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Study on the Performance of Laser Cladding Ni based Self Lubricating Composite Coating

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Abstract

Based on the principle of in-situ generation of lubricating phase and addition of lubricating phase to reduce friction, a novel composite self-lubricating coating was prepared on 42CrMo substrate using Ni60A coated WC and MoS2 powders as raw materials and laser cladding; Further analysis was conducted on the hardness and friction coefficient of the new composite self-lubricating coating. The study found that the performance of the new composite self-lubricating coating with MoS2 was significantly improved compared to 42Cr. The minimum stable friction coefficient of the composite coating was 0.32, which was reduced by 45.8% compared to 42CrMo; The maximum hardness of the composite coating is 700Hv, which is 150% higher than 42CrMo.

Keywords

Laser Cladding; Self-lubricating Coating; MoS_2; Niki.

1. Introduction

In the production process of large mines, due to the high viscosity of ore (powder) in some mines, serious sticking phenomena often occur in the excavation bucket or bucket. Due to the extremely difficult cleaning of sticking materials, the effective volume of the excavation bucket or bucket is significantly reduced, and the effective operation volume of large mining machinery at the same time is significantly reduced, resulting in a surge in mining costs, Therefore, it is extremely important to develop a friction reducing coating to reduce the adhesion between minerals and excavators.

Adding special self-lubricating materials to reduce the friction coefficient while improving or not affecting other mechanical properties, self-lubricating composite coatings with reduced friction energy are one of the effective ways to solve the above problems [1-2]. In order to reduce the friction coefficient of the coating, lubricating phases are introduced into the coating, which can be divided into direct addition method (such as graphite, h-BN, metal oxides, fluoride) and in-situ generation method (CrS, TiS, Ti2SC) according to their sources. The in-situ synthesis method of laser cladding can avoid the problem of lubricating phase and incompatibility with the matrix. As the lubricating phase grows from the original nucleation of the metal matrix, it can effectively reduce defects caused by poor compatibility [3].

MoS2 is a typical solid lubricant with a layered structure. The crystal structure of MoS2 is hexagonal. In the molecular layer, atoms are bound by strong Covalent bond, while the interlayer is bound by weak molecular bonds. Therefore, the interlayer is easy to be sheared, showing a small friction coefficient during wear, and has a broad application prospect [4]. The decomposition temperature of MoS2 is 1370 ℃, which can be decomposed into Mo and S elements. The metal sulfides formed by S elements and metals generally have a lubricating effect. Ni based materials have good comprehensive properties, including good wear resistance, hardness, corrosion resistance, and good wettability with the substrate. Nickel has good compatibility with various metal elements [5]. Xue Minpeng et al. [6] prepared a composite

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coating with CrS as the lubricating phase on the surface of 45 steel using powders such as Ni/CrC/MoS2 as raw materials by laser cladding. During the friction process, a lubricating transfer film was formed to provide lubrication, with a minimum friction coefficient of 0.40. Chen Zheyuan et al. [8] used MoS2/TiC/Ni powder as raw material and prepared a friction reducing and wear resistant coating with CrS and TiS as lubricating phases on the surface of 45 steel by laser cladding, with a minimum friction coefficient of 0.376. Sun Ronglu et al. [8] prepared a laser cladding coating with excellent friction performance on the surface of titanium alloy TC4 using NiCrBSi+Ni/MoS2 powder as raw material and laser cladding. Yuan et al. prepared and treated NiCr/TiC-10% Cu-10% MoS2 powder on a 30CrMnSi matrix, using CrS as the lubricating phase and TiWC2, TiC as the starting material, γ- (Fe, Ni) alloy coatings with hard phases have a minimum friction coefficient of 0.31.

2. ExperimentsSection Headings

2.1. Experimental Materials

The matrix used in the experiment was 42CrMo, with the main chemical components (mass fraction,%) being 0.42C, 0.25Si, 0.70Ni, 1.20Cr, 0.25Mo, and Fe residue. The matrix size is 65mm * 15mm * 10mm. The cladding material adopts Ni60A self soluble powder (particle size 125-300 mesh), with the composition shown in Table 1. WC powder (particle size 125-300 mesh) and MoS2 powder (particle size 12500 mesh) are used.

Table 1. Composition of Ni60A Components (Mass Fraction,%)

Material	Al	V	Fe	C	N	O	H	Cr	B	Si	Ni	Ti
Ni60A	-	-	3.8	0.7	-	-	-	15.0	3.2	4.0	cushion	-

2.2. Preparation of Composite Powder and its Coating

The composite powder is weighed according to the ratio in Table 2. In a planetary ball mill, ceramic balls are used, with a ball to material ratio of 4:1, a rotational speed of 120r/min, and mixed for 120min. Grind the 42CrMo substrate with sandpaper to remove the oxide layer, and then wipe the polished surface with anhydrous ethanol to remove grease. Preposition the evenly mixed powder with anhydrous ethanol as the binder on the substrate, with a powder thickness of about 1mm, and place it in a drying oven. Dry at 100 ℃ for 120 minutes.

