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Satbayev University

ХАБАРЛАРЫ

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ
НАУК РЕСПУБЛИКИ
КАЗАХСТАН
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ANALYSIS OF A NEW FILAMENT MAKING MEL PRESSING DEVICE

Abstract. The filament for Fused Deposition Modeling technology was developed in a new melt pressure pressing device using metal-polymer composite material.

Phase analysis of metal-polymer composite material was carried out by X-ray diffraction. The material was subjected to XRD analysis in the 2θ, 3–90° range, and in Cu Kα radiation at 1.5408 Å and a pitch of 0.02° on a Rigaku MiniFlex. Thermogravimetric analysis was carried out in a Perkin Elmer Pyris instrument at a temperature range of 0 °C – 512.6 °C under a nitrogen atmosphere of 40 mL/min by volume.

It was studied at what temperature the heaters in this device should be maintained. In addition, it was found that the metal powders contained in the metal-polymer composite material can be changed to adhesive powders by mechanical compression under a pressure of 18 MPa. The research was carried out under the grant No. AP08857034.

Key words. New press device, XRD analysis, Thermogravimetric analysis, filament.

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ЕРІТІНДІДЕН ҚҰРЫЛҒАН ЖІП АЛУ ҮШІН ЖАҢА ЭКСТРУЗИЯЛЫҚ ПРЕСТІ ТАЛДАУ

Аннотация. Тұндыруды модельдеу технологиясына арналған жіп металл полимерлік композиттік материалды қолдана отырып, балқыманы қысыммен басатын жаңа құрылғыда жасалды.

Металл-полимерлі композитік материалдың фазалық талдауын рентгендік дифракциямен жүргізілді. Материалды 2θ, 3–90° диапазонында, және Cu Kα сәулесінде 1,5408 Å, және қадамы 0,02° болатын Rigaku MiniFlex құрылғысында XRD анализы жүргізілді. Термогравиметриялық талдау 0°C – 512,6°C температура аралығында көлемі бойынша 40 мл/мин азот атмосферасында Perkin Elmer Pyris құралында жүргізілді.

Бұл құрылғыдағы қыздырғыштардың қандай температурада болатынын қарастырылды. Атап айтсақ, шнек бойымен балқытылып ағылған полимер (құрамында метал ұнтақтары бар) үш қыздырғыш зонасынан өтіп (қыздырғыштардың қуаты 8,4 кВт), яғни үш зонада үш түрлі температурадан өтіп, (180°C, 200°C, 220°C градустарда қыздырылып) полимер жеткілікті балқиды, және арнайы жасалған камераға жиналады. Камерадағы жиналған материал суып қалмау үшін, камераны да сыртынан 220°C градус температурасымен қыздыру операциясы жүргізіледі. Сонымен қатар металл-полимерлі композиттік материалдың құрамындағы металл ұнтақтарын механикалық 18 МПа қысымен қысу арқылы адгезиялық ұнтақтарға ауыстыруға болатынын анықталды.

Зерттеу № AP08857034 гранты аясында жүргізілді.

Түйін сөздер. Жаңа пресс құрылғы, XRD анализы, Термогравиметриялық талдау, филамент.

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АНАЛИЗ НОВОГО ЭКСТРУЗИОННОГО ПРЕССА ДЛЯ ФОРМОВАНИЯ НИТЕЙ ИЗ РАСПЛАВА

Аннотация. Нить для технологии Fused Deposition Modeling была разработана в новом устройстве прессования под давлением расплава с использованием металлополимерного композитного материала.

Фазовый анализ металлополимерного композиционного материала проводили методом рентгеноструктурного анализа. Материал подвергали рентгенофазовому анализу в диапазоне 2θ, 3–90° и в Cu Kα-излучении при 1,5408 Å и шаге 0,02° на приборе Rigaku MiniFlex. Термогравиметрический анализ проводили на приборе Perkin Elmer Pyris в интервале температур от 0 °С до 512,6°С в атмосфере азота с объемной скоростью 40 мл/мин.

