



Assessment of Microstructure, Porosity and Hardness of Plasma Sprayed Nanostructured YSZ-alumina Composite Coatings on 316L Stainless Steel

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ABSTRACT

AISI 316L stainless steel is extensively used in various engineering applications owing to its ability to resist corrosion and mechanical stability; however, the material suffers from limited tribological behaviour in view of its limited hardness and poor wear resistance. Though atmospheric plasma-sprayed (APS) YSZ–Al₂O₃ coatings have the promise to improve the surface characteristics, there is little information available on synergistic impacts of plasma power (PP) and stand-off distance (SOD) for the nanostructured 70 wt.% 8 mol.% yttria-stabilised zirconia (8YSZ)–30 wt.% Al₂O₃ coatings on AISI 316L stainless steel. This study systematically investigates the deposition of nanostructured 70YSZ–30Al₂O₃ composite coatings onto AISI 316L substrates through APS by varying the PP level at 20, 25 and 30 kW and SOD at 100 and 120 mm. Coating microstructure, porosity, surface roughness (Ra) and microhardness were evaluated using optical microscopy and standard testing procedures. The findings revealed that PP and SOD influences more on the coating's microstructure and mechanical properties. It was observed that the coating deposited using 30kW PP and 100 mm SOD exhibited a lower porosity level and higher microhardness value as compared to the other conditions. The porosity level, microhardness and Ra of the coating under 30kW PP and 100mm SOD yielded 5.63%, 914H V0.3 and 6.09 µm, respectively. The enhancement in hardness and reduction in porosity level and Ra is due to enhanced particle melting and reduced unmelted particles, resulting in denser splat formation at higher PP and moderate SOD. The results showed that the micro-mechanical properties of the 70YSZ–30Al₂O₃ coatings can be successfully controlled by adjusting the PP and SOD, which provides a new perspective for the development of wear-resistant surfaces for 316L SS components for industrial applications.

Keywords: Atmospheric plasma Spraying; Plasma power; Stand-off distance; YSZ–Al₂O₃ composite coating; 316L stainless steel; Porosity; Microhardness.

1. INTRODUCTION

AISI 316L stainless steel is extensively utilised in numerous engineering fields such as heat exchanger units, chemical processing machinery, and naval applications because of its superior corrosion resistance and thermal endurance. However, the disadvantage of this material is its inadequate hardness (~200 Hv) and wear resistance, which restricts its suitability for tribological applications under sliding conditions (Misra *et al.* 2020). Therefore, it is necessary to prevent surface degradation of the SS 316L by enhancing the wear resistance. Several surface modification techniques were recently explored to enhance the SS 316L wear resistance, including nitriding (Matijošius *et al.* 2024), carburising (Zhang *et al.* 2023a), laser surface processing (Lin *et al.* 2024), anodising (Allal *et al.* 2022), and PVD coatings (Ichou *et al.* 2024). However, the surface modification described above is effective to make the 316L type stainless steel (SS 316L) harder and more wear-resistant; it normally modifies the surface only by a few micrometres. For instance, conventional

diffusion treatments such as nitriding typically modify only 5–50 µm of the surface (Matijošius *et al.* 2024), which can be rapidly removed under severe wear conditions. To achieve thicker protective layers, thermal-sprayed ceramic coatings have attracted significant attention.

APS is a versatile technique to deposit thick ceramic coatings for wear and corrosion protection at elevated temperatures. Recently, ceramic coating has garnered greater interest to enhance the material's surface properties. Plasma-sprayed ceramics are key to high-efficiency applications such as aviation turbines and power infrastructure (Karthikeyan *et al.* 2025a; Karthikeyan *et al.* 2025b). A few ceramics such as Al₂O₃, ZrO₂, yttria stabilised zirconia (Manivasagam *et al.* 2015), TiO₂ (Sundaraselvan *et al.* 2025) and TiC (Senthilkumar, 2024) are commonly used to offer thermal protection, resistance to wear and to resist corrosion at extreme temperatures. Among several ceramic powders, Al₂O₃ and YSZ have gained greater importance to boost the surface qualities of materials.

Al₂O₃ is an essential ceramic coating material that offers high hardness and chemical stability, while 8 mol% yttria-stabilised zirconia (YSZ) provides phase stability and thermal insulation (Han *et al.* 2024).

