

Fe-Cr-C-V 等离子堆焊层改善旋耕刀耐磨性和冲击韧性

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摘要:为解决农机触土部件耐磨性差、失效频繁等问题, 该文采用等离子堆焊技术在 65Mn 钢基体上制备 Fe-Cr-C-V 堆焊层; 利用金相显微镜、X 射线衍射仪分析了堆焊层的显微组织和物相构成; 利用显微硬度计、往复式摩擦磨损试验机、自制土槽磨损试验机、冲击试验机等设备测试了堆焊层的显微硬度、耐磨性及冲击韧性。结果表明, 堆焊层与基体呈良好的冶金结合, Fe-Cr-C-V 堆焊层主要由 α -Fe、 Cr_7C_3 、 M_7C_3 ([Fe,Cr] $_7\text{C}_3$)、Fe-Cr 固溶体、VC 等组成。与 65Mn 淬火钢相比, Fe-Cr-C-V 堆焊层的维氏硬度提高了 75%, 磨损质量降低了约 67%。与 Fe-Cr-C 堆焊层相比, Fe-Cr-C-V 堆焊层维氏硬度提高了 $\text{HV}_{0.5}100$, 冲击韧性提高了 21%。与常用的 65Mn 铲尖相比, 有 Fe-Cr-C-V 堆焊层的深松铲铲尖磨损质量减少了 78%, 与常用 60Si2Mn 旋耕刀相比, 有 Fe-Cr-C-V 堆焊层的旋耕刀平均磨损质量减小约 50%。该研究可为延长旋耕刀使用寿命提供参考。

关键词: 复合涂层; 显微结构; 等离子; 旋耕刀; Fe-Cr-C-V 堆焊层; 耐磨性; 冲击韧性

doi: 10.11975/j.issn.1002-6819.2019.03.004

中图分类号: TG174.4

文献标志码: A

文章编号: 1002-6819(2019)-03-0024-07

郝建军, 杨泽宇, 马璐萍, 赵建国, 刘敬春. Fe-Cr-C-V 等离子堆焊层改善旋耕刀耐磨性和冲击韧性[J]. 农业工程学报, 2019, 35(3): 24-30. doi: 10.11975/j.issn.1002-6819.2019.03.004 http://www.tcsae.org

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0 引言

农机触土部件在使用过程中长期承受来自土壤中石英、长石、植物硅酸体及作物秸秆、杂草等的频繁冲击与磨损。石英、长石中的 SiO_2 以及植物茎秆中的硅酸体都是硬度极高的磨料, 显微维氏硬度最高可达 $\text{HV}_{0.5}1250$ ^[1]。旋耕刀、深松铲、开沟器、犁铧等农机触土部件在与这些硬质颗粒接触的过程中极易因磨粒磨损而失效。据不完全统计, 80%以上的农机触土部件因磨粒磨损失效而报废, 农机触土部件的早期失效严重影响作业质量和作业效率, 提高作业成本^[2-5]。同时, 频繁更换失效刀具还会增加劳动强度、延误农时。为了改善农机触土部件的力学性能, 很多国内外学者借助氩弧熔覆、激光熔覆、火焰喷焊、感应熔覆等手段, 在触土部件表面制备 Fe 基、Ni 基、Co 基等自熔性合金粉末涂层^[6-9], 如郝建军等^[10]利用氩弧熔覆技术在廉价的碳钢表面原位合成了 TiC/Ni 基复合材料涂层, 熔覆层成型良好, 试验表明可用于农机耐磨件的制造与再制造, 并具有良好的经济效益。郝建军等^[11]利用氧乙炔火焰喷焊技术在鞭式灭茬刀具上制备了 Ni-WC 喷焊层, 结果表明 WC 能够对镍基合金产生弥散强化、晶界强化和固溶强化的作用, 提高喷焊层耐磨性。屈平等^[12-13]利用等离子熔覆技术在犁铧表面制备了 Ti

