IJL, Issue 1, Vol. 23, 2024 **Research Article**
https://doi.org/10.31900/ijl.v23i1.416

IRAQI JOURNAL OF LASER

Influence of scanning velocity on Co24.7Cr5Mo5.4W alloy built via selective laser melting on roughness properties

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Article history: Received 4 Sept. 2023; Revised 18 Oct. 2023; Accepted 19 Oct. 2023; Published online 15 Jun. 2024

Abstract: The utilization of Selective Laser Melting (SLM) in the production of intricate metal items has gained significant attention in the medical and dental sectors. Products created using SLM must possess surfaces that exhibit a high degree of smoothness. The objective of this research is to examine the impact of various laser process parameters, specifically the scan rate and hatch spacing, on the surface roughness of Co-Cr dental alloys fabricated in three dimensions (3D) by selective laser melting (SLM) technology. The results indicate that a scanning speed of 700 mm/s yields superior surface morphology and microstructure. The parameter investigation conducted in this paper resulted in the attainment of relative densities as high as 98.9% for the additively built workpieces. The present study focuses on investigating surface roughness in Co–Cr alloys fabricated using powder metallurgy techniques, namely selective laser melting.

Keywords: Selective Laser Melting technology, surface roughness, Co-Cr dental alloys.

1. Introduction

Selective Laser Melting (SLM) is a rapid prototyping technique that has been under development since the late 1980s and is applicable to a wide range of alloys [1-4]. The utilization of Selective Laser Melting (SLM) technology in the fabrication of metal powders is advised to achieve components with a high level of density, eliminating the necessity for additional thermo-mechanical procedures [5]. During the process of selective laser melting (SLM), the alloy's powder particles undergo complete melting with the application of a laser beam with varying energy or power levels [6]. Subsequently, the metal bath undergoes a transition from a liquid phase to a solid phase, leading to the development of physical-chemical and mechanical properties that are influenced by the specific processing technical parameters [7-10]. Selective Laser Melting (SLM) technology enables the production of metal components with intricate shapes [11-13] due to the technology's computer-aided design and computer-aided manufacturing (CAD/CAM) capabilities [14,15]. To facilitate the production of a component using Computer-Aided Design (CAD), it is important to engage in the creation of a three-dimensional design and subsequently generate a Standard Tessellation

Language (STL) file for the final part. Conversely, the Computer-Aided Manufacturing (CAM) component pertains to the physical processing of the part using specialized equipment [16-18]. Under these circumstances, it is advisable to utilize 3D printing or Rapid Prototyping (RP) technology to produce various industrial components, particularly metal elements used in medical prosthetics, including dental prostheses [19-22].

The technological parameters associated with selective laser melting (SLM) processing, namely scan speed and hatch spacing (H), have a significant impact on both the surface quality and mechanical qualities of metal parts [23-26]. The optimization procedure is necessary to determine the optimal values of these parameters, which are crucial for achieving the desired functional and durability qualities in the products obtained [27, 28]. As a result, it is imperative to exercise stringent control over laser processing parameters to achieve optimal roughness levels for the resulting surfaces. According to references [29, 30], certain post-processing activities conducted after selective laser melting (SLM) can be partially or completely omitted using this approach.

The objective of this experimental research is to investigate the effects of two technical parameters, namely scan speed (v scan) and hatching space (H), on the surface roughness of exterior surfaces in both non-mechanical grinding state and mechanical grinding state. In a recent study, Pupo et al. (2012) investigated the impact of different process parameters on the surface quality of Co-Cr alloys manufactured using selective laser melting (SLM). Hence, it is recommended to expand the scope of these assessments by incorporating comprehensive multi-layer formation studies. These experiments aim to investigate the impact of different processing parameters on the surface roughness of Co-Cr alloy products fabricated by Selective Laser Melting (SLM) technology. Hence, the primary objective of this laboratory investigation is to examine the impact of laser process parameters, specifically scan rate and scan hatching spacing, on the surface roughness of Co-Cr alloys made using selective laser melting (SLM) technology. These alloys are commonly employed in dental applications. The purpose was to examine the effects.

The surface has garnered significant attention in numerous research since it has been demonstrated that 90% of failures in engineering components are initiated by surface-related factors. These phenomena manifest themselves through mechanisms such as fatigue cracking, stress corrosion, wear, and erosion [31-38]. From the perspective of the medical and dental domains, the examination of the interaction between a surface and biological tissue raises the topic of attachment of microbiological organisms. Achieving complete surface smoothness is theoretically unattainable due to the inherent tiny texture left by the production components on any surface during the manufacturing process. The phenomenon being described is commonly known as surface texture or surface topography, which comprises a collection of elevated points and depressed areas, each characterized by distinct dimensions, intervals, and configurations (Blunt & Jiang, 2003).

A number of recent studies have been published, focusing on the application of selective laser melting (SLM) and its impact on the properties of products manufactured using CoCr powders. These studies investigate the influence of changing SLM process parameters on the features of the resulting products.
The study conducted by Hong et al. (2016) aimed to examine the impact of different laser process parameters, including laser power, scan rate, and scan-line spacing, on the surface roughness of a Co-Cr dental alloy. This alloy was fabricated using a three-dimensional (3D) printing technique known as selective laser melting (SLM). The experimental setup involved the utilization of a ytterbium fiber laser beam (specifically, the IPG YL-200 model) with a spot size measuring 0.08 mm and a maximum power output of 200 W. The laser beam was operated within an environment saturated with nitrogen gas, with a constant flow rate of 5 L/min. In the beginning, a test employing a single-line formation was conducted to ascertain the appropriate laser power (200 W) and scan rate (128.6 mm/s) that yielded beads with an optimal profile. The results of this work indicate that the surface quality of Co-Cr dental alloys manufactured by selective laser melting (SLM) is significantly influenced by laser process parameters. The prevention of balling during a single-line formation test was achieved by decreasing the laser intensity and increasing the scan rate. The surface quality of Co-Cr dental alloys produced by SLM is influenced by critical parameters such as laser power, scan rate, and scan-line spacing, as established by previous studies. The user did not provide any text to rewrite.