Recently, the investigators have concentrated on a new ceramic combination for protecting the surface degradation of materials from different severe environments. A significant number of studies showed that YSZ-Al₂O₃ coatings created by plasma spraying provide greater wear resistance and are very beneficial for extremely fast and extreme load-bearing applications (Perumal *et al.* 2014; Zhao *et al.* 2008). Al₂O₃-incorporated with a YSZ matrix composite coatings exhibit superior hardness, wear resistance, corrosion resistance, and stable phase structure, compared to monolithic Al₂O₃ or YSZ, due to synergistic toughening effects (Han *et al.* 2022; Zhang *et al.* 2023b). Earlier investigations have shown that YSZ-Al₂O₃ coating is suitable for harsh service environments. (Tesar *et al.* 2026) examined plasma sprayed hybrid coatings consisting of an Al₂O₃ matrix with oxides such as Cr₂O₃, TiO₂, YSZ, ZrO₂ deposits and compared them to an alumina coating. Among the four hybrid coatings, the Al₂O₃-YSZ and Al₂O₃-ZrO₂ coatings show better performance in terms of porosity, microhardness and wear resistance (Tesar *et al.* 2026). (Dai *et al.* 2022) investigated the effect of microstructure changes in Al₂O₃-YSZ coatings on thermal cycle life. The report revealed that the tetragonal zirconia present in the coating has improved spallation resistance with low micro-strain in thermal cycling of Al₂O₃-YSZ coatings (Dai *et al.* 2022). Zirconia and alumina have been shown to work well together in several outstanding durability composite systems, including alumina-toughened zirconia (Li *et al.* 2022). The 70 wt.% YSZ–30 wt.% Al₂O₃ composition is of particular interest because 20–40 wt.% Al₂O₃ additions enhance mechanical properties without compromising the tetragonal phase stability of YSZ effects (Zhang *et al.* 2023b).

However, the most crucial factor in achieving advantageous coating properties like minimal porosity, excellent hardness, high bonding strength of coating with substrate, and an appropriate structure is crucial for longer life and superior service performance. Among the various thermal spraying methods, APS emerged as reliable method to deposit ceramic materials due to its unique advantages. The performance of APS coatings is strongly governed by plasma processing parameters, which control particle melting, molten particle velocity, and solidification. Plasma power (PP) determines jet enthalpy and particle temperature, while stand-off distance (SOD) influences particle velocity and cooling before impact (Fernández *et al.* 2023). These aforementioned criteria are varied on different types, sizes, and forms of feedstock materials. Recent investigations have correlated spray conditions with

coating performance using online diagnostic methods such as in-flight particle temperature, digital image and design of experiments (Fernández *et al.* 2023). It has been shown that increasing the PP increases particle temperature and velocity that improves particle melting then reduces porosity, leading to higher hardness (Li *et al.* 2024; Song *et al.* 2020). On the other hand, excessive SOD could lead to porous coatings with unmelted or partially melted particles by causing the particles to cool before the impact (Klenam *et al.* 2023; Liu *et al.* 2025). While (Misra *et al.* 2020) noticed that ideal settings for PP resulted in better hardness of YSZ, the combined effect of PP and SOD was not decoupled (Misra *et al.* 2020). (Aruna *et al.* 2012) reported that the denser coatings and hardness were strongly dependent on the PP and SOD during the spray deposition procedure, but used conventional micro-sized powders (Aruna *et al.* 2012).

Despite extensive work on YSZ-Al₂O₃ coatings for thermal barrier applications (Mehta and Vasudev, 2025), studies focusing on their tribological performance are limited. Moreover, the combined effects of PP and SOD on the micro-mechanical properties of nanostructured 70YSZ–30Al₂O₃ coatings on SS 316L remain unreported so far. To our knowledge, this is the first study to correlate PP and SOD with porosity, surface roughness, and microhardness for this coating system.

Therefore, this study aims to evaluate the effect of PP (20, 25, 30 kW) and SOD (100, 120 mm) on the microstructural characteristics, porosity, surface roughness, and micro-hardness of APS-deposited nanostructured 70YSZ–30Al₂O₃ composite coatings on SS 316L. This study addresses the gap by establishing process-structure-property relationships for key APS parameters. The results are expected to provide a processing window to achieve dense, hard 70YSZ–30Al₂O₃ coatings, enabling enhanced wear resistance of 316L components in demanding engineering applications.

2. MATERIALS AND METHODS

2.1 Materials

SS 316L plates with dimensions of 25 × 35 × 5 mm³ were used as the substrate. Table 1 shows the element makeup of the SS 316L material. Commercially available nanosized powders of yttria stabilised zirconia (8 mol% Y₂O₃) with 45nm mean diameter and Al₂O₃ powders with 30nm mean diameter, both >99.5% purity, served as the feedstock particles. To produce sprayable 8YSZ-Al₂O₃ feedstock, 70 wt.% 8YSZ and 30 wt.% Al₂O₃ nanoscale powders were ball-milled for 30 h using ZrO₂ milling media in ethanol wet-mixed condition and ball-to-powder weight ratio was 10:1 at 300 rpm. The wet-mixed slurry then sprayed using a

laboratory spray dryer with an entry temp. of 250 °C, exit temperature of 120 °C, atomization pressure of 0.3 MPa, and feed rate of 25 ml/min.