Рассматривалось, при какой температуре функционируют нагреватели в данном устройстве. В частности, полимер (содержащий металлические порошки), расплавленный по шнеку, проходит через три зоны нагревания (мощность нагревателей 8,4 кВт), то есть в трех зонах с тремя различными температурами (нагревается при значениях 180°С, 200°С, 220°С) и собирается в специально предназначенную камеру. Чтобы собранный в камере материал не остыл, камеру также следует прогреть снаружи при температуре 220°С. Установлено также, что металлические порошки, содержащиеся в металлополимерном композитном материале, могут быть заменены на адгезионные порошки путем сжатия механическим давлением 18 МПа. Исследование проводилось в рамках гранта № AP08857034.

Ключевые слова: новое пресс-устройство, рентгеноструктурный анализ, термогравиметрический анализ, филамент.

Introduction. Production development is based on the use of advanced technologies. 10 main technologies are identified in the data source (Michaeli et al., 1991:05, Roshchupkin et al., 2020, Bazlov et al., 1996). Among these ten technologies, additive and MIM technologies take the first place. However, due to the presence of many disadvantages in the use of MIM technology, there are several limitations (Korotchenkoa et al., 2004, Roshchupkin et al., 2020). MIM technology has two main methods in use, one based on a combination of thermoplastic molding technology and conventional powder metallurgy (Stranoa et al., 2019, Abdel-Ghany et al., 2015). In classical powder metallurgy, steel powders are pressed into a mold under a certain pressure and baked at a high temperature (about 1300°C) (Ren et al., 2017, Raza et al., 2013, Banerjee et al., 2012). Powdered materials only coalesce during cooking, when bulk diffusion occurs. In MIM technology, the polymer is used to hold the steel powders or as a binder.

There are enough new technologies for making complex products, one of which is additive technology (Masood et al., 2004, Naksoo et al., 2006). Additive technology means pressing the product layer by layer (Tingrui et al., doi.org/10.1177/8756087916649006). Additive technology is divided into many methods. In recent times, interest in the field of printing products on 3D printers using metal-polymer composite materials has been growing in the world (Matula et al., 2018, Xiaokang et al., doi: 10.1039/c7ra11271h.).

Currently, scientists are thinking of finding a low-cost alternative to selective laser melting (SLM) technology, which starts at $1 million per product, based on solving two main problems (Chepchurov et al., 2019, Rauwendaal, 2013). SLM technology is based on combining metal powders to obtain a product, but products made using this technology are very expensive. This means that the development of additive technology is inhibited (Paul et al., Williams et al., 2010, Aboulkas et al., 2010).

However, our research group has made sure that it is possible to create a complex product with metal-polymer material using Fused Deposition Modeling technology. Therefore, we have come up with a new method of fusion compression, and the filament obtained by this method can be manufactured using Fused Deposition Modeling technology.

The main purpose of this article is to study the structure of molten metal-polymer material and to develop a new press device in the process of bringing metal powders closer to each other, i.e. adhesion.

Experimental. Description of the material. In this research, metal polymer composite material was used. Ready-made raw materials containing stainless steel powders and polymers as a binder were used. Stainless steel brand 316L.

Phase analysis of the material was carried out by X-ray diffraction. XRD analysis of the material was carried out on a Rigaku MiniFlex with a 2θ range of 3–90° and a Cu Kα beam of 1.5408 Å and a pitch of 0.02°. In addition, we used a scanning electron microscope (SEM Zeiss Crossbeam 540) to study the structure and internal process of the metal-polymer composite, and we selected an electron working energy of 5 kV.

Melting point analysis. A thermogravimetric analysis of the required temperature was carried out in order to give the melting parameter of the metal-polymer composite material in a special device prepared for making filament, and to prevent the material from freezing in a special back pressure chamber.