According to Tonellia et al. (2020), The samples under investigation were fabricated utilizing the selective laser melting (SLM) apparatus, namely the SISMA MYSINT100, which is equipped with a Yb-fiber laser operating at a wavelength of 1070 nm. The laser has a maximum power output of 200 W and can produce a focused spot with a nominal diameter of 50 µm. A diverse set of process parameters were considered to investigate a broad spectrum of energy densities (LED = 43.2–267.9 J mm−3). Therefore, the results have been categorized into three distinct groups based on the intensity of light-emitting diodes (LEDs): low (up to 100 J mm−3), medium (100−150 J mm−3), and high (150−270 J mm−3). A relationship was established between the value of LED (light-emitting diode) and various characteristics of parts produced using selective laser melting (SLM), including density, surface quality, microstructural features, and hardness.

Insufficient power output from the low LED results in incomplete melting of the feedstock particles, leading to a highly unstable liquid pool. Due to significant deficiencies in fusing, the SLM samples displayed a porosity level ranging from 1% to 7% in terms of area. Additionally, the top surface of these samples exhibited a high roughness with an average roughness (Ra) ranging from 13 µm to 7 µm. Furthermore, there was a notable variation in the microhardness of the samples, ranging from 18 HRC to 36 HRC. The utilization of medium and high light-emitting diodes (LEDs) has shown effective in achieving the complete fusion of all powder materials and the retrieval of intact sound components. Additionally, this process resulted in a significantly low level of porosity, ranging from 0.5% to 0.1%, and smoother upper surfaces with roughness average (Ra) values ranging from 5 to 2.5 micrometers. The primary flaws seen were gas porosities at the micro-scale. However, it should be noted that excessive energy density (LED > 200 J mm3) can lead to the occurrence of keyhole collapses. There appears to be no discernible correlation between the energy density and the quality of the lateral surfaces of the samples, as well as the size of the laser tracks, in both the transverse and longitudinal sections. The user did not provide any text to rewrite.
In their study, Marta Revilla et al. (2021) conducted a comparative analysis of the chemical composition, surface roughness, and ceramic shear bond strength between two distinct manufacturing procedures: subtractive (milled) and additive (SLM) groups. The specific manufacturing systems used in the additive group were EOS, 3D Systems Layer wise, Concept Laser 100W, and Concept Laser 200W. The focus of the investigation was on Co-Cr alloys. The chemical composition of milling and selective laser melting (SLM) Co-Cr alloys exhibited a notable disparity. The surface roughness of the Co-Cr specimens studied was found to be significantly influenced by both subtractive and additive manufacturing processes.

The study conducted tests on Co-Cr dental alloys produced by both the SML AM and milling techniques and determined similar values for ceramic bond strength. The user's text is not sufficient to rewrite in an academic manner.

2. Experiment

2.1 Characterization of Powders

In this investigation, the raw material utilized for the selective laser melting (SLM) technique was gas-atomized Co24.7Cr5Mo5.4W powder obtained from SENTESBIR, a research institution located in Turkey. The particles exhibit a mostly spherical morphology and are scattered throughout a variety of sizes, as evidenced by the Scanning Electron Microscope (SEM) images and histogram chart depicted in Figure 1. The mean diameter of particles within a certain size distribution is 30 µm, with a range spanning from 15 µm to 45 µm. Table 1 presents the chemical composition of the Co24.7Cr5Mo5.4W powder used in this study, as received from the manufacturer's datasheet.

2.2 Production of SLM samples

The experimental procedure involved the utilization of an industrial Selective Laser Melting (SLM) machine, namely the Mlab cusing R model manufactured in Germany. This machine was employed to fabricate the desired alloy in accordance with the predetermined shape specified by Computer-Aided Design (CAD) software.

Table 1. Chemical composition of Co24.7Cr5Mo5.4W powder.

Element	Co	Cr	W	Mo	Si
Percentage (wt%)	63.9	24.7	5.4	5	<1

Table 2. Physical mechanical properties of Co24.7Cr5Mo5.4W of powder.

Flowability (gr)	Density (gm/cm^3)	Thermal expansion coefficient (CTE) (1/K)	Melting range (^{o}C)	Tensile strength (MPa)	Yield strength (MPa)	Youngs Modulus (GPa)
14s/50	8.50	12.9×10^{-6}	1380-1420	1150-1400	790-1000	210

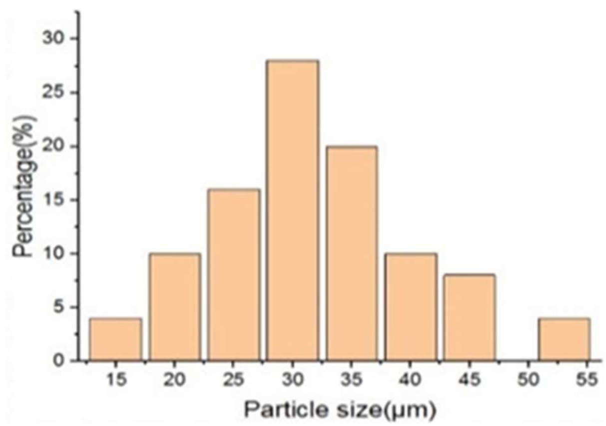

Fig. 1: SEM for the particle size and shape for the employed Co24.7Cr5Mo5.4W powder.