Table 1. Chemical composition of SS 316L

C	Mn	P	S	Si	Ni	Cr	Mo	N	Fe
0.034	2.01	0.045	0.031	1	12	17	2.5	0.1	Bal

2.2 Development of Plasma Spray Coatings

The coatings were developed using a 40 KW Metco 3MB plasma gun APS system. Before coating deposition, substrate surfaces were grit-blasted by 24 mesh Al₂O₃ grit at 0.5 MPa pressure, stand-off distance was 100 mm, and 90° blast angle to achieve a surface roughness of Ra = 6µm. The substrates were ultrasonically cleaned in acetone for 5 min and preheated to 150 °C immediately before deposition (Thirumalaikumarasamy *et al.* 2015). All composite powder was directly placed on SS 316L substrate without bond coating to evaluate the direct coating-substrate interaction. The impacts of the PP and SOD on the characteristics of the coating were investigated for different PP and SOD. PP was varied at 20, 25, and 30 kW, and SOD at 100 and 120 mm to produce four coating conditions, designated C1–C4, as shown in Table 2. All other parameters were held constant during the experimental period. The primary (Ar) gas flow is 40 lpm, the secondary (H₂) gas flow is 10 lpm, the powder flow rate is 20 g/min, the carrier gas flowrate is 4 lpm, gun traverse speed 450 mm/s, and powder injection angle 90°. All the parameters utilised for the APS process are listed in Table 3. Three samples were produced for each parameter setting to ensure reproducibility.

Table 2. Symbols for coatings developed using different plasma parameters

Symbols	Plasma Power (kW)	Stand of distance (mm)
C1	20	100
C2	25	100
C3	30	100
C4	30	120

Table 3. Plasma parameters used in this study

Parameters	Levels
Plasma input power (kW)	20, 25, 30
Stand of distance (mm)	100, 120
Primary gas flow rate (lpm)	40
Secondary gas flow rate (lpm)	10
Carrier gas flow rate (lpm)	4
Powder feed rate (g/min)	20

2.3 Characterization

An optical microscope (Inverted Trinocular Metallurgical Microscope equipped with De-winter Material plus version-2 software) was used to examine the coatings' cross-sectional morphology. For microstructural analysis, coated samples were sectioned, cold-mounted in epoxy, and polished using standard metallographic procedures down to 0.05 µm using various grades of SiC emery sheets. Coating thickness was measured at 5 locations per sample from optical micrographs. Image analysis software was used to assess the porosity at the cross-section of the coatings. Five optical micrographs for each coating at 200X magnification were used for the porosity measurement and were averaged to determine the porosity value. For porosity measurements, images were converted to 8-bit, thresholded using the Otsu method, and analysed over a 500 × 400 µm² area per image. The Surftest SJ-210 series roughness tester with a cut-off length of 0.8 mm, evaluation length of 4 mm, and traverse speed of 0.5 mm/s, according to ISO 21920-2, was used to assess the surface roughness of the as-sprayed coating. Roughness statistics were obtained by averaging the findings from five measurements. According to ASTM E384, A digital microhardness tester (HDNS-Kelly Instruments, China) was used to measure the Vickers microhardness on the coatings' cross-section using a 300g load for 15 seconds (Tamrakar *et al.* 2025). To ensure that the data was reliable, the hardness was assessed at ten different locations at the mid-thickness region of each coating to avoid substrate and surface effects. All quantitative results are averaged, and the mean value was reported.

3. RESULTS AND DISCUSSION

3.1 Microstructural Characterisation

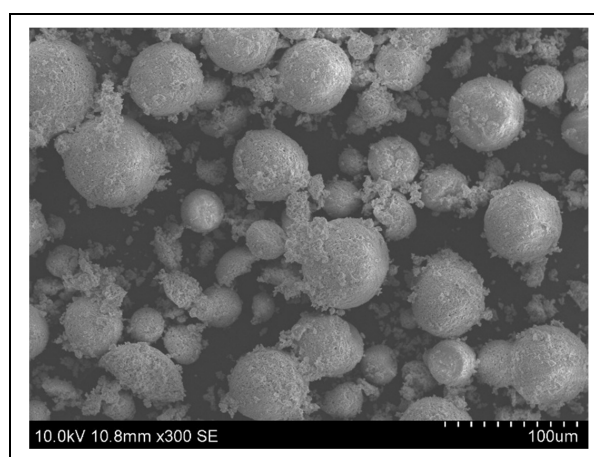


Fig. 1: SEM image of 8YSZ-30wt%Al₂O₃ spray-dried powder

Figure 1 shows the SEM picture of the spray-dried agglomerated particles, exhibits a spherical shape ranging from 30–45 µm diameter in average. The

spherical shape improves powder flowability during plasma spraying (Iovane *et al.* 2024).