The temperature range was 0°C – 512.6°C in a nitrogen atmosphere at 40 mL/min by volume on a Perkin Elmer Pyris instrument. The heating rate is 10°C / min.

Melt pressure pressing device. During the design of the device for making filament from metal-polymer composite material, the main geometric parameters of the barrel were determined and 48 drawings were prepared.

Basic parameters of the extruder

Screw diameter Ds=30 mm

The length of the screw is L=565 mm

Transmission area Lf=0.25L=0.25x565=141 mm

Compression area Lp=0.35L=0.35x565=175 mm

Dosing area Ld=160 mm

According to this device, we put our metal-polymer composite material into the hopper, the material goes into the first heating zone. We placed the auger for the purpose of conveying, mixing and giving certain pressure to the materials.

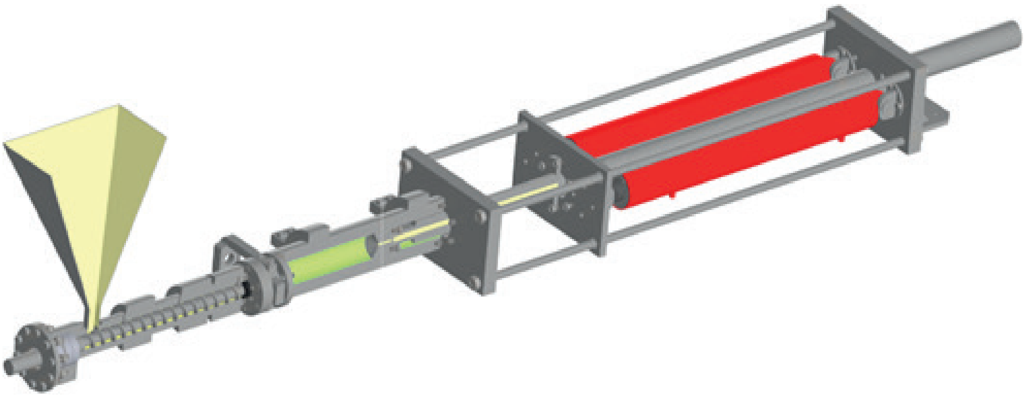

Figure 1 - Sketch of a new filament press machine

We rotate the auger with a gear motor with a power of 7.5 kW, and the rotation speed of the auger is 0-250 rpm. The molten polymer (containing metal powders) flowing along the screw passes through three heating zones (the power of the heaters is 8.4 kW), that is, it passes through three different temperatures in three zones (heated at 180°C, 200°C, 220°C) and the polymer melts sufficiently, and is collected in a specially designed chamber. In order for the collected material in the chamber not to cool down, the chamber is also heated from the outside with a temperature of 220°C. We compress the collected material with a hydraulic pressure of 18 MPa using the reverse pressure method, and get a filament with a diameter of 2 mm.

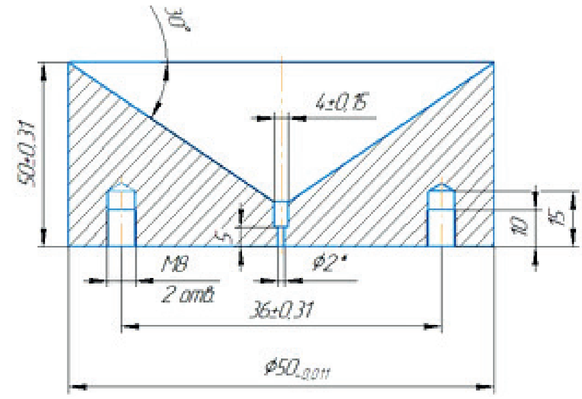

Figure 2 - Press form

The reason for using the matrix shown in Figure 2 is that with this matrix, there is no material residue inside the chamber, and we obtain adhesive powders in a matrix with an angle of 30° during the compression period from a hydraulic pressure of 18 MPa.

