда соңғы уақытта металл ұнтақтарымен басып шығару өзекті бола бастады. Бұл әсіресе шағын өндіріс жағдайларына қатысты. Өздеріңіз білетіндей, кең тұтыну

тауарлары бар және мұндай жағдайларда оларды өндіру ірі зауыттар мен зауыттарда жүзеге асырылады. Алайда, аз мөлшерде және арнайы мақсаттағы өнім шығаруды жолға қою қажет өндіріс салалары бар.

Металл ұнтақтарын алу мәселесі де бар. Қазіргі уақытта біздің елде металл ұнтақтары өндірілмейді. Металл ұнтақтары шет елдерде сатып алынады.1 килограмм металл ұнтағының бағасы 200 000 теңгеге жетеді. Сонымен қатар, біздің елімізде тау-кен және металлургия салаларының техногендік қалдықтары түріндегі шикізаттың орасан зор қоры бар. Бұл қалдықтарды әртүрлі құрамы мен қасиеттері бар металл ұнтақтарын алу үшін пайдалануға болады. Бөлшектер мен тораптарды дайындау процесінде қымбат импортталған металл ұнтақтарын отандық өндірістің арзан металл ұнтағына ауыстыруға болады. Мақалада Зерттеудің мақсаты ұнтақтың оңтайлы құрамын анықтау болып табылады процесті автоматтандыру ұнтақтардың әртүрлі құрамдарымен ғылыми эксперименттер жүргізу. Бұл ретте келесі міндеттер шешілді:

- алынған нәтижелер бойынша ұнтақтың сапалық құрамына салыстырмалы талдау жүргізу;

- бөлшектер мен тораптардың қажетті параметрлерін алу үшін алдын ала белгіленген қасиеттері бар металл ұнтағын алу технологияларын автоматтандыру.

Түйін сөздер: алгоритм, аддитивті технологиялар, бағдарламалық код, компьютерлік модельдеу, нейрондық желі, соңғы синтез.

АВТОМАТИЗАЦИЯ УПРАВЛЕНИЯ ПАРАМЕТРАМИ СЕЛЕКТИВНОГО ЛАЗЕРНОГО ПЛАВЛЕНИЯ (SLM) НА ОСНОВЕ КОМПЬЮТЕРНОГО АНАЛИЗА ГРАНУЛОМЕТРИЧЕСКОГО СОСТАВА МЕТАЛЛИЧЕСКИХ ПОРОШКОВ

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Развитие индустрии 3Д принтинга требует новых подходов в плане выбора материалов для производства изделий. Особое место в этом вопросе занимает выбор металлических порошков. Если на начальном этапе развития в основном речь шла о пластике как основном виде материала для 3Д печати, то в последнее время более актуальным становится печать металлическими порошками. Особенно это касается случаев мелкосерийного производства. Как известно существуют товары широкого потребления и в таких случаях их производство осуществляется на крупных заводах и фабриках. Однако есть сферы производства, где необходимо наладить выпуск продукции в небольших количествах и особого назначения.

Также существует проблема получения металлических порошков. В настоящее время в нашей стране не производят металлические порошки. Металлические порошки закупаются в зарубежных странах. Цена 1 килограмма металлического порошка достигает 200 000 тенге. В тоже время наша страна обладает огромными запасами сырья в виде техногенных отходов горнодобывающей и металлургической отраслей. Эти отходы можно использовать для получения металлических порошков с различными составами и свойствами. В процессе изготовления деталей и узлов можно заменить дорогостоящий импортный металлический порошков на недорогой металлический порошок отечественного производства.

В статье целью исследования является выявление оптимального состава порошка посредством автоматизации процесса проведение научных экспериментов с различными составами порошков.

При этом решались следующие задачи:

- по полученным результатам проведение сравнительного анализа качественного состава порошка;

- автоматизировать технологии получения металлического порошка с заранее заданными свойствами для получения требуемых параметров деталей и узлов.

Ключевые слова: алгоритм, аддитивные технологии, программный код, компьютерное моделирование, нейронная сеть, послойный синтез.