The laser cladding device is the FL020 fiber laser produced by ROFIN company in Germany, and the robotic arm is the KR30-3 6-axis robot produced by KUKA company in Germany. The process parameters are: multi pass cladding, overlap rate of 50%, laser power of 1000W, spot diameter of 3mm, speed of 5mm/s, and argon gas as protective gas.

Table 2. Composition of Composite Powder (Mass Fraction,%)

Coating	Ni60A	Ni60A cladding15%WC	MoS_2
N_1	95%	0%	5%
N_2	0%	95%	5%
N_3	90%	0%	10%
N_4	0%	90%	10%

2.3. Coating Analysis Methods

Before conducting morphology analysis, use silicon carbide sandpaper of models 150 #, 400 #, 600 #, 800 #, 1000 #, 1200 #, 1500 #, and 2000 # for polishing, and finally use 1.5 μ Polish the sample with diamond polishing agent m, and then use an ultrasonic cleaning machine to clean the polished sample to remove impurities and debris. The polished sample is then corroded on

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the section for observation of the metallographic phase using self prepared aqua regia (HCl: HNO_3=3:1) for 30 seconds. The microhardness was tested using the HV-1000 microhardness tester produced by Shanghai Yeshuai Precision Technology Co., Ltd., loaded with 1000gf and held for 10 seconds. The friction coefficient was measured using the T-EC4000 multifunctional friction and wear tester produced by Lanzhou Institute of Chemistry, using an Al_2O_3 ceramic ball with a diameter of 9.525mm, loaded with 10N, with a frequency of 2Hz, and a friction length of 5mm.

3. Results and Analysis

3.1. Macro Morphology of Laser Cladding Layer

Figure 1 (a-d) shows the macroscopic appearance analysis of N1, N2, N3, and N4 cross-sections. The amount of MoS_2 added has a significant impact on the quality of laser cladding coatings. With the increase of MoS_2 mass fraction, MoS_2 with low decomposition temperature in laser cladding will decompose significantly, producing more SO_2 gas, resulting in an increase in the number of pores in the coating layer. More pores will connect together, forming larger pores or cracks.

Laser cladding is a sudden heating process. At the beginning, there is less laser action and the existence time of the molten pool is short, resulting in a smaller melting depth and a larger melting height; With the progress of laser cladding, the continuous heating time increases, and the existence time of the molten pool increases, leading to an increase in melting depth and a decrease in melting height; At the end of the cladding, due to the lack of powder on one side of the laser beam forming a new molten pool, the melting height of the cladding layer increases under the effect of spheroidization.

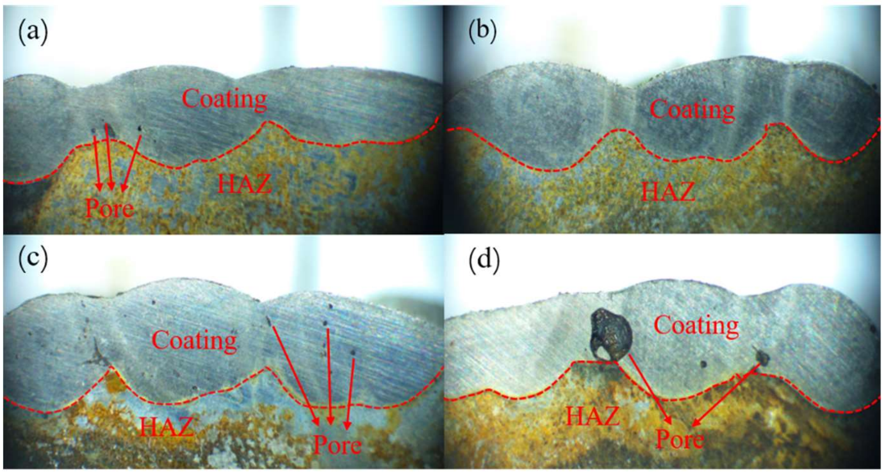

Figure 1. Cross section size and morphology of the cladding layer: (a) Laser cladding coating N1 (b) Laser cladding coating N2(c) Laser Cladding Coating N3 (d) Laser Cladding Coating N4

3.2. Friction Coefficient Analysis

1) The friction coefficients of 42CrMo, N1, N2, N3, and N4 at room temperature are shown in Figure 4, and their friction coefficients remain stable at around 0.59, 0.38, 0.36, and 0.32, respectively. MoS_2 in the mixed powder can be decomposed into Mo and S at around 1370 ℃. S can not only react with Cr to generate CrS, but also react with Ni and Fe to generate NiS, FeS, all of which are in-situ generated friction reducing phases. They can spread on the contact surface of the friction pair during wear and form a transfer film, converting the direct high stress contact between the friction part and the coating into indirect contact between the

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friction part and the lubricating film, as well as between the lubricating film and the coating, This reduces the friction coefficient [10].