(C,N)-WC 复合陶瓷涂层, 熔覆后的犁铧耐磨性明显提高, 使用寿命延长。赵建国等^[14]利用反应氮弧熔覆技术在旋耕刀上成功制备了 TiCN/Fe 金属陶瓷涂层, 涂层成型良好, 显微硬度达 $\text{HV}_{0.5}1089$, 田间试验表明相同条件下, 涂层旋耕刀的磨损量仅为 65Mn 旋耕刀的 1/2, 耐磨性优良。赵建国等^[15]采用火焰喷焊技术在深松铲铲尖上制备了铁基合金涂层, 并利用喷焊后余温对其进行了淬火处理, 结果表明喷焊余温淬火使涂层组织得到细化, 提高了涂层耐磨性。张旭等^[16]针对灭茬刀耐磨性不足, 报废、更换频繁的问题, 采用氧乙炔火焰喷焊技术在灭茬刀上制备了 Fe6 涂层, 结果显示喷焊 Fe6 涂层的灭茬刀硬度和耐磨性显著提高, 使用寿命得到有效延长。王海淞等^[17]利用氩弧熔覆技术在淬火后的 65Mn 深松铲铲尖上制备了 TiC 颗粒增强镍基复合涂层, TiC 颗粒呈弥散分布, 熔覆后的深松铲具有较好的耐磨性。Satit 等^[18]采用高速氧燃料喷涂方法在旋耕刀表面制备了 WC/Co 复合涂层, 田间试验结果表明, 喷涂 WC/Co 耐磨层的旋耕刀延寿效果明显。Amardeep Singh Kang 等^[19]利用热喷涂技术在旋耕刀表面分别制备了 WC-Co-Cr、 $\text{Cr}_3\text{C}_2\text{NiCr}$ 、Stellite-21 涂层, 田间试验结果表明, 喷涂 WC-Co-Cr、 $\text{Cr}_3\text{C}_2\text{NiCr}$ 、Stellite-21 三种涂层的旋耕刀磨损质量较原刀具下降明显, 耐磨性显著提高。由此可见, 上述方法均在不同程度上提高了农机触土部件的耐磨性和使用寿命, 但上述方法多存在设备昂贵、工艺过程复杂或者原材料 Ni、Co、WC、TiC 成本高等不足。Fe-Cr-C 系涂层具有成本低、硬度高、耐磨性好等优点, 已被广泛应用

收稿日期: 2018-10-30 修订日期: 2019-01-09

基金项目: 国家重点研发计划 (2017YFD0300907)

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于材料表面强化领域,但涂层韧性差,易产生裂纹和脆断现象^[20-22]。Fe-Cr-C 系合金中适量加入 V 元素,可达到细化晶粒和沉淀强化的作用^[23],有望改善涂层的综合力学性能。为此,本文针对农机触土部件的使用特点,尝试运用等离子堆焊技术在 65Mn 钢表面制备耐冲击、耐磨损的 Fe-Cr-C-V 堆焊层,以期为农机触土刀具的强化提供有效手段。

1 材料与方法

1.1 试验材料

试验基材为未经热处理的 65Mn 钢板(120 mm×50 mm×12 mm),试验所用粉末为粒径 100~150 μm 的 FJ-19(上海铸宇材料科技有限公司)和粒径为 200~300 μm 的 FeV80 钒铁粉(南京市鑫盾合金焊材喷涂有限公司),化学成分见表 1。

表 1 试验材料化学成分

| 粉末 Powder | C | B | Si | Mo | Ni | V | Cr | Mn | Fe |
|-----------|------|-----|-----|-----|-----|----|----|-----|-------|
| FJ-19 | 3.6 | 1.9 | 3.4 | 3.1 | 5.3 | - | 31 | - | 51.7 |
| FeV80 | 0.15 | - | 1.5 | - | - | 80 | - | 0.5 | 17.85 |