Results and Discussion. Materials characterization results. The arrangement of atoms was determined as a result of XRD analysis. Since the polymer peak was not detected, we shot in steps of 0.02°, and the polymer peak began to appear from this step. (Figure 3) Fe-Cr-Ni austenitic alloy began to be observed at sharp peaks of 2θ = 44.65°, 64.98°, 82.30°, 98.88°, and 116.31°. The percentage of metal elements in the composition is shown in table 1.

Table 1 is the percentage of metal elements in the metal-polymer composite material

C	Cr	Ni	Mo	Mn	Si	Fe
≤0.03	16.0-18.0	10.0-14.0	2.0-3.0	≤2.0	≤1.0	Bal.

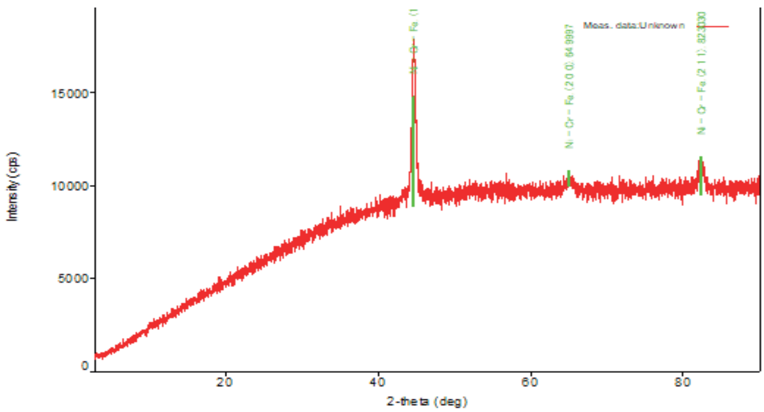

Figure 3 - X-ray result in the range of 2θ, 10-90°

As a result of the SEM analysis, we found that the size of the metal powders in the metal-polymer composite material is 7-3 μm. Also, as shown in Figure 3, the polymer length of chemical elements was removed and the elements were analyzed individually according to their percentage.

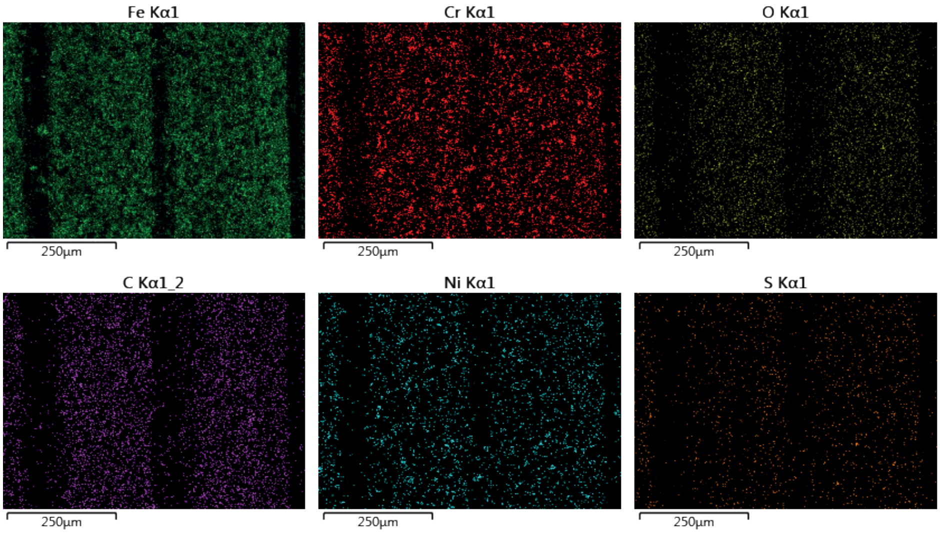

Figure 4 - Analysis of chemical elements using a scanning electron microscope

As a result of the analysis, we found out that it is possible to eliminate or reduce the number of black lines, i.e. dislocations in Figure 4, by bringing the metal powders closer to each other under high mechanical pressure during the production of each filament.