Fig.2 displays optical microscope (OM) images of the 8YSZ-30 wt% Al_2O_3 powder coatings prepared under experimental conditions C1, C2, C3, and C4. It shows that the coating thickness varies between 250 ± 14 and $300 \pm 12 \mu\text{m}$, depending on PP and SOD. The micrographs of all the coatings showed a reasonably dense and homogeneous coating structure. All the coatings display a lamellar, porous structure characteristic of this type of coating (Yang *et al.* 2022), with dark patches indicating pores scattered within the coating matrix.

The plasma spraying procedure parameters substantially influence the coating's morphology. The splats are separated by interlamellar pores following quick solidification of the lamella, very small voids that are generated by incomplete intersplat interactions or surrounding unmelted particles and cracks due to thermal stresses and tensile cooling-induced relaxation stresses (Odhiambo *et al.* 2019). From the optical microscopy images, it is possible to notice the disparity of the porosity for the various coatings and also its variability from the interface with bonding to the substrate surface.

The coatings achieved under C1, C2 and C3 conditions show more pores of different sizes at the coating cross-sections. At the coating-substrate interface, tiny microcracks are also seen. These cracks result from the thermal strains that are caused by a swift cooling during the spray process (Tao *et al.* 2023). C3 coating shows a considerably reduced porosity level, demonstrating enhanced particle melting and deposition behaviour. Moreover, the interface between coating and substrate seems uninterrupted and defect-free with no obvious cracks or delamination, indicating strong interfacial bonding between coating and Substrate (Wang *et al.* 2013). This is because an increased PP that ensures substantial melting and increases the molten particle velocity sufficiently. Further, moderate SOD prevents the inflight solidification of melted particles before the impact over substrate material. This can be related to effective particle spreading and flattening during the plasma spraying technique (Liu *et al.* 2026). Furthermore, the coatings fabricated under C3 and C4 circumstances exhibit homogeneous and smooth surface morphology. In general, the coatings generated under C3 conditions show better quality than C4, due to the combined effect of increased PP and moderate SOD.