A total of eight sets of samples were generated, with each set consisting of three specimens measuring 15 (L) × 15 (W) × 4 (H) mm. The SLM system utilizes a continuous wave Ytterbium fiber laser to induce the melting of particles on the powder layer in a linear scanning pattern. The thickness of each layer is 25 µm, and these layers are printed using a zero-orientation building (0o). The initial coating of powder was evenly distributed onto a substrate composed of stainless steel. The procedure was iterated multiple times till achieving the ultimate thickness of the sample, which measured 4 mm. The process of selective laser melting (SLM) was conducted under controlled conditions, with a consistent laser output of 100 W, within an environment enriched with nitrogen. The individual effects of the scanning speed (v) and hatch space (h) process parameters on the product qualities were investigated using the one factor at a time method. The specific product attributes examined are presented in Table 3. The volumetric energy density (VED) is regarded as a significant measure for evaluating the outcomes of selective laser melting (SLM) results, as it encompasses the process parameters of the SLM process[42] .

$$VED = \frac{P}{v.h.t} \quad (1)$$

Equation (1) represents the relationship between the volumetric energy density (VED) and the laser power (P), scanning speed (v), space (h), and thickness of a single powder layer (t). In this equation, P is measured in watts (W), and v is measured in millimeters per second (mm/s). hatch h is measured in millimeters (mm), and t is measured in millimeters (mm).

The samples underwent a mechanical grinding and polishing procedure, utilizing waterproof silicon carbide paper with varying grit sizes (80, 200, 400, 800, and 1200) sequentially under a continuous water stream. The specimens underwent a concluding polishing procedure utilizing a 0.5 µm diamond suspension on a polishing cloth affixed to a rotary grinding/polishing apparatus, followed by cleansing with ethanol to eliminate any impurities or debris.

The samples were subjected to surface morphology examinations using a scanning electron microscope (SEM) of the FEI-Quanta 250/USA model. This analysis focused on examining the cross-sections, worn areas, and corroded surfaces of the samples. The crystal phase structure and element distribution were examined using a GNR explorer X-ray diffractometer from Italy. The analysis utilized Cu Kα radiation with a wavelength of 1.5418 Å, and the measurements were taken on a 2θ scale ranging from 10◦ to 90◦. Additionally, an energy-dispersive spectroscope (EDS) is utilized. The Archimedes approach was employed to determine the relative density of the samples produced under various process conditions using the formula [43].

$$RelativeDensity\ \frac{\rho_{SLM}}{\rho_{Std}} \frac{\rho_{water} \times m_{air}}{(\rho_{Std} \times m_{air}) - (\rho_{std} \times m_{water})} \qquad (2)$$

In equation (2), ρSLM represents the density of the Co24.7Cr5Mo5.4W alloy produced using selective laser melting (SLM). ρstandard denotes the standard density of the Co24.7Cr5Mo5.4W alloy. ρwater corresponds to the density of water at a temperature of 4 ◦C. mair represents the average mass of the SLM sample when measured in air, while m water represents the average mass of the SLM sample when measured in water. The relative densities of the selective laser melting (SLM) samples are presented in the table. The user's text is too short to be rewritten in an academic manner.

The measurement of surface roughness was conducted using a profilometer, namely the Mahr surface profilometer. The analysis of the specimens' surface roughness was conducted by measuring the parameters Ra and Rz. The software program utilized for this purpose was Marserve 20, developed by Mahr. The programme was configured with the following settings: The length of traversal is measured at 2.4 mm, whereas the standard critical wavelength is recorded at 0.25 mm. The velocity of the system is calculated to be 0.1 mm/s. The measurements were conducted utilizing a probe with a diameter of 2 mm, positioned perpendicular to the direction of polishing, and employing a cutoff length of 0.4 mm. The manufacturer has stated that the profilometer accuracy is 25 mm on the vertical scale and 1 mm on the horizontal scale. The experiment involved conducting three repetitions of each measurement and subsequently calculating the average value. The surface roughness was quantified through measurement

Table 3. SLM process parameters.

Process Parameter	value
P (W)	100
t (mm)	0.025
v (mm/s)	700 -1000
h (mm)	0.06 - 0.08

3. Results and Discussion

The selective laser melting (SLM) technique was utilized to fabricate samples of CoCrWMo alloy, employing various combinations of process parameters. The objective of this work was to investigate the features of these samples and determine the optimal combination of parameters. A study was conducted to investigate the impact of different scanning speeds on the relative density at two distinct levels of hatch spacing, namely 0.06 mm and 0.08 mm. The relative density exhibited an increase with a decrease in scanning speed, as depicted in Figure 2, while maintaining a constant laser power of 100 W and layer thickness of 0.025 mm. The highest relative density, exceeding 98.0%, was achieved when the scanning speed was set to its lowest setting of 700 mm/s and the hatch spacing was increased to 0.08 mm. The influence of hatch space on relative density is observed mostly at elevated levels of laser power and scanning speed. The relative density experienced a decrease from 98.2% to 94.4% when the scanning speed increased to higher values, leading to a reduction in the energy input. In this scenario, the extent of overlap drops considerably, impeding the complete melting of the powder. Additionally, the absence of a bonding neck between successive phases leads to the creation of pores and a decline in relative density. The level of laser energy received by the powder during the Selective Laser Melting (SLM) process is rather low, resulting in incomplete melting of a significant number of powder particles present in the sample. The liquid phase of CoCrWMo is diminished during the printing process, leading to inadequate filling of cavities and holes in the CoCrWMo samples caused by incomplete powder bed melting. Consequently, the presence of defects is amplified. Furthermore, it can be observed that the microstructure of the specimen has a larger grain size. The form and size of the melt pool are unaffected by variations in scanning speed. The configuration of the molten pool is primarily influenced by the dimensions of the laser focal point, the spacing between successive laser passes, and the trajectory followed by the laser during scanning. The porosity is influenced by the scan speed. This finding is consistent with the study conducted by Shiwen Zou et al. (44), which examined the relationship between scan speed and defect size. The researchers observed that as the scan speed increased, the defect size also tended to increase. Additionally, they found that counterparts produced at higher scan speeds displayed fusion faults that were attributed to an inadequate fusing process. The microstructural analysis revealed that the cellular morphology of the selective laser melting (SLM) CoCrWMo alloy exhibits growth perpendicular to the molten pool border.