Introduction. Developing a new product type is a long and time-consuming process that requires several stages of design and evaluation before mass production begins. The methods of 3-dimensional computer modeling that are being implemented all over the world help to dramatically speed up the passage of these stages. Modern computer-aided design (CAD) systems can also significantly reduce the time and money spent on developing and designing new products [1-2]. However, the problem of producing the first physical image and even a single part for a product of any complex shape remains the most challenging area, as developing the manufacturing technology and associated tooling often requires costs comparable to the development of the product itself. Figures 1 and 2 show a laboratory test rig (prototype) for testing computer vision algorithms and calibrating optical inspection channels.

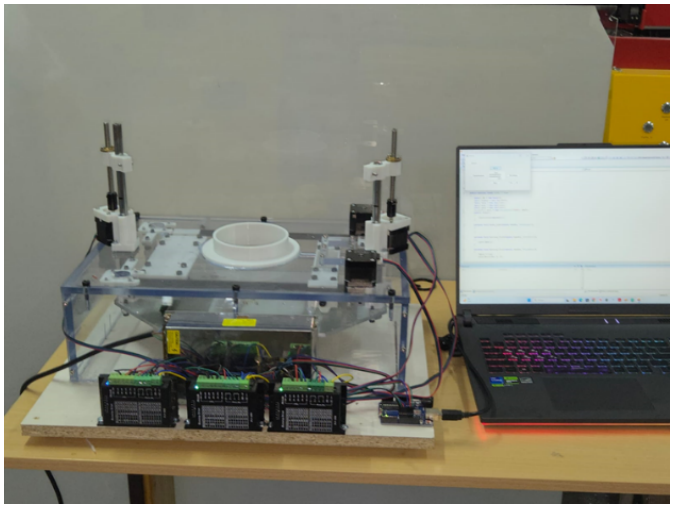


Fig.1 - Experimental setup

In the process of working on a project, especially at the stage of complex design, it is difficult to identify various errors and shortcomings only on the display screen. Having a real physical model of the future product, you can detect and eliminate various errors, adjust the ways to continue the design process. The product prototype can be used as a conceptual model for visualizing and analyzing the design. It allows you to perform improvements and perform some functional tests, and can also serve as a master model for making tooling. In addition, the prototype can be used for marketing purposes or in determining the cost of manufacturing [3-4].

Materials and methods. Layer-by-layer synthesis involves the construction in an inert gas environment with cooling of certain zones, with local metal shrinkage, with the capture of ambient gas molecules (nitrogen or argon), with the formation of defects caused by laser operation, inhomogeneity of the model material [5-7]. When using AF technologies, all stages of project implementation from idea to materialization (in any form, intermediate or finished product) are located in a ”friendly” technological environment,

in a single technological chain, where each technological operation is also performed in a digital CAD/CAM / CAE system. (Fig.2)