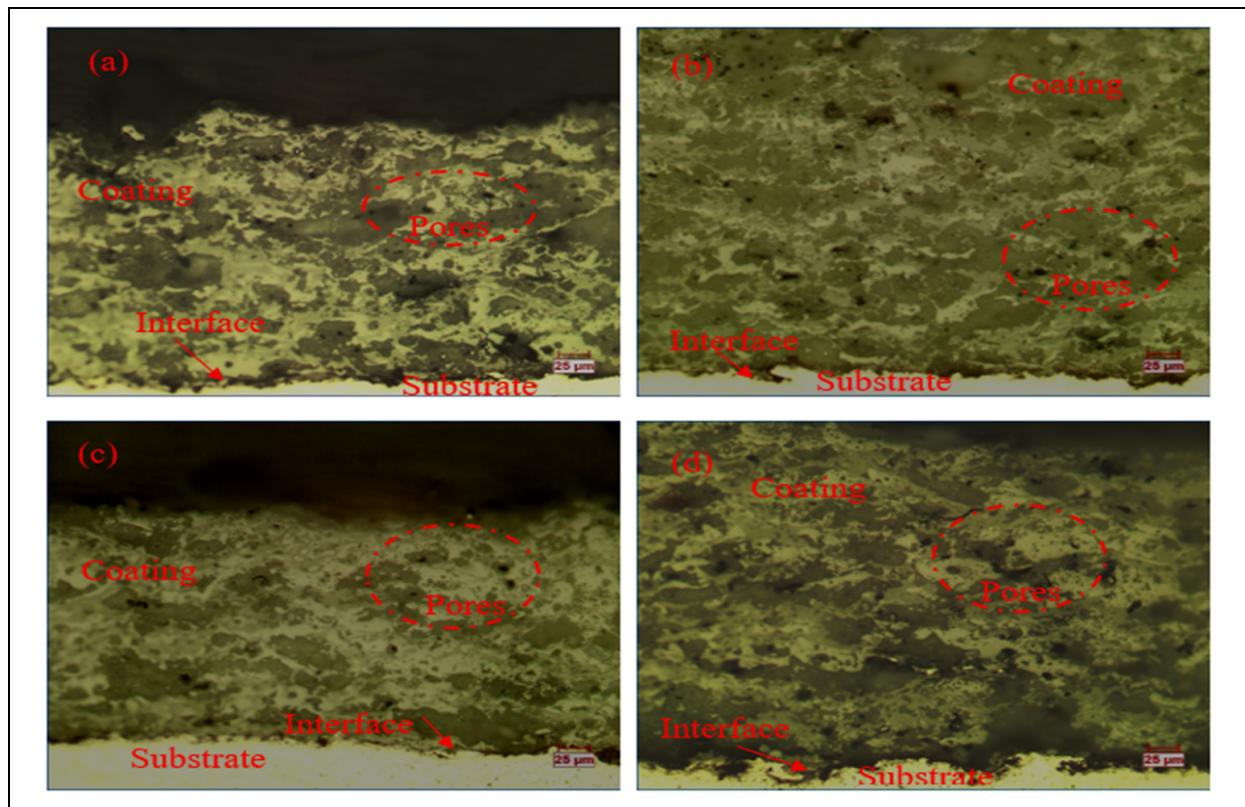


Fig. 2: Optical microstructure of coatings (a) C1 (b) C2 (c) C3 and (d) C4

3.2 Porosity

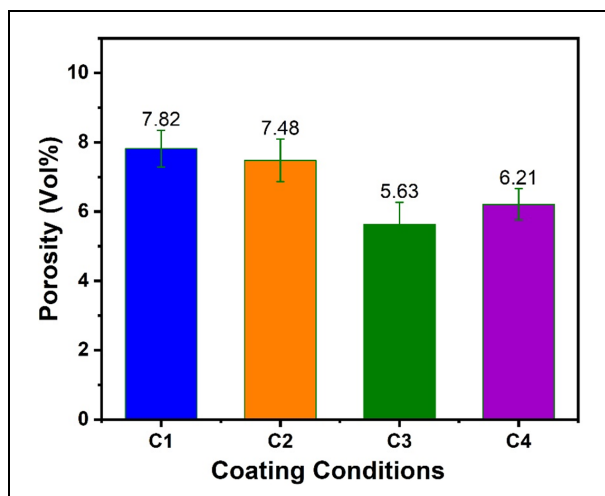


Fig. 3: Effect of plasma spray parameters on porosity

The coatings' porosity can be evaluated both quantitatively and qualitatively by microstructural inspection and image analysis techniques. Optical micrograph of coating cross sections is presented to allow direct analysis of the coating's microstructure as well as comparative information about porosity for the different coatings. The grey level fluctuation in the pictures is related to the composition of the microstructure. The pores are quite black and thus can be recognised and quantified by image analysis. Pores were recognised by thresholding the brightness of the pores to form a binary picture, then the dark area portion in the binary image was analysed, and the percentage of pores was calculated (Ziel *et al.* 2008).

The porosity values of each layer were estimated by ImageJ software as presented in Fig.3. The binary mask image of the coating from ImageJ used for porosity analysis is presented in Fig.4. The threshold was adjusted such that the pores are shown in white and the coating in black. Percentage of coating porosity was defined as the area proportion of white pixels in the matrix. The Figures show that porosity decreases significantly when the PP increases from 20 to 30 kW. Minimum porosity was observed in the coating created under C3 conditions (30 kW, 100 mm), with the value being 5.63%. It is 1.38, 1.32 and 1.1 times lower than the coatings created under C1, C2 and C4 settings, respectively. This porosity reduction is attributed to the better melting and densification of the particles (Odhiambo *et al.* 2019). This is attributed to deposition at 30 kW PP and moderate SOD of 100 mm. These parameters ensured extensive melting of the feedstock powder and provided sufficient kinetic energy for spreading and flattening of molten particles, resulting in coating densification and reduced porosity (Mathanbabu *et al.* 2022). The largest porosity level was observed in the coating created under C1 conditions, which is 7.82%, because this coating is developed using lower plasma power (20kW, 100mm SOD). At lower PP, limited particle melting happens because of lesser heating energy input. This results in the poor splat spreading and flattening, increasing the porosity of the coating (Grimm *et al.* 2025). In the coating developed under C4 conditions, the porosity increases little as the SOD increases from 100 mm to 120 mm because the completely melted particles solidify before impacting the substrate. These observations correlate well with the microstructure study of the coatings