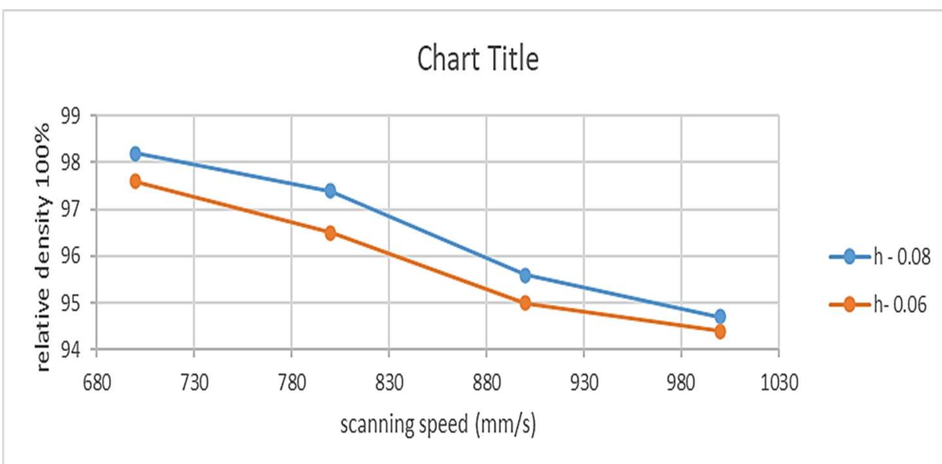

Fig.2: shows density curves for SLM-created Co24.7Cr5Mo5.4W alloys at a range of laser scanning speeds.

Metallographic analyses were conducted on the top surfaces of eight fabricated samples, as depicted in Figure 3, using scanning electron microscopy (SEM) imaging. The aim of this study is to examine the impact of scanning speed and hatch spacing on the surface quality of the produced puros, as indicated by the density and form. The results presented in Figure 5a indicate that the optimal surface can be achieved by employing a lower scanning speed of 700 mm/s and a higher hatch spacing of 0.08 mm. The Volumetric Energy Density (VED) values are 71.42 J/mm3 for a hatch space of 0.08 mm and 95.23 J/mm3 for a hatch space of 0.06 mm. These values suggest that the sample surface is smooth, as depicted in Figure 3a and Figure 3e. The relative density value ranges from 98.2% to 97.6%. The scanning speed and volumetric energy density yield the best results, along with a powder that is tightly bound and exhibits exceptional fusion capability. When the scanning speed is increased to 800 mm/s, the pores on the surface become visible. Additionally, there is a noticeable increase in the number of balling particles, as depicted in Figure 3b and Figure 3f. The observed phenomena can be attributed to an excessive scanning speed, leading to insufficient energy input, which in turn causes incomplete melting of the powder and the subsequent creation of pores. Nevertheless, when the scanning velocity is heightened, and the energy density is diminished, the uppermost layer of powder fails to attain adequate heat for complete powder fusion. Consequently, this leads to a decrease in the formation of strong bonds between the powder particles and the emergence of voids inside the material. As a result, the relative density experienced a reduction ranging from 97.4% to 96.5%. When the scanning speed is increased to 900 mm/s, it is evident from the observations made in (Figure 3 g) that the presence of balling particles and pores becomes apparent on the surface. The energy density inside this particular region is measured to be within the range of 55.55-74.07 J/mm3. The acceleration in scanning velocity has resulted in a reduction of the duration of contact between the powder and laser, leading to a decrease in temperature for certain particles below their respective melting points. Consequently, the powder undergoes partial melting.