2) At the beginning of friction, the WC particles of the N2 and N4 coatings fall off, affecting friction and wear, causing a significant fluctuation in the friction coefficient of the composite coating. After a period of friction, the WC particles are pressed into or removed from the friction area, and the friction coefficient begins to stabilize [11].

3) The friction coefficient of the coating containing 5% MoS2 is slightly smaller than that of the coating containing 10% MoS2, due to the latter having more pores and cracks; The friction coefficient of coatings containing 15% WC coating is smaller than that of coatings without 15% WC coating. This is because WC is a ceramic material that can refine grains, making the generated lubricating phases CrS, FeS, and NiS more finely and uniformly present in the cladding layer, reducing the friction coefficient.

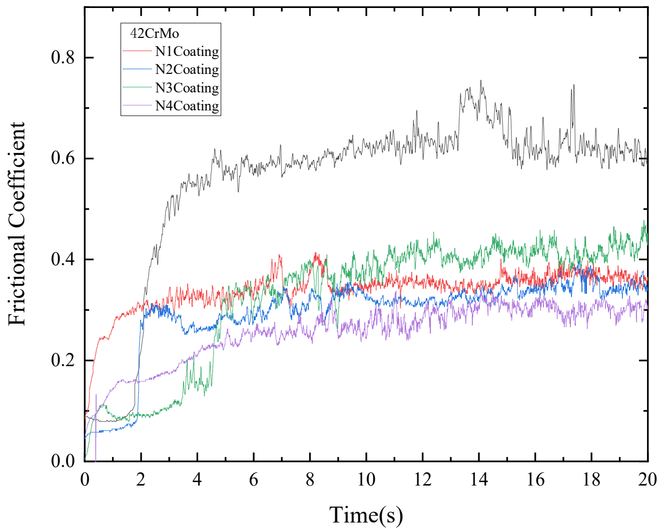

Figure 2. Friction Curve of 42CrMo Matrix and Coating with Sliding Time

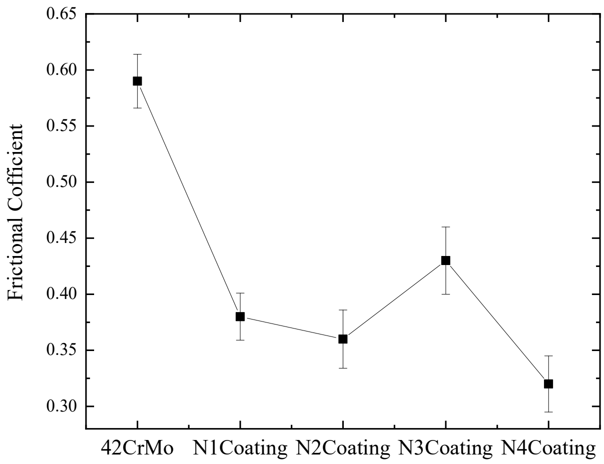

Figure 3. Stable average friction coefficient between 42CrMo substrate and coating

3.3. Microhardness Analysis

The microhardness distribution of N1, N2, N3, N4 and 42CrMo matrix is shown in Figure 5. The friction coefficients of the four composite coatings are 513.1Hv, 554.6Hv, 569.4Hv, 692.5Hv, and the hardness of the 42CrMo matrix phase is significantly increased compared to 280.4Hv. This is because the composite coating contains Mo generated by MoS2 decomposition, which

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can play a Solid solution strengthening role and increase the hardness; The hardness of the coating containing ceramic phase WC will further increase. WC is not only distributed as a hard phase inside and on the surface of the composite coating, effectively improving the hardness of the cladding layer, but also serves as a heteromorphic core to promote the formation of a large number of secondary dendrites, increase nucleation rate, and further refine crystal particles [12], improve hardness, and the C generated by its decomposition can form metal carbides with higher hardness with metal elements such as Cr in the composite coating.