1.2 试验方法

1.2.1 堆焊层制备

对 65Mn 试件表面进行喷砂处理(喷砂压力 0.7 MPa, G16 钢砂,喷砂角 75°,喷砂距离 100 mm),直至表面出现金属光泽,然后用浓度为 99.5%的丙酮溶液清洗试件,并用风机吹干。用 FA2204B 型电子分析天平按 1:7(前期大量试验及相关测试分析证明,V 元素质量比小于 5% 时 V 固溶于基体,不会形成 VC,而超过 15% 时堆焊合金硬度和耐磨性呈下降趋势,V 质量比为 10% 的 Fe-Cr-C-V 堆焊层显微形貌和综合性能良好)的比例称取 FeV80 和 FJ-19 粉,然后采用 DQM 型行星式球磨机进行球磨混粉(转速 90 r/min,球磨时间 8 h,球料比 5:1,干磨)。利用 DML-V02BD 型等离子堆焊机采用相同的堆焊工艺参数在 65Mn 钢基体上分别制备厚度为(1.5±0.2) mm 的 Fe-Cr-C 系和 Fe-Cr-C-V 系堆焊层。堆焊工艺参数为:堆焊电流 55 A,送粉量 25 g/min,离子气 1.5 L/min,送粉气 2.5 L/min,保护气 0.5 L/min,堆焊速度 16 cm/min,堆焊角度为 90°±8°,堆焊距离 5~8 mm。

1.2.2 堆焊层性能表征

采用 SG9000 型数控电火花线切割机分别对普通 65Mn 钢试件、Fe-Cr-C 系堆焊试件和 Fe-Cr-C-V 系堆焊试件进行线切割,分别制备用于显微分析的试件(15 mm×15 mm×12 mm)和用于耐磨性测试的试件(25 mm×25 mm×12 mm),耐磨性测试试件每种切取 3 个,测试结果取平均值。采用徕卡 DM4000M 型金相显微镜观察堆焊层微观组织形貌;采用德国布鲁克生产的 TECBRUKER D2PHASER 型 X 射线衍射仪对堆焊层进行物相分析,(衍射角度范围 10°<2θ<90°,步进角度 0.02°);采用上海恒一精密仪器有限公司生产的 MH-6 型显微维氏硬度仪测

试试件的显微维氏硬度(加载载荷 500 gf,加载时间 10 s),每组硬度测试 6 次,结果取平均值。

1.2.3 堆焊层冲击韧性试验

采用 JB-300B 型冲击试验机测试 Fe-Cr-C 系和 Fe-Cr-C-V 系堆焊层的冲击韧性。按 GB229-84 和 GB/T1817—2007 的有关要求将堆焊层制备成 55 mm×10 mm×5 mm 的 V 形缺口试件进行冲击韧性测试。每种成分堆焊层各制备 3 个冲击韧性测试试件,测试结果取平均值。

1.2.4 堆焊层耐磨性测试

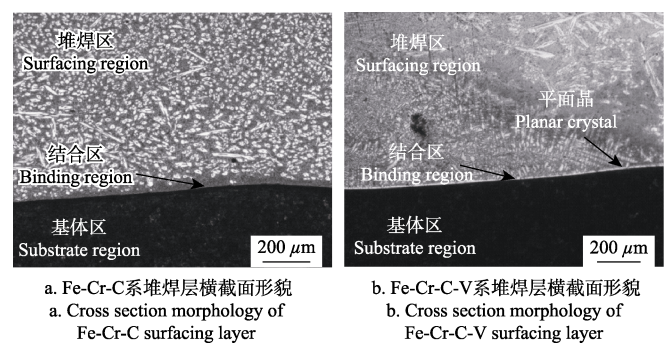
采用 HSR-2M 型往复摩擦磨损试验机测试堆焊层的耐磨性,加载载荷 50 N,转速 300 r/min,往复距离 4 mm,磨头为直径 4 mm 的 SiN 陶瓷球,每隔 1 h 测量 1 次磨损质量,总磨损时间为 5 h,每测试 1 个试件更换 1 次 SiN 陶瓷球,每个试件重复 3 次测试。利用 FA2204B 型电子分析天平称质量并计算磨损质量,称质量前用 SB-5200D 型超声波清洗仪清洗试件后再用风机吹干。

