

正向氧化电压对 ZAlSi12Cu2Mg1 微弧氧化膜形成的影响

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摘要:通过改变正向氧化电压,对 ZAlSi12Cu2Mg1 微弧氧化膜的形进行研究,研究其对微弧氧化膜层特性的影响,并测定了膜层的相组成。结果表明:电压为 430 V 时,膜层厚度仅 65 μm,膜层硬度 434 HV,在 30 min 的干摩擦后膜层的磨损量为基体合金的 29.86%;电压提高到 440 V 时,膜厚增到 154 μm,膜层中含有 3Al₂O₃·2SiO₂、SiO₂、α-Al₂O₃、γ-Al₂O₃ 和 WO₃,膜层硬度提高到 898 HV,膜层的磨损量仅为基体的 12.45%。超过 440 V 后,膜层厚、硬度及耐磨性均有所下降。

关键词:正向氧化电压; ZAlSi12Cu2Mg1; 微弧氧化

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Effect of Forward Voltage on Coating Formed of ZAlSi12Cu2Mg1 Alloy by MAO

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Abstract: The forming of ceramic coating on the surface of ZAlSi12Cu2Mg1 by MAO with different forward voltage was investigated. The influences of forward voltage on characteristics of the coating were analyzed respectively. The XRD was employed to analyze phase compositions of coating. The results show that while the forward voltage rises from 430 V to 440 V, the thickness of coating rises gradually from 65 to 154 μm, the hardness increase from 434 HV to 898 HV, the mass loss of coating after 30 min decreases from 29.86% to 12.45%, the coating is composed of mullite, SiO₂ and α-Al₂O₃ besides γ-Al₂O₃. But as the voltage exceeds 440 V, the mass loss of the coating ascends while the thickness and hardness decrease.

Key words: forward voltage; ZAlSi12Cu2Mg1; micro-arc oxidation (MAO)

ZAlSi12Cu2Mg1 作为现代发动机活塞的主要材料,现代工艺对其表面高温耐热性、耐磨性和耐蚀性的要求在不断提高^[1-2]。在该合金表面通过微弧氧化形成一定厚度、硬度且均匀致密的陶瓷氧化膜,可大幅度延长其使用寿命,拓展其应用领域^[3-8]。在影响微弧的诸多因素中,预设电压是关键因素之一^[9-10]。本文在一种电解液组成下,通过改变正向氧化电压,研究其对 ZAlSi12Cu2Mg1 微弧氧化膜层形成过程的影响。

1 实验材料与方法

选用 ZAlSi12Cu2Mg1 铸造铝合金,其化学成分(质量分数,%)为:11.0~13.0Si,1.0~3.0Cu,0.4~1.0Mg,0.3~0.9Mn,<0.7Fe,余为 Al;尺寸为 30 mm ×

20 mm × 5 mm。采用 WHD-30 型多功能微弧氧化电源。负向电压取 130 V,频率取 100 Hz。选用 CSPM 4000 型扫描探针显微镜测试膜层面和线粗糙度。采用 D8 Advance Bruker 型 XRD 分析仪分析陶瓷膜层相组成,HCC-25 型电涡流测厚仪测膜厚度。用 MMW-1 型立式万能摩擦磨损试验机对氧化处理前后的试样进行 30 min 的磨损试验。电解液组成:10 g/L Na₂SiO₃, 2 g/L Na₂WO₄, 2 g/L NaOH, 2 g/L Na₂EDTA 和 10 mL/L C₃H₈O₃。电压取 430、440、460、480 和 490 V。

2 结果及分析

2.1 膜层厚度与硬度

图 1 为正向氧化电压对微弧氧化膜厚度及硬度的影响。可看出,当电压由 430 V 升高到 440 V,膜层厚度从 65 μm 增加到 154 μm,硬度从 434 HV 增大到 898 HV,硬度的提高与膜层生成的物相有关。图 2 为 430 V 和 440 V 下氧化膜的 XRD 衍射图谱。430 V 下膜层中含有 Al、Si 及 γ-Al₂O₃ 相;而电压升高到 440 V 时氧化膜中含有 3Al₂O₃·2SiO₂、SiO₂、

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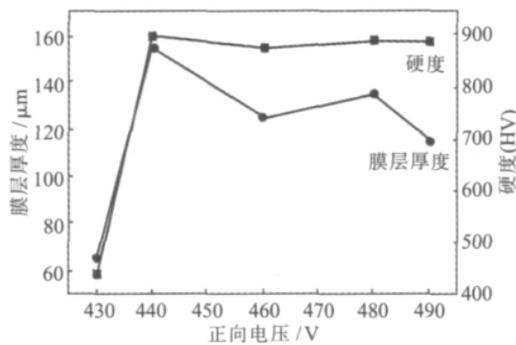