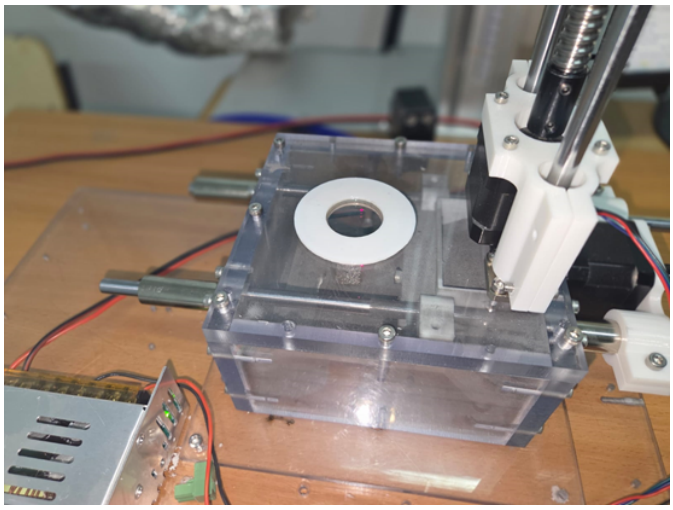


Fig. 2- Product prototype

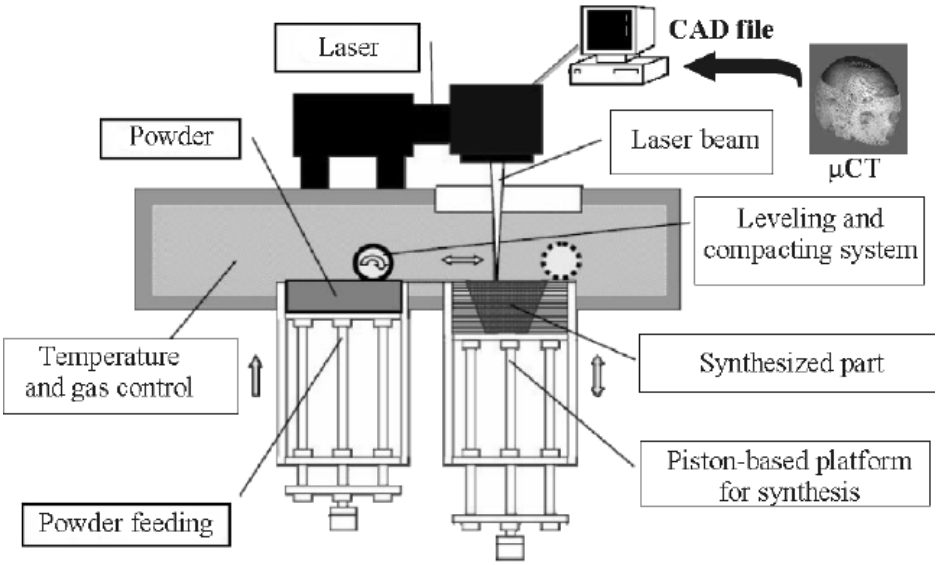


Fig.3 - SLM schematic diagram

The camera itself and the particle recognition algorithm were tested on the prototype. Halogen illumination was used.

The essence of SLM (selective laser melting) technology is as follows (Fig.3): thin layers of high-quality metal powder, ceramics, polymer with a grain size of 10 ...40 microns are evenly distributed using a special coating mechanism, forming a layer with a thickness of 20 ...40 microns, the platform on which the powder is located can be lowered vertically. The entire process takes place inside the chamber, which maintains strict control of atmospheric inert gases (argon, nitrogen, oxygen). Each layer is then formed by selectively exposing the powder surface to lasers using two high-frequency scanners [8-9]. This creates a 2D cross-section of the model. SLM technology uses high-power pulsed lasers (usually YAG-fiber lasers

(1064 nm, 1070 nm)) − 0.05....1 kW.

Laser melting uses the same installations and procedures as in the SLS process. The only difference is that the SLM process completely melts the powder. This significantly improves the microstructure and product characteristics compared to DMLS. The density of 99.99% for metal products is achievable without subsequent heat treatment, and their characteristics are comparable to those of parts obtained by mechanical processing.

The military-industrial complex has shown an increased interest in AF technologies since their introduction; the ability to eliminate many constraints on the path from project to production allows you to implement solutions that increase efficiency and reduce the weight of parts. Moreover, by its very nature, this market requires small-scale production of high-quality parts, so getting rid of tools, including unique special equipment offered by AF technologies, brings significant benefits [10].

However, the main problem of introducing these technologies into the production process of manufacturing products for the military-industrial complex is their certification, since the physical and mechanical characteristics, stability of these characteristics, and surface quality of parts manufactured using additive technologies are subject to strict requirements that are not always possible to fulfill.

Currently, there are no general requirements for metal-powder compositions used in additive technologies. Different manufacturing companies recommend working with the material supplied by the company itself. Weanalyzed the results of experimental studies of layer-by-layer formation of three-dimensional objects by the SLM method, on the basis of which it was found that the use of inexpensive metal powders, the granules of which have an arbitrary shape during 3D printing, violates the packing density of granules and at the focus point of laser energy, bulk shrinkage and uneven fusion of metal powder appear, which reduces the quality of the printed part.

