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Substrate temperature dependence of splat morphology for plasma-sprayed cast iron on aluminum surface

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ABSTRACT

In the plasma-sprayed coatings, the morphology of the splats plays an important role in optimizing the microstructure and performance of the coating. Especially, the splashing of impinging droplets during deposition weakens the splat–substrate/intersplat bonding and increases the porosity of the coating. Consequently, the integration of the coating is deteriorated. In the present study, cast iron particles were plasma-sprayed on the surface of polished aluminum substrate to form a single splat. During spraying, the surface of aluminum substrate was preheated in a temperature range from 25 °C to 320 °C. The impact of the substrate preheating temperature on the morphology of the splats was studied using a field emission scanning electron microscope. Results showed that the substrate temperature had significant effects on the morphology of splats. At room temperature, the splats mainly exhibited a splash type with network or radial lines on the splat periphery. While, the splashed splats deposited onto a high temperature substrate showed a star shape on the splat periphery. When the substrate was preheated to 130 °C, the mean percentage of the splashed splats decreased to a minimum value of 18.4% and the disk-like splats prevailed. With the increase of the substrate temperature from 130 °C to 290 °C, the mean percentage of the splashed splats increased monotonically to 78.3%. When the substrate temperature reached to 320 °C, the mean percentage of the splashed splats slightly reduced to 76.6%.

1. Introduction

Due to the superior wear resistance and low cost, cast iron has been widely used in many industrial fields. In automobile industry, to enlarge the weight reduction and improve the fuel efficiency for automobile engines, the application of aluminum alloy cylinder block without cast iron liner has been growing for years. Nevertheless, the poor antiwear ability of aluminum alloy makes the cylinder bores easy to be worn and broken down early. Therefore, many techniques have been employed to strengthen the aluminum alloy cylinder bores [1]. It was suggested that thermal spray technique is one of the most versatile processes of depositing coating to improve the wear and corrosion performance [2,3]. Especially, a thermally sprayed cast iron coating was considered one possible candidate for surface coating to strengthen aluminum cylinder bores [4].

In order to obtain favorable service performance of the cylinder block, it is necessary to ensure no coating could peel off from the substrate (cylinder bores) during working. In other words, enhancing the adhesion strength between the coating and the substrate is expected.

Generally, it is thought that the coating is mechanically bonded together with the substrate. The adhesion strength is usually enhanced by roughing and cleaning the substrate surface prior to spraying coating. During the coating deposition process and following working process of coated aluminum alloy cylinder block, the thermal stress, derived from the large difference in thermal expansion coefficient between aluminum alloy and cast iron, would make against the enhancement of adhesion strength between the coating and the substrate.

A plasma-sprayed coating is built up by a stream of molten droplets. The individual droplet forms a splat through the processes of impacting, flattening, rapid solidification and cooling. During spraying, the deposition behavior of single droplet determines the droplet–substrate interaction, the splat structure, and the coating properties. According to a previous report [5], the deposition behavior of a droplet is nearly independent of the impingement of forthcoming droplets. Therefore, the deposition behavior of single droplet is important in determining splat formation.

As reported up to now, there are lots of factors, including spray conditions [6,7], spray materials [8,9], state of substrate surface such as oxidation state [6,8], surface roughness [10–12] and the wetting of droplet to substrate surface [6,8], that could influence the splat formation. Generally, the splat forms two different morphologies during spraying, one presents a disk-like shape and the other behaves as a splashed

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Table 1
Substrate preheating temperature for splat deposition.

Sample	S1	S2	S3	S4	S5	S6
T_s (°C)	25	130	190	240	290	320

splat which may deteriorate the coating quality. Usually, splashing occurs during the flattening of a droplet even on a flat surface at ambient atmosphere, which leads to the formation of irregularly complicated splats [8]. The occurrence of these splats goes against the formation of strong splat-substrate or intersplat bonding, as well as the adhesion or cohesion strength [13].

Many studies have showed that splash-type splats formed at low substrate temperatures and disk splats appeared at high substrate temperature [14–17], although the transition temperature [18] on splat morphology varies for different splat–substrate combinations. Morks et al. [19] prepared the cast iron splats on preheated aluminum alloy substrate surface in low-pressure atmosphere. They found that splash-type splats appeared at low substrate temperatures and both disk- and star-shaped splats appeared at high temperatures. Whereas, under atmospheric conditions, no literature has been found dealing with the influence of substrate preheating on formation of splat morphology for cast iron–aluminum combination.

In the present work, polished aluminum substrates were preheated to different temperatures, then individual cast iron splat was plasma-sprayed onto the surface of preheated substrate. The influence of preheating temperature on splat morphology formation was investigated.