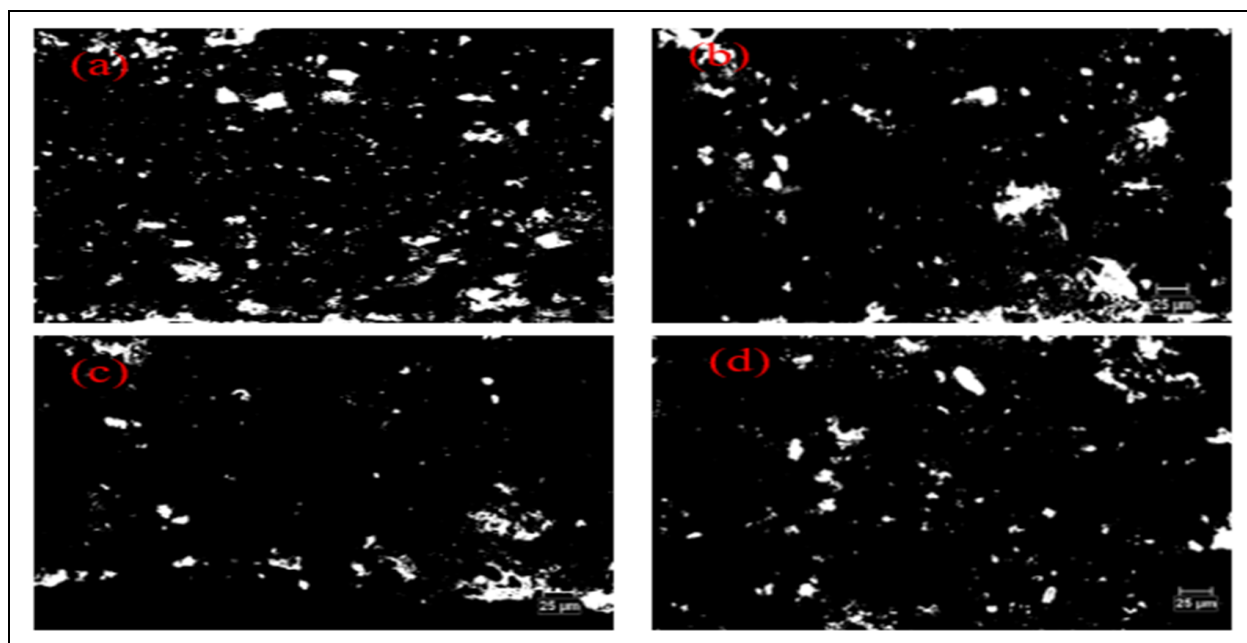


Fig. 4: Binary mask image of coating from ImageJ used for porosity analysis C1 (b) C2 (c) C3 and (d) C4

3.3 Surface Roughness

Fig.5 displays the coatings' surface roughness. The surface roughness of the composite coatings decreased with increased plasma power, as shown in Fig.5. The lowest roughness value ($6.09\ \mu\text{m}$) is observed in the coating created at C3 condition (30 kW, 100 mm), indicating improved particle melting and uniform flattening of the splats. This condition ensures substantial particle melting, provides adequate kinetic energy to the molten particles and impedes premature solidification of particles before their impact on the substrate, resulting in improved deformation and smoothing of splats, which leads to lower surface roughness (Noureen and Javid, 2025). A higher roughness value was observed in the coatings developed at lower PP (C1 and C2), which is due to incomplete melting and poor spreading and flattening of molten particles on the substrate. An increased SOD to 120 mm (C4) results in slightly higher roughness due to premature solidification of molten particles, leading to poor spreading and flattening over the substrate. Overall, higher PP combined with moderate SOD produces smoother coating surfaces (Tankal *et al.* 2024) Top of Form

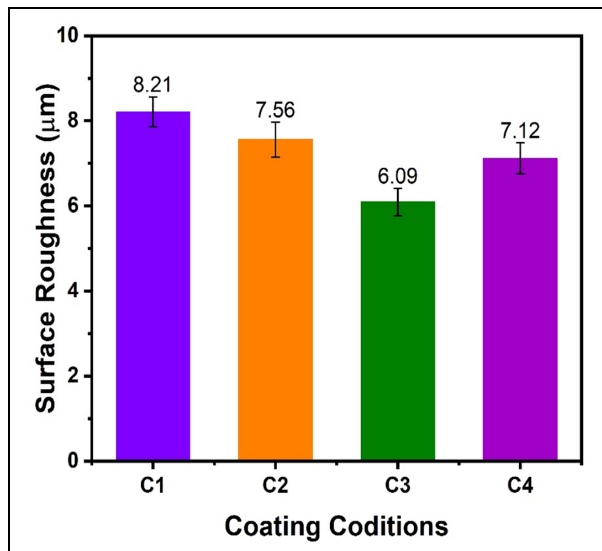


Fig. 5: Effect of plasma spray parameters on surface roughness

3.4 Microhardness

Fig. 6 demonstrates the coating microhardness developed in different spray parameters. It can be seen that the composite coatings microhardness increases with increasing PP from 20 kW to 30 kW. The average microhardness of the composite coating developed in C3 condition is higher than that of the coatings developed at other conditions. The micro hardness of the coatings created at C3 condition reveals 1.07, 1.06 and 1.01 times higher than the coatings created at C1,