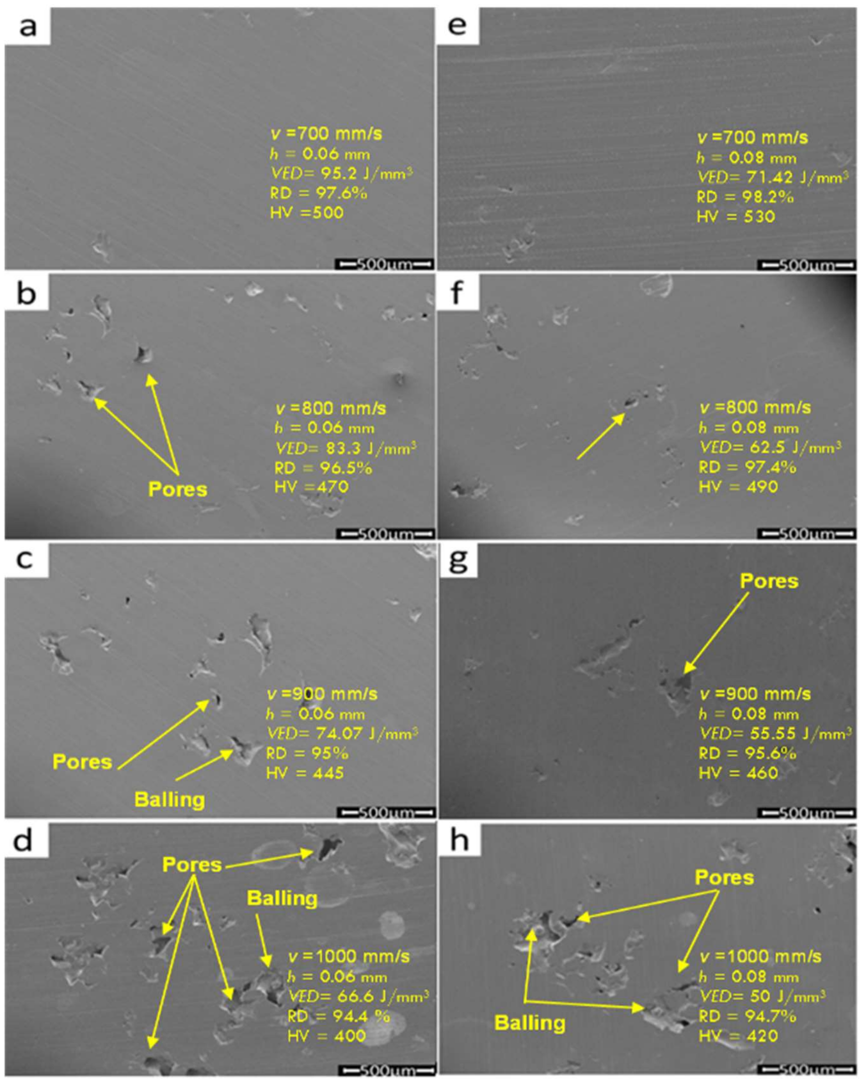

Fig.3: SEM images for Co24.7Cr5Mo5.4W alloy samples produced with different sets of process parameters after mechanical grinding.

In this particular scenario, the fusion of neighboring particles occurs as a result of the substantial generation of liquid material [28]. Nevertheless, it is important to note that the region where agglomeration takes place remains in a condition characterized by the coexistence of both liquid and solid phases.

The observed trend in the relative density of CoCrWMo alloy samples is a reduction as the scanning speeds, which correspond to the energy input, rise. Furthermore, the relative density ranges from 95.6 to 95 percent. When the scanning speed is increased to 1000 mm/s for hatch spaces of 0.08 and 0.06, the corresponding energy values (VED) are found to be 50 J/mm3 and 66.66 J/mm3, respectively. The presence of pores, unmelted powders, and agglomerated balling on the surface is of more concern, as larger-sized pores and balling particles are observed on the surface (Figure 3 d, h). The presence of spherical particles and pores on the surface of the preceding layer has an impact not only on the binding within the same layer but also on the binding across different layers, thereby influencing the overall density of the sample. As seen from the data presented in Figure 3 d and h, The relative density within this range is 94.7-94.4%

The X-ray diffraction (XRD) pattern of the CoCrWMo specimen is depicted in Figure 4. The X-ray diffraction (XRD) analysis reveals that the CoCrWMo alloy displays a combination of two distinct phases, namely the gamma (Ɣ) phase with a crystallographic plane orientation of (111) in a face-centered cubic (FCC) structure and the zeta (ꜫ) phase with a crystallographic plane orientation of (200) in a hexagonal close-packed (HCP) structure. In general, it is seen that CoCr-based alloys undergo a phase transition from the Ɣ (111) phase to the martensite ꜫ (200) phase as they are cooled. The creation of the ꜫ (200) phase occurs as a result of a martensitic transformation triggered by thermal stress. The higher quantity of the FCC (Face-Centered Cubic) phase, denoted as Ɣ (202), is likely retained due to the inhibitory conversion of the metastable Ɣ (202) phase to the martensite ꜫ (200) phase during rapid cooling of the molten pool.

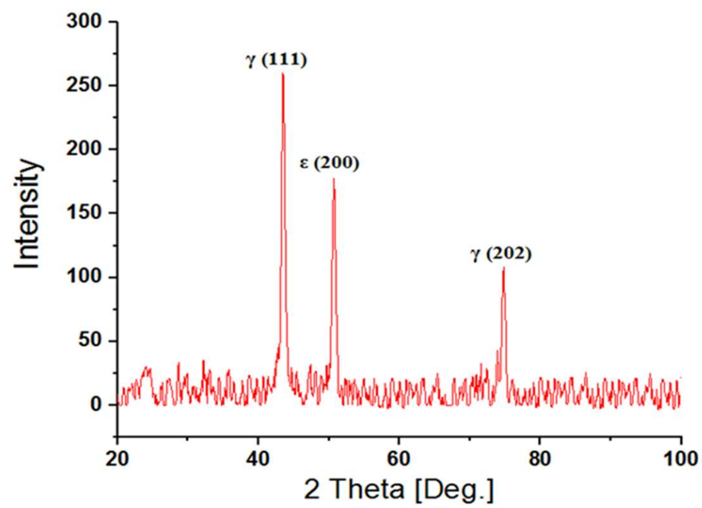

Fig.4: XRD pattern of the CoCrWMo specimen.

Figure 5 displays the microscope image of the CoCrWMo alloy, accompanied by demarcated regions indicating the local microanalysis of its chemical composition. Additionally, the spectrograms of the produced X-radiation are presented in the figure. A comprehensive examination of the notable regions is documented in the table. As depicted in the figure, the matrix of the tested material exhibits a greater concentration of Co and Cr as compared to the eutectic precipitates, wherein Mo, W, and Si are present in higher proportions. The state and texture of a surface, as well as the degree of surface roughness prior to undergoing mechanical grinding, resulted in varying surface profiles across the samples, depending on the specific processing method employed (see Figure 6). All of the samples displayed a comparable surface, characterized by heights ranging from 0.50 to -50 µm for the majority of the specimens. The Ra center line average (CLA), with an average roughness ranging from 20 to 31 µm, was found to have an impact on the friction coefficient, microhardness, and wear resistance of the materials (45).