再准备 2 组 65Mn 材质的深松铲铲尖(110 mm×70 mm×8 mm),其中 1 组不做表面强化处理,另 1 组在易磨损部位制备 Fe-Cr-C-V 堆焊层。采用自制的土槽磨损试验机(专利号:ZL-201520998176.0,ZL201521030760.3)模拟深松铲实际工作过程,通过测试深松铲铲尖的磨损质量评价耐磨性。测试所用土壤为粒径 200 目、含水率 15% 的沙壤土,试验机转速 45 r/min,试验时间 12 h,磨损前后,用清水将试件冲洗干净,吹干后称质量。

2 结果与分析

2.1 涂层横截面形貌

图 1a 和图 1b 分别为 Fe-Cr-C 系和 Fe-Cr-C-V 系合金堆焊层横截面显微组织形貌。由图 1 可见,堆焊层具有较低的稀释率,没有出现明显的气孔及夹杂物,堆焊区、结合区、基体区分布较为明显,在结合区可以看到堆焊层与基体相互渗透,呈现良好的冶金结合。Fe-Cr-C 系结合区为很窄的一条暗色“带状”区域^[21],是由基体与堆焊层相互渗透形成的。而 Fe-Cr-C-V 系结合区为白亮色“带状”区域,呈现如 P 区域所示的平面晶形态^[21,24],这是由于基体的稀释作用,结合区 Cr/C 比降低,共晶点左移,向亚共晶组织转变造成的。



a. Fe-Cr-C系堆焊层横截面形貌
a. Cross section morphology of Fe-Cr-C surfacing layer
b. Fe-Cr-C-V系堆焊层横截面形貌
b. Cross section morphology of Fe-Cr-C-V surfacing layer

图 1 堆焊层横截面形貌(65Mn 基体)
Fig.1 Cross section morphology of surfacing layer (65Mn substrate)

2.2 涂层显微组织

图 2a、图 2b 为 Fe-Cr-C 系合金堆焊层微区的细微形貌，未添加钒铁的 Fe-Cr-C 堆焊层硬质相呈空心六边状、针叶状及其他不规则形状，分布杂乱，且硬质相较为粗大（其中，针叶状硬质相可达 $200\ \mu\text{m}$ ）。在空心六边形心部存在单个或多个孔洞，孔洞内部充满基体金属，金属组织为奥氏体或奥氏体转变产物^[25]。图 2c、图 2d 为 Fe-Cr-C-V 系堆焊层显微组织形貌，硬质相形貌得到改善，除原有的针叶状和六边形初生碳化物外，还出现了弥散分布的球状碳化物及柱状晶 Q 、等轴晶 R 等组织。与图 2a、2b 相比，硬质相尺寸明显减小，约为 $10\sim 20\ \mu\text{m}$ 。Fe-Cr-C-V 系涂层结合区附近靠近激冷层处出现胞状晶和柱状晶垂直于界面，定向生长^[24,26-27]。定向生长的硬质相为板条状晶体，其在不同方向上的硬度差异很大，由测试结果显示，板条横截面上的显微硬度为 $\text{HV}_{0.5}1\ 700\sim 1\ 900$ ，而纵截面的显微硬度为 $\text{HV}_{0.5}1\ 300\sim 1\ 500$ ，晶体的定向生长使大部分抗磨面为板条状晶体的横截面，有利于提高堆焊层整体硬度和抗磨性。