Melting point analysis results. A material with a low melting point in the composition of the metal-polymer composite, that is, the polymer, melts first. As the material in the metal-polymer material is removed, the overall weight is reduced. melting of the polymer and loss of mass were determined during the melting point analysis. As shown in Figure 5, we consider the peak of weight loss as the peak of the beginning of the main process.

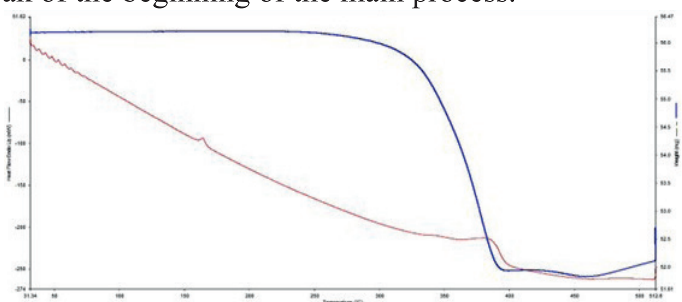

Figure 5 - Thermogravimetric analysis

The endothermic process was determined as 166.7°C, 396.8°C, 471.2°C, 514.6°C, 766.8°C. Paraffin, polypropylene and stearic acid, which are part of the polymer, decompose between 190-600°C. Between the temperature of 160-200°C, the thermal effect increases, and at 354-410°C, this process increases. As a result, 9.7% lost weight.

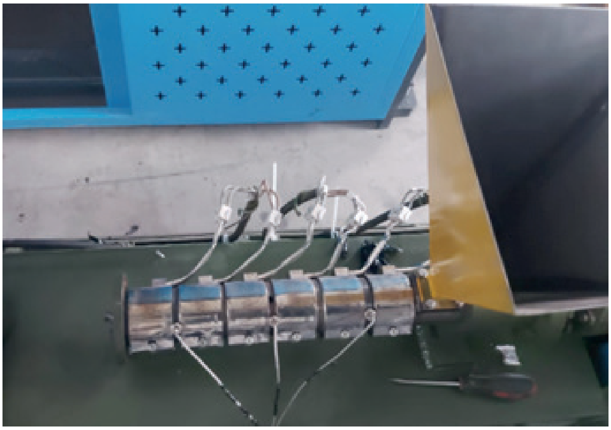

Figure 6 – Zone of heaters

In the extruder of the new filament machine (Figure 6), the temperatures of the 3 burners are between 180°C, 200°C, 220°C, sufficient to melt the metal-polymer material.

Results of the melt press machine. There are many parameters that affect the melt compression process. It is considered important to bring the parameters to the desired index and to connect them with each other. In the melt pressing method, the speed of the material must be constant from start to finish. If the material feed rate is constant, it is important that after the first batch of material, the second batch of material passes through the three different melting zones along the screw at the same speed. The general structure is shown in Figure 7.

Figure 7 - Melt pressure pressing device

The screw speed was controlled in 20 rpm increments up to 120 rpm, with the extruder operating at each speed for approximately five minutes. To determine the influence of the mold design, that is, the size of the opening, on the pressure in the extrudate, we used sections of the opening with a diameter of 5 to 10 mm.

Conclusion. In this work, new technological studies of filament production from metal-polymer composite material in a new melt pressure pressing device were carried out. The device was designed taking into account the structure and melting point of the material. Also, if the speed of the auger is high, the structure of the material changes due to the addition of additional temperature due to the friction of the material. For this reason, the additional temperature caused by the rotation of the screw at high speed was also considered. At the same time, if the size of the steel powder is the same, it will cause the polymer to spread more evenly. This means that the method of adhesion between powders is performed.

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