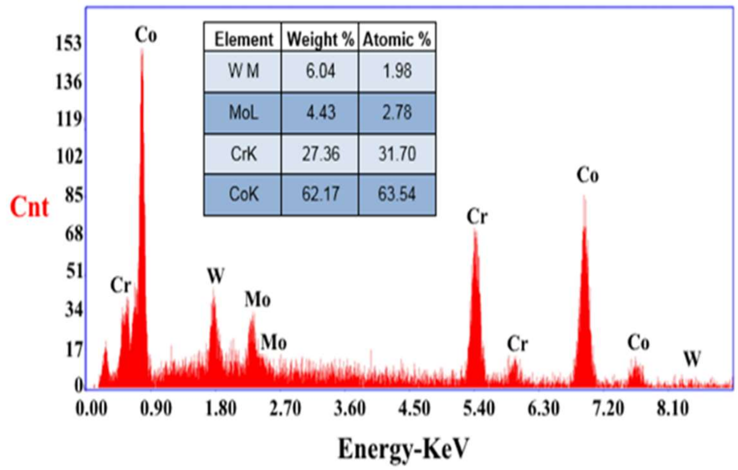

Fig. 5: EDS image spectrogram of Co24.7CrWMo.

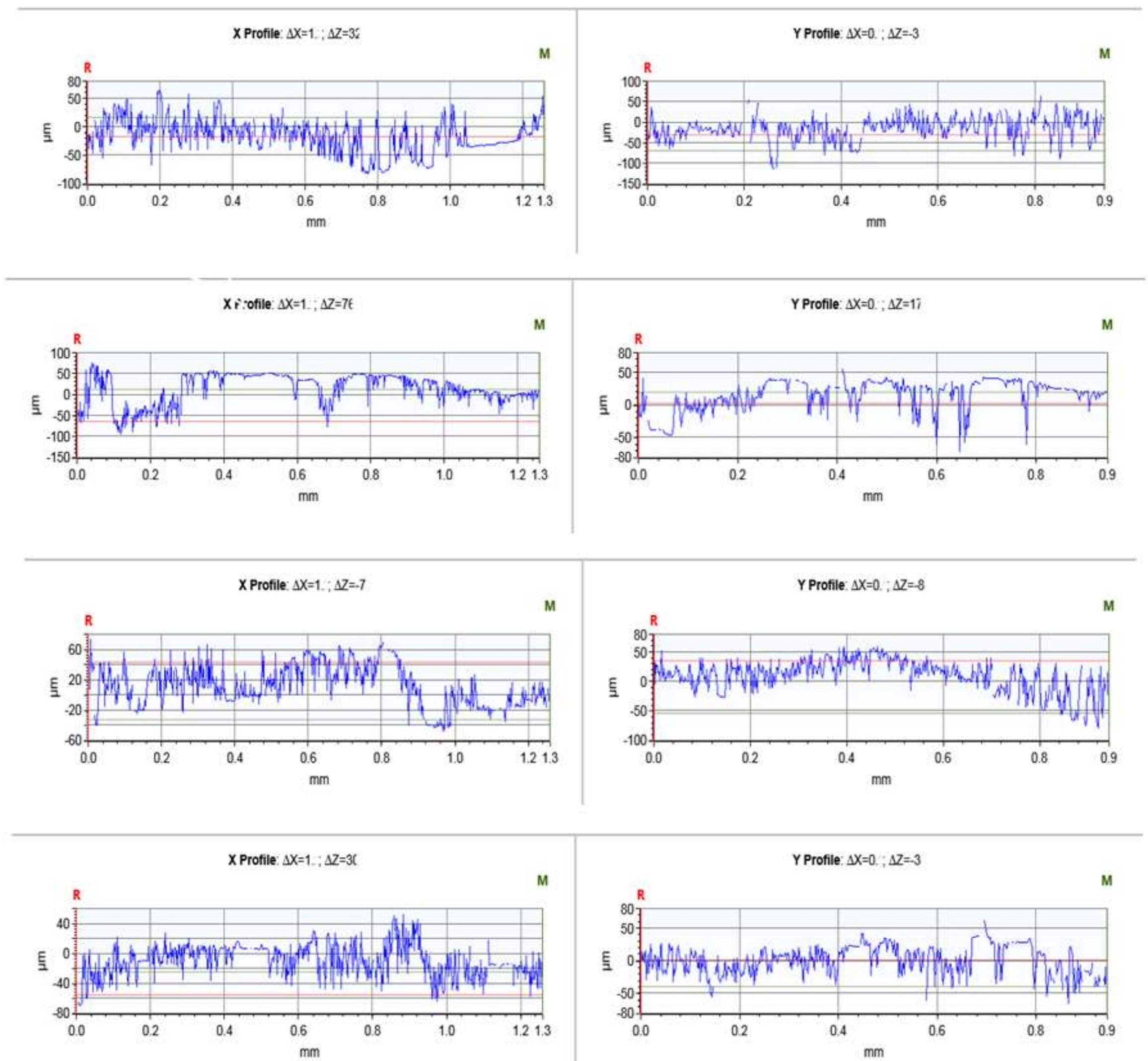

Fig.6: .Profilometry of the surfaces of the samples:(a)v=700mm/s h=0.06 µm ,(b) v=700mm/s h=0.08 µm,(c) v=800mm/s h=0.06 µm (d) v=800mm/s h=0.08 µm,(e) v=900mm/s h=0.06 µm,(f) v=900mm/s h=0.08 µm,(g) v=1000mm/s h=0.06 µm,and(h) v=1000mm/s h=0.08 µm.