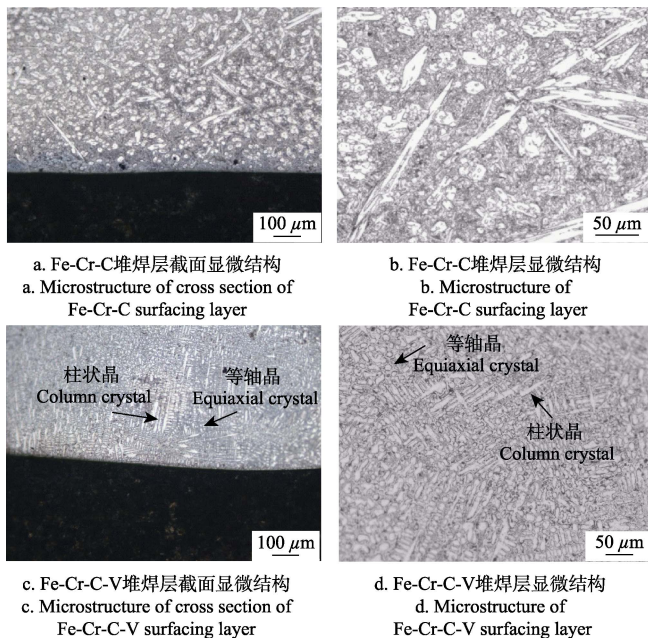


图 2 合金堆焊层显微结构 (65Mn 基体)

Fig.2 Microstructure of alloy surfacing layer (65Mn substrate)

2.3 涂层物相

图 3 为 Fe-Cr-C 系和 Fe-Cr-C-V 系堆焊层的 XRD 物相分析结果。由图 3a 可以看到 Fe-Cr-C 合金堆焊层主要由 $\alpha\text{-Fe}$ 、Fe-Cr 固溶体、 M_7C_3 ($[\text{Fe}, \text{Cr}]_7\text{C}_3$)、 Cr_7C_3 组成，其中 M_7C_3 和 Cr_7C_3 是主要硬质相。 Cr_7C_3 的显微维氏硬度可达 $\text{HV}_{0.5}1\ 700$ ，其晶体属于斜方晶系，而 M_7C_3 显微维氏硬度可达 $\text{HV}_{0.5}1\ 900$ ，是铬原子溶入 Fe_7C_3 后形成的稳定化合物^[28-31]。图 3b 为 Fe-Cr-C-V 系堆焊层物相分析结果，衍射结果表明，堆焊层中出现了 VC 新相，且 M_7C_3 和固溶体的峰值有所增加。文献[32]研究表明，V 是强碳化物形成元素，主要存在于 M_7C_3 型碳化物中。由 Bramfitt 理论，C 优先与 V 形成高熔点立方晶结构的 VC^[33]，VC 与 M_7C_3 的错配度为 8.6%，凝固过程中可以作为 M_7C_3 型碳化物的异质形核基底，细化共晶组织。