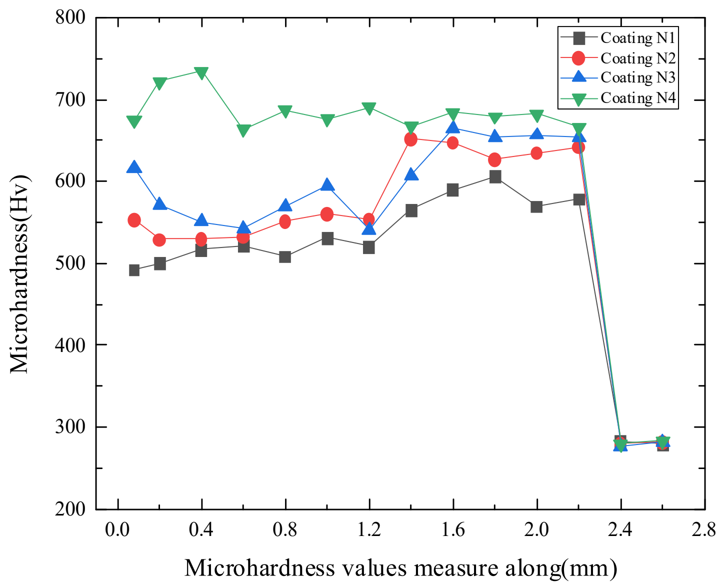

Figure 4. Changes in Microhardness of Laser Cladding Coatings

4. Conclusion

A composite coating with high bonding strength, low friction coefficient, and high hardness was prepared on the surface of 42CrMo substrate using laser cladding technology, using Ni60A coated 15% WC/MoS2 powder as raw material. With the increase of MO2 content, the friction coefficient of the composite coating slightly increases and the hardness increases; When WC is added to the coating, the tribological properties and hardness of the composite coating will be improved. When the composite powder is coated with Ni60A and 5% WC/10% MoS2, the friction coefficient of the prepared composite coating is the smallest. At this time, the friction coefficient is stable at around 0.32, and the maximum hardness can reach 692.5Hv. The composite coating is composed of in-situ generated CrS, FeS, and NiS as lubricating phases, and WC and CrxCy as hard phases.

References

[1] LU XIAOLONG, LIU XIUBO, YU PENGCHENG, et al. Effects of annexing on laser clad Ti2SC/CrS self fluxing anti wear composite coatings on Ti6Al4V alloy: Micros structure and tr topology [J] T ology International, 2016 (101): 356-363.

[2] HAN BIN, ZHANG MENGKE, QI CHONGHUA, et al. Characterization and friction reduction performancesofcomposite coating produced by laser claddingand ionization [J] Materials Letters, 2015 (150): 35-38.

ISSN: 2710-0588

[3] Fang Liu Yang, Yao Yansong, Yan Hua, et al Research progress in laser cladding self-lubricating composite coatings [J] Applied Laser, 2017,37 (3): 7.

[4] Shen Zehui, Sun Ronglu Performance of laser cladding nickel based self-lubricating coating [J] Metal Heat Treatment, 2015, 40 (9): 5.

[5] Tan Jinhua, Sun Ronglu, Niu Wei, et al. Research status of TC4 alloy laser cladding materials [J] Material Introduction, 2020, 34 (15): 6.

[6] Xue Minpeng, Han Bin, Zhang Shaochun, et al. Study on Microstructure and Antifriction Performance of Ni/MoS2 Composite Coating [J]. Hot working Process, 2013, 42 (20): 4. DOI: CNKI: SUN: SJGY. 0.2013-20-050.

[7] Chen Zheyuan, Xu Jiang, Liu Wenjin, et al. Study on the microstructure and wear performance of laser cladding MoS2/TiC/Ni anti friction and wear composite coatings [J]. Journal of Material Heat Treatment, 2007, 28 (B08): 6. DOI: 10.3969/j.issn.1009-6264.2007.z1.062.

[8] Sun Ronglu, Niu Wei, Lei Yiwen, et al. Microstructure and friction and wear properties of NiCrBSi+Ni/MoS2 coating on titanium alloy TC4 laser cladding [J]. Journal of Material Heat Treatment, 2014 (6): 6. DOI: CNKI: SUN: JSCL.0.2014-06-029.

[9] Yuan J, Yao Y, Zhu M, et al. Effects of Cu and MOS2 addition on microstructural evolution and tribological properties of self-lubricating anti wear coatings prepared by laser cladding [J] Tribology International, 2021, 157 (3): 106872.

[10] Gao Qiushi Research on Laser Cladding Ni Based Self lubricating Composite Coating on Titanium Alloy Surface.

[11] Li Qian, Chen Faqiang, Wang Qian, et al Research progress in laser cladding WC reinforced composite coatings [J] Surface Technology, 2022 (002): 051.

[12] Liu Jiandi, Zhang Shuquan, Wang Huaming Microstructure and Wear Resistance of Laser Cladding WC Particle Reinforced Composite Coating [J] Chinese Journal of Non ferrous Metals, 2012, 22 (9): 8.