The sample with a height of 30 µm had a relatively large average amplitude in the height direction (Rq), while the sample with the smoothest surface had the smallest Rq value (Table 2). In order to assess a surface state in the vertical direction, two parameters were employed: The Rp, Rv, and RT metrics validate that the samples subjected to Al_2O_3 and SiO_2 sandblasting exhibited the most polished surface, with the sample displaying the most pronounced profile variations and the sample showcasing the least pronounced profile differences (indicating the finest surface).

The CoCrWMo alloy produced via the process of selective laser melting is depicted in Figure 7. The plot illustrates the relationship between surface roughness and laser bulk energy density prior to the application of mechanical grinding, encompassing all relevant data points. Upon analysing the dispersed data points, it becomes evident that the process under consideration is selective laser melting (SLM) formation. The increase in energy density leads to a decrease in the top surface roughness (Ra) of the CoCrWMo alloy. Choose a representative specimen for surface analysis in the context of selective laser melting (SLM) additive manufacturing. In terms of morphological observation, Figure 7 displays the samples that have been generated using varying laser volume energy densities.

The observation reveals that when the laser bulk fluence is low (50 J·mm−3), a significant quantity of unmelted powder accumulates on the sample's surface. Additionally, the melting channel exhibits discontinuity, resulting in inadequate lapping effects. These outcomes can be attributed to the laser body's lower energy density. The high thermal energy poses challenges in achieving complete fusion of the powder, while the surface roughness is around 29 µm. The laser bulk energy density applied to the surface of the sample was measured to be 71 J·mm−3. The melting channel has a significant degree of overlap, demonstrating a continuous nature, with little instances of unmelted powder adhesion. Furthermore, the reduction in surface roughness is observed to be 25 µm. At elevated levels of laser bulk energy density (95 J mm−3), the melting channel observed on the surface of the lower sample exhibits enhanced smoothness and straightness, accompanied by a progressive reduction in surface roughness. The laser bulk fluence results in the generation of heat, which can cause the size to decrease to as low as 20 µm. Excessive elevation of temperature might result in the vaporisation of a portion of the powder, leading to the formation of circular voids.

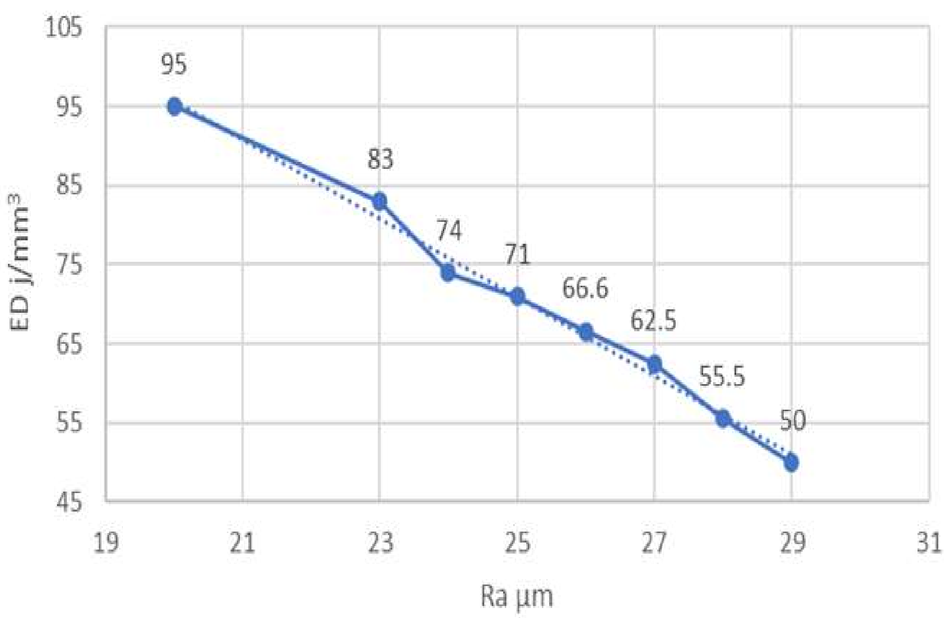

Fig. 7: Surface Roughness of Co24.7Cr5Mo5.4W alloys produced with SLM using different volumetric energy densities before mechanical grinding.

It is widely recognized that surfaces exhibiting elevated roughness levels, indicative of lower quality, tend to possess diminished fatigue resistance. Conversely, surfaces characterized by reduced roughness, signifying higher quality, exhibit enhanced fatigue resistance, as well as heightened resistance to corrosion. The excessive refinement of surfaces, resulting in a significant reduction in roughness, does not necessarily guarantee improved functionality of the components. In fact, it often leads to an unwarranted increase in production costs. Based on the data shown in Table 3 and Figure 8, an observation can be made regarding the relationship between surface roughness following mechanical grinding followed by a polishing procedure and volumetric energy density. The upper limit for roughness, as measured by the arithmetic average height (Ra), is 29 µm .The present study emphasizes the enhanced efficiency of mechanical grinding (MG) subsequent to selective laser melting (SLM) processing, as evidenced by a notable decrease in roughness values (Δ Ra) by 35%. One potential approach for analyzing the experimental results involves considering the energy density (VED). In this particular scenario, it is worth noting the following:

The specimens subjected to non-mechanical grinding (MG) exhibited the lowest roughness values when processed using selective laser melting (SLM) with an energy density (ED) of 95. The optimal settings of technological parameters for mechanical grinding (MG) specimens are often recommended to have a VED value of 95J.mm^{-}3. The present study used a synthetic analysis to examine the findings, specifically focusing on the roughness (Ra) aspect. It is advisable to consider specific combinations of values for the two technological parameters, denoted as (H) and (vscan). The value of h is 60 µm, and the value of v is 700 mm/s. The present study employs a synthetic analysis to examine the findings, specifically focusing on the perspective of roughness (Ra).