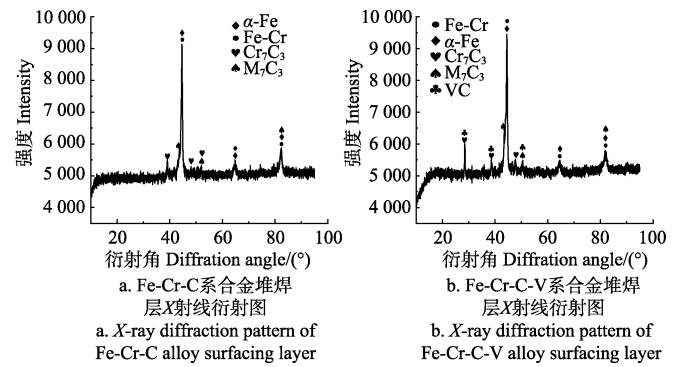


图 3 堆焊层 XRD 衍射图谱

Fig.3 X-ray diffraction (XRD) spectrum of surfacing layer

2.4 显微硬度分析

图 4 为 65Mn 钢 (840 °C 淬火、400 °C 回火处理)、Fe-Cr-C 系和 Fe-Cr-C-V 系堆焊试件的截面显微硬度分布。由图 4 可见: 65Mn 钢的维氏硬度平均值为 $\text{HV}_{0.5}460$, Fe-Cr-C 系合金 1 mm 厚堆焊层的维氏硬度平均值为 $\text{HV}_{0.5}710$, 而 Fe-Cr-C-V 系合金 1 mm 厚堆焊层的维氏硬度平均值为 $\text{HV}_{0.5}810$, 比 Fe-Cr-C 系合金涂层硬度约增加了 $\text{HV}_{0.5}100$, 相比于普通热处理 65Mn 钢, 维氏硬度提升了 75%。Fe-Cr-C-V 系涂层比 Fe-Cr-C 系涂层具有更高的硬度, 且在涂层横截面上硬度较均匀, 在垂直于涂层表面的方向上硬度没有明显的梯度变化, 硬度均匀一致, 这说明硬质相在涂层内是弥散分布的。新生相 VC 是硬度极高的硬质相^[34-35], 显微维氏硬度达 $\text{HV}_{0.5}2\ 800$, VC 的钉扎作用提高了涂层的整体硬度。

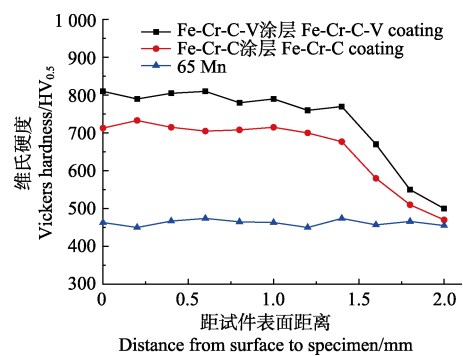


图 4 试件横截面硬度分布

Fig.4 Cross section hardness distribution of specimen

2.5 耐磨性分析

图 5 为 65Mn 热处理试件、Fe-Cr-C 系堆焊试件及 Fe-Cr-C-V 系堆焊试件在 HSR-2M 型往复摩擦磨损试验机上测试的磨损质量变化。由图 5 可知, 65Mn 试件的磨损速率约为 $6\ \text{mg/h}$, 磨损速度快、磨损过程极不稳定, 4 h 以后进入急剧磨损阶段, 而 Fe-Cr-C-V 系堆焊层的磨损速率约为 $2\ \text{mg/h}$, 总体来说 Fe-Cr-C-V 系合金层的磨损质量相比 65Mn 钢降低了约 67%。Fe-Cr-C 系和 Fe-Cr-C-V 系堆焊层耐磨性较好, 但 Fe-Cr-C-V 系堆焊层的磨损质量更小, 磨损曲线更加稳定, 具有更加优良的耐磨性能。这是因为 65Mn 基体上弥散分布的碳化物硬质相起到了抗磨骨架的作用, 而 Fe 基体中的韧性相又对碳化物粘结固化, 二者相互作用共同提高了涂层的耐磨性能。

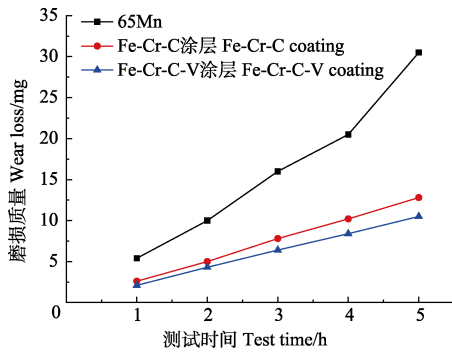


图 5 试件磨损质量对比
Fig.5 Contrast of wear loss of specimen

图 6 所示为土槽试验对比实样的磨损形貌。由图 6 可见, 无堆焊层的 65Mn 试件磨损严重, 端部有严重擦伤、犁沟明显 (磨损质量为 54.6 g); 而端部制备 Fe-Cr-C-V 堆焊层的涂层试件磨损表面光洁, 未见严重的磨痕和堆焊层剥落现象 (磨损质量为 12 g), 与无涂层铲尖相比, 磨损质量减少了 78%。由此可见, Fe-Cr-C-V 堆焊层具有更加优良的耐磨性能。