C2 and C4 conditions, respectively. Further, the microhardness value obtained for all developed coatings at different plasma spray settings is higher than that of the 316L SS manufactured through a hybrid laser wire and laser powder bed additive approach, which exhibited microhardness value are in the range of 169 to 239 Hv (Keller *et al.* 2025). The highest hardness value observed in the coating created at condition C3 is 914Hv, indicating superior coating densification. Lower hardness observed in the coatings created at C1 and C2 conditions is attributed to higher porosity and incomplete particle melting. Increasing SOD to 120 mm (C4) slightly reduces hardness due to prior solidification while travelling the molten particles to a longer distance, resulting in poor spreading and flattening on the substrate (Thirumalvalavan *et al.* 2025). Overall, higher PP and moderate SOD enhance coating hardness significantly (Bhosale and Rathod, 2020). The changes in the microhardness value of the current work aligned with the previous research (He *et al.* 2018). It revealed that the microhardness increased from 540 to 605Hv with alumina contents varied from 10 wt% to 55 wt%. This enhancement is attributed to alumina addition that helps to fill the voids created by the pre-solidified YSZ splats.

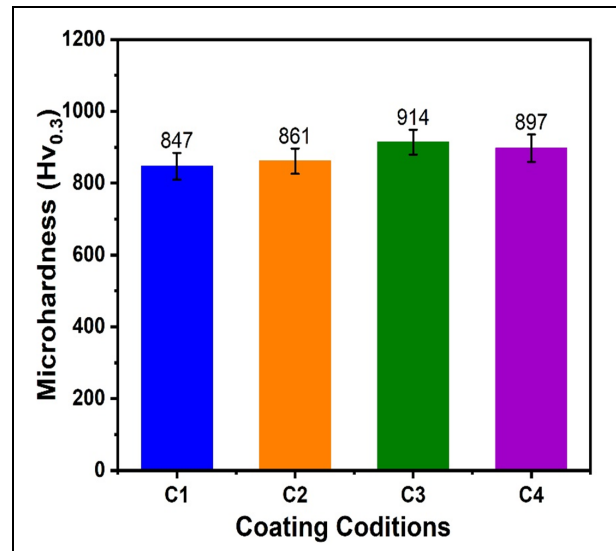


Fig.6: Effect of plasma spray parameters on microhardness

The outcomes demonstrated by Figs. 2 through 6 show the effect of APS parameters on coatings efficacy. Whenever PP increases from 20 kW to 30 kW that improves particle melting, resulting in improved coating densification. This is the reason for the higher microhardness values and reduced porosity level observed in the coatings created under C3 conditions. Generally, the higher PP resulted in the low the porosity and the improved hardness of the coatings. The increased PP led to an enhancement of the plasma plume temperature and a higher particles kinetic energy, which shows more rigid bonding between the splats, the

decrease in coating porosity and the increase of the hardness (Zou *et al.* 2021). The influence of plasma power on the hardness and porosity of NiCrAlY/8YSZ coating was studied in previous works, and it was found that hardness increases with increasing PP. This study showed that raising the PP from 24.75 to 34.8 kW, the hardness and bond strength was improved from 682 to 818 HV and 12.48 to 22.49 MPa, respectively. The porosity analysis also shows the reduction of the coating's porosity from 22.59% to 18% with the increase of the PP (Kiasati *et al.* 2018). Simultaneously, surface roughness decreases due to better splat formation and uniform particle spreading. The microstructural observations of coatings developed at C3 settings, as shown in Fig.2, further confirm a dense, homogeneous coating with minimal porosity and better interfacial bonding between the substrate and coatings. However, increasing the SOD from 80 to 120 mm (C4 condition) leads to slight deterioration in coating properties, including reduced hardness, increased roughness and porosity. This is attributed to earlier cooling of molten particles before impact on the substrate, which limits proper spreading and flattening. Under such a situation, the impingement of particles over the substrate will not be flattened effectively to fully cover the layers, resulting in larger porosity and decreases the hardness values (Abbas *et al.* 2021). Overall, the optimized condition C3 (30 kW, 100 mm) yields superior coating characteristics. The combined analysis confirms that higher PP and moderate SOD are critical for achieving dense, smooth, and mechanically robust 8YSZ–30 wt.% Al₂O₃ composite coatings. These advantageous qualities were obtained in the prior investigations. At moderate SOD, the increased molten droplet temperature and sufficient kinetic energy allow the emerging molten droplets to be able to flow viscously and spread effectively. Thus, the splats are flattened, and the intersplat spaces are effectively packed. This condition has a positive influence to reduce the porosity and enhanced hardness (Sobhanverdi and Akbari, 2015). The limitation of this work is that the quantitative SEM-based microstructural characterisation, such as pore size distribution, crack density, and splat dimensions to strengthen the relationship between microstructure and performance characteristics, was not performed due to a lack of SEM data, and this will be addressed in future work.