图 1 正向氧化电压对膜层厚度、硬度的影响
Fig.1 Effect of forward oxidation voltage on thickness and hardness of coating

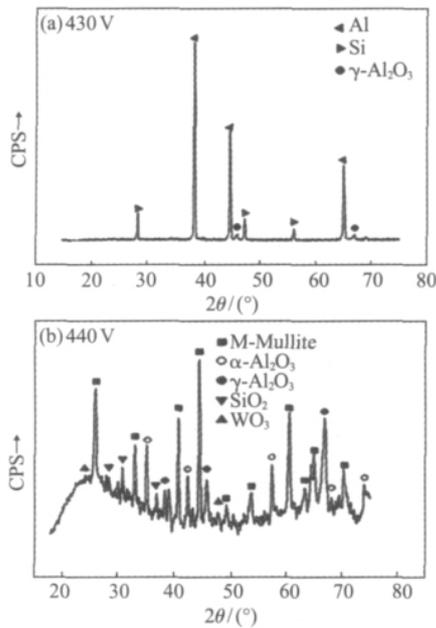


图 2 不同正向氧化电压下获得膜层的 XRD 谱
Fig.2 XRD patterns of coating formed with different forward oxidation voltage

α - Al_2O_3 、 γ - Al_2O_3 、 WO_3 及非晶相。其中 α - Al_2O_3 、 SiO_2 及 WO_3 是高硬度相。电压从 440 V 到 490 V 变化时,电流快速下降,膜层的温度很快接近电解液的温度,体积收缩不均匀,造成膜层脱落,导致膜层厚度由 154 μm 减到 115 μm 。

2.2 膜层的耐磨性

表 1 为预设正向电压 440~490 V 时试样分别经过不同时间的磨损质量损失以及相对于基体磨损质量损失的百分比。在干摩擦 30min 后,试样的磨损量为基体合金的 29.86%。当电压升高到 440 V 时,摩擦 30 min 后,试样的磨损量仅为 12.45%,耐磨性有了很大提高。随着正向电压的继续提高,膜层在强电流放电和急冷条件的作用下,膜层的表 1 不同正向电压下试样磨损质量损失对比致密性和附着力下

表 1 不同正向电压下试样磨损质量损失对比

Tab.1 Wear mass loss of samples treated with different forward voltage

试件编号	基体		430 V		440 V		460 V		480 V		490 V	
	mg	(%)	mg	(%)	mg	(%)	mg	(%)	mg	(%)	mg	(%)
5	28	100	15.3	54.64	4.20	15.00	66	23.57	4.00	14.29	3.80	13.57
10	51.3	100	22.3	43.47	7.20	14.04	9.1	17.74	7.30	14.23	7.10	13.84
15	65.2	100	29.3	44.94	10.2	15.64	10.6	16.26	10.3	15.79	10.2	15.64
20	82.7	100	31.5	38.09	12.2	14.75	13.0	15.72	12.6	14.24	11.8	14.27
25	100.5	100	33.5	33.33	13.8	13.73	13.8	13.73	14.8	14.73	14.6	14.53
30	118.9	100	35.5	29.86	14.8	12.45	18.1	15.22	16.8	14.13	15.6	13.12

降,膜层硬度降低,耐磨性会变差。正向电压提高到 460 V 时,膜层厚度减小,膜层硬度降到 850 HV,摩擦 30 min 后,试样的磨损量为基体的 15.22%。电压提高到 480 V 和 490 V 时,磨损质量损失百分比分别是基体的 14.13%和 13.12%,均超过 440 V 时获得膜层的磨损量。

3 结论

(1) 电压为 430 V 时,膜层厚度为 65 μm ,含 γ - Al_2O_3 相;提高到 440 V 时,膜厚增到 154 μm ,膜层中含有 $3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$ 、 SiO_2 、 α - Al_2O_3 、 γ - Al_2O_3 、 WO_3 及非晶相。

(2) 经 30 min 的干摩擦后,电压为 430 V,膜层硬度为 434 HV,膜层的磨损量为基体合金的 29.86%;电压提高到 440 V 时,膜层硬度为 898 HV,膜层的磨损量仅为基体 12.45%;超过 440 V 后,膜层硬度及耐磨性均有所下降。

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