Results and discussions. Different machines use powders of different fractional compositions. One of the parameters that characterizes the powder is the average particle diameter d50. For example, d50 = 40 microns means that 50% of the powder particles have a particle size less than or equal to 40 microns. So, for example, Phenix Systems machines use powder with d50 = 10 microns; for Conzept Laser machines, the powder dispersion is in the range of 25 ...52 microns at d50 = 26.9 microns; for Arcam machines, the particle size is 45...100 microns, for SLM Solutions machines, d50 = 10-30, etc.

In the process of laser synthesis, for example, using SLM technology, when building a part, the laser beam not only fuses powder particles to form the part body, but also ”spoils” the material directly adjacent to the surface of the part under construction. Therefore, in the practice of working with SLS machines, methods of sieving waste material are used to remove the ”defective” part with further mixing of the ”used” powder with fresh one. Since mixing proportions are set by each company, the identity of samples built on the same machine and from the same powder is not guaranteed.

There are quite a lot of varieties of metal-powder compositions. These include the following:

Al-Ni-Co, Fe-Nd-B - magnet production

Aluminum Bronze - ship screws

Al-Si-Mg - with heat-resistant structure

Al-Sn-Cu - sliding bearings

Al- alloys with high thermal strength

Bi-Te - Devices using the Peltier effect

Cr-Al - protective coatings

Co-Cr - alloys for dental prosthetics

Cu-Ba, Cu-Y – superconductors

Cu-Cr-Zr - beryllium-free electrical conductors

Cu-In-Ga-Selenide - photovoltaic materials

Cu-Mn-Ni, Cu-Ti-Sn - Cutting tool

We conducted experiments with different powder compositions and based on the results obtained, we conducted a comparative analysis of the qualitative composition of the powder to obtain the required

parameters of parts and assemblies. Determination of the composition of metal powders includes particle size analysis and chemical analysis. Figure 4 shows the program code inPython.

```
import cv2
import numpy as np
# Uploading a powder micrograph image
image = cv2.imread(”powder_sample.jpg”)
# Image processing to improve contrast and search for particles
# Apply blur to reduce noise
blurred = cv2.GaussianBlur(image, (5, 5), 0)
# Binarization (converting to black and white)
_, thresh = cv2.threshold(
    cv2.cvtColor(blurred, cv2.COLOR_BGR2GRAY),
    0,
    255,
    cv2.THRESH_BINARY + cv2.THRESH_OTSU,
)
# Search for particle contours
contours, _ = cv2.findContours(
    thresh,
    cv2.RETR_EXTERNAL,
    cv2.CHAIN_APPROX_SIMPLE,
)
# Particle size analysis
particle_sizes = []
for cnt in contours:
    # Avoid making noise that is too small
    if cv2.contourArea(cnt) > 10:
        # Calculation of the equivalent diameter (area of the circle)
        area = cv2.contourArea(cnt)
        diameter = 2 * np.sqrt(area / np.pi)
        particle_sizes.append(diameter)
if particle_sizes:
    print(f”Total particles: {len(particle_sizes)}”)
    print(f”Average diameter: {np.mean(particle_sizes):.2f} pixels”)
    print(f”Median diameter: {np.median(particle_sizes):.2f} pixels”)
else:
    print(”No particles found.”)
# Optional: Visualization of results
cv2.drawContours(image, contours, -1, (0, 255, 0), 2)
cv2.imshow(”Particles”, image)
cv2.waitKey(0)
cv2.destroyAllWindows()
```

Fig.4 - Python program code

Conclusion. As a result of the work, an algorithm for optical-digital analysis of the geometry of microparticles of powder composites was developed, which allows for the determination of the average diameter of fractions in the range of 10-50 μm with an error of no more than 3.5%. This

ensures automated express control of raw materials before loading into the SLM chamber.

In conclusion, we can note that as a result of our research, we were able to experimentally identify the optimal composition of the powder. It is worth noting that the powder composition obtained by us is 90 percent composed of inexpensive materials. Moreover, industrial waste from the mining industry is used as raw materials. In the end, this will significantly reduce the cost of the products received and reduce the share of dependence on foreign suppliers. Thus, we increase the percentage of domestic product.

It is also worth noting that the process of identifying the optimal powder composition was fully automated, which allowed us to significantly increase the speed of processing the results obtained and reduce the time for obtaining results.

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