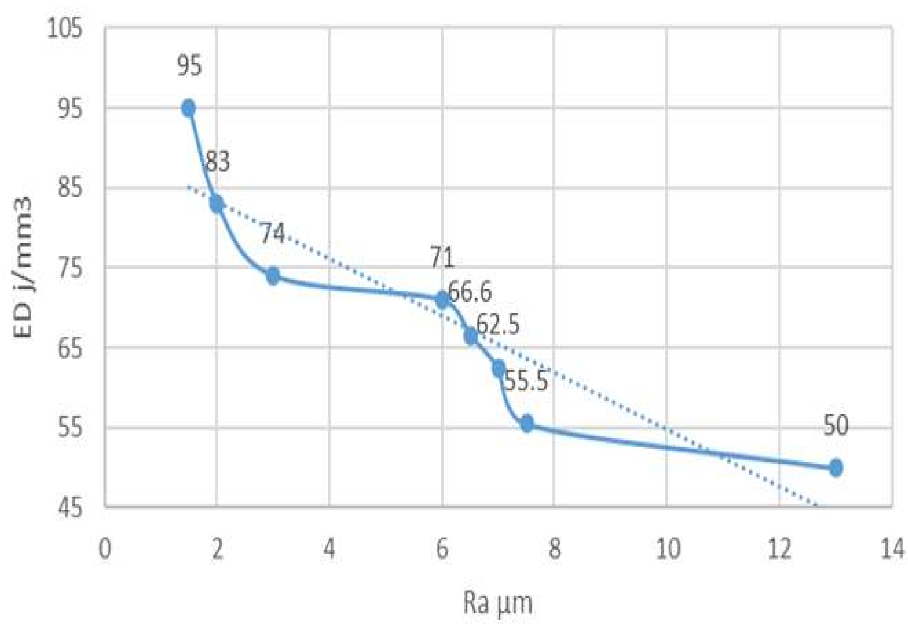

Fig. 8: Surface Roughness of Co24.7Cr5Mo5.4W alloys produced with SLM using various energy density after mechanical grinding.

Table 4. Surface Roughness of Co24.7Cr5Mo5.4W alloys produced with SLM using various energy density before and after mechanical grinding**.**

Ra(µm) before	Ra(µm) after	ED(j/mm^{-3})
29	13	50
28	7.5	55.5
27	7	62.5
26	6.5	66.6
25	6	71
24	3	74
23	2	83
20	1.5	95

The conducted experiments indicate that values of hatching space less than 60 µs and scanning speeds below 700 mm/s are not advisable for the selective laser melting (SLM) processing of the Co-Cr-W powder. This is due to the detrimental impact on the energy density (Ed), which in turn negatively affects the selective melting and solidification processes of the metal powder. One of the immediate outcomes of insufficient selective laser melting (SLM) processing is the production of exterior surfaces with elevated roughness.

4. Conclusions

The study discusses the utilisation of the Selective Laser Melting (SLM) technique employing a laser beam to treat Co-Cr-W metal powders. Eight sets of specimens were created using varied values of the variable technological parameters, namely hatching space (H), scanning speed (vscan), and energy density (VED). Measurements of roughness (Ra) were performed on surfaces subjected to mechanical grinding and non-mechanical grinding techniques. Based on the observed exterior surface roughness, the following conclusions have been derived.The optimal parameter combinations for non-mechanical grinding and mechanical grinding are determined to be H = 60 µm and vscan = 1000 mm/s. From a volumetric energy density (ED) perspective, it is not advisable to use scanning speeds (vscan) above 700 mm/s and pulse durations (H) exceeding 80 µs for selective laser melting (SLM) processing of Co-Cr-W powders, as these parameters will lead to elevated roughness values.

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تأثير سرعة المسح عل سبيكة الكوبلت كروم ملبوديوم تنكستن المبنية عن طريق ذوبان الليزر الانتقائي على خصائص الخشونة

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الخلاصة:اكتسب استخدام الصهر بالليزر الانتقائي (SLM) في إنتاج العناصر المعدنية المعقدة اهتمامًا كبيرًا في قطاعي الطب وطب الأسنان. يجب أن تمتلك المنتجات التي تم إنشاؤها باستخدام SLM أسطحًا تظهر درجة عالية من النعومة. الهدف من هذا البحث هو دراسة تأثير معلمات عملية الليزر المختلفة، وتحديداً معدل المسح وتباعد الفتحات على خشونة السطح لسبائك الأسنان Co-Crالمصنعة في ثلاثة أبعاد (3D) بواسطة تقنية الذوبان بالليزر الانتقائي .(SLM) تشير النتائج إلى أن سرعة المسح البالغة 700 مم/ثانية تنتج مورفولوجيا سطحية وبنية مجهرية فائقة. أسفرت دراسة المعلمات التي أجريت في هذه الورقة عن تحقيق كثافات نسبية تصل إلى 98.9٪ لقطع العمل المبنية بشكل إضافي. تركز الدراسة الحالية على دراسة خشونة السطح في سبائك Co-Crالمصنعة باستخدام تقنيات تعدين المساحيق، وهي الذوبان الانتقائي بالليزر.