2. Materials and experimental procedure

Commercially available Fe–4.1C–1.5Si–1.5B–36.6Cr (all compositions in weight percent) powder (DG.Fe-05, Chengdu Daguang Thermal Spraying Materials Co., Ltd., China) was used as the starting powder. The powder exhibits a spherical shape with the size ranged from 20 to 75 μm. A commercial plasma spray system (GP-80, Aerospace Research Institute of Materials & Processing Technology, China) was used to

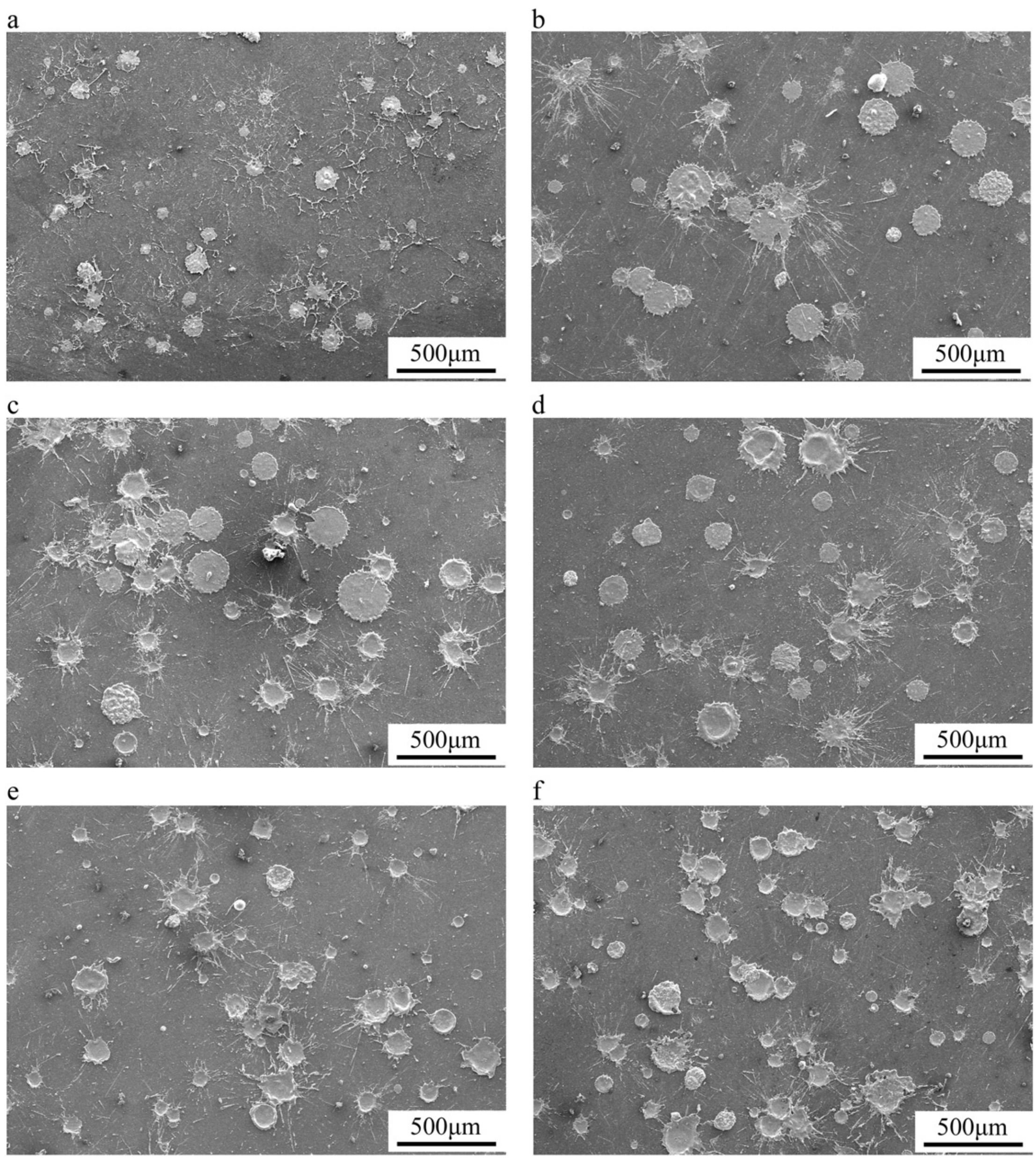

Fig. 1. Top view of the splats for (a) S1, (b) S2, (c) S3, (d) S4, (e) S5, and (f) S6.