4. CONCLUSION

8YSZ-30wt%Al₂O₃ composite coatings were developed on AISI SS 316L using the APS method by varying the plasma parameters to investigate their effect on coatings porosity, microhardness and surface roughness. The following conclusions were arrived at.

- The present study demonstrates that plasma spray parameters showed significant importance to determine the microstructures and mechanical

properties of 8YSZ-30 wt%Al₂O₃ composite coatings developed on AISI SS 316L.

- The optical micrograph of the coatings developed at C3 conditions revealed a dense, homogeneous coating structure with fewer pores, with uniform distribution of pores and absence of cracks and indicates stable deposition behaviour. Increasing the PP from 20 kW to 30 kW significantly enhances the thermal energy available for particle melting, resulting in improved coating densification. This enhanced melting promotes better splat formation and inter-splat bonding, which directly contributes to improved coating integrity.
- The coating developed under C3 conditions (30 kW, 100 mm SOD) exhibits a lower porosity value than the other coatings. Its porosity value is 1.38, 1.32 and 1.1 folds lower than the coatings created under C1, C2 and C4 settings, respectively. This reduction in porosity value is due to ensuring extensive melting of the feedstock powder and providing sufficient kinetic energy for spreading and flattening of molten particles, resulting in coating densification.
- The lowest roughness value (6.09 µm) was observed in the coatings developed at C3 condition (30 kW, 100 mm). Its surface roughness was 1.35, 1.24 and 1.16 fold lower than the coatings created at C1, C2 and C4 conditions, respectively, indicating improved particle melting and uniform flattening of the splats. This lowest surface roughness is attributed to ensuring substantial particle melting, providing adequate kinetic energy to the molten particles and impeding premature solidification of particles before their impact on the substrate, resulting in improved deformation and smoothing of splats.
- Among all experimental conditions, the coating developed under C3 conditions (30 kW, 100 mm) exhibits superior performance, achieving the highest microhardness value of 914 HV_{0.3}. Its microhardness is 1.07, 1.06 and 1.01 times higher than the coatings created at C1, C2 and C4 conditions, respectively. This improvement is primarily ascribed to reduced porosity and the creation of a dense microstructure as a result of uniform particle spreading and effective layer formation during deposition.
- Conversely, coatings produced at lower PP (C1 and C2) show relatively higher porosity and surface roughness due to insufficient particle melting, leading to poor inter-splat bonding. The influence of SOD is also evident, as increasing

the distance from 100 mm to 120 mm (C4) causes a slight deterioration in coating properties. This is mainly due to the prior solidification of molten particles before their impact, which reduces their ability to deform and adhere effectively to the substrate.

- The study gap was an inadequate level of data on the combined influence of plasma power and SOD on porosity and microhardness of 8YSZ-30wt%Al₂O₃ coatings. This work fills this gap by examining 4 parameter sets and quantifying coating qualities. In particular, the coating produced at 30 kW plasma power and 100 mm SOD (C3) had 5.63% porosity and microhardness of 914 HV_{0.3}. The results reveal that the moderate SOD reduced porosity and enhanced hardness with increasing plasma power in the investigated range. The results thus give new preliminary data on parameter–property connections for Ce coatings.
- The minimal porosity and high hardness of the coating show its potential for defensive surface applications such as turbine blades or valves with additional evaluation.
- The limitation of the work is that the wear resistance, adhesion strength and phase stability were not measured in this work. These will be assessed in future research for full optimisation.

FUTURE SCOPE

Future scope of work includes tribological and corrosion testing to evaluate the wear resistance and physical degradation behaviour of 8YSZ-30wt%Al₂O₃ coatings. Pull-off or scratch tests are recommended for adhesion strength assessment to evaluate adhesive strength beyond optical microscope observations. The authors advise utilising XRD phase characterisation to correlate differences in mechanical parameters with crystal phases. These additional tests will give a full dataset for the evaluation of the coatings in industrial applications.

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CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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