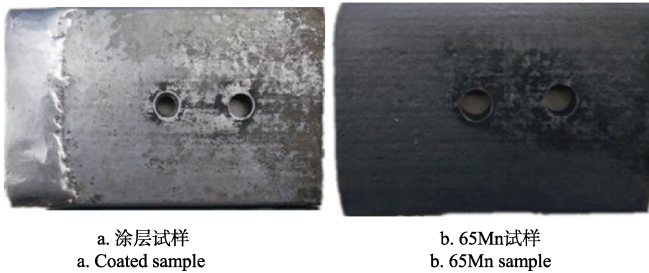


图 6 土槽磨损试验后深松铲铲尖形貌
Fig.6 Deep-shovel tip morphology after soil wear test

2.6 冲击韧性分析

图 7 为 Fe-Cr-C 系和 Fe-Cr-C-V 系堆焊合金冲击韧性测试结果, Fe-Cr-C 系堆焊试件的平均冲击韧性为 6.2 J/cm², 而 Fe-Cr-C-V 系堆焊合金的平均冲击韧性为 7.5 J/cm², 与 Fe-Cr-C 系合金相比, Fe-Cr-C-V 系合金的冲击韧性提高了 21%。堆焊合金冲击韧性的提高主要得益于碳化物形貌的改善, Fe-Cr-C 系合金中碳化物呈网状聚集, 对基体的割裂作用尤为严重, 在宏观上表现为涂层的开裂和剥落^[36]; 而 Fe-Cr-C-V 系堆焊合金冷凝时析出细小的二次 VC, 有效消耗熔池中的 C 原子, 避免初生碳化物呈网状聚集、长大。

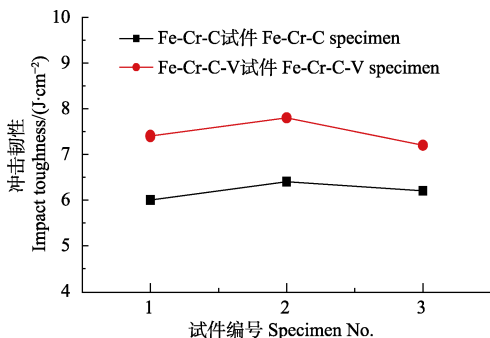


图 7 冲击韧性测试结果
Fig.7 Impact toughness test results

3 田间试验与结果分析

取 60 把 60Si2Mn 材质的 245 旋耕刀 (840 °C 淬火、400 °C 回火), 其中 30 把采用本文试验方法在其刃部制备 1.5 mm 厚的堆焊层。将 60 把旋耕刀洗净、称质量后交错安装在 1GKN-220 型旋耕机上, 在石家庄市藁城区绿之宝家庭农场进行田间试验。作业现场如图 8 所示, 总作业面积 23.3 hm², 机组前进速度 4~5 km/h, 土壤性质为砂壤土, 含水率 18%。



图 8 田间试验
Fig.8 Field test

图 9 为旋耕刀田间磨损宏观形貌对比, 由图 9 可知, 未堆焊 Fe-Cr-C-V 涂层的旋耕刀, 在正切刃和侧切刃相交区域出现明显磨痕, 且刀刃钝化严重, 而有堆焊层的旋耕刀刃部堆焊层保留较为完好, 未出现严重磨损及涂层剥落。对所有刀具洗净吹干后称质量, 普通刀平均磨损质量为 60 g, 涂层刀平均磨损质量为 32 g, 与无涂层铲尖相比, 磨损质量减少了 50%。在田间试验过程中涂层刀具有较好的耐磨性。



图 9 田间试验后刀具形貌
Fig.9 Blades morphology after field test

4 结论

1) Fe-Cr-C-V 等离子堆焊层与基体呈良好的冶金结合, 堆焊层无气孔、夹渣等缺陷。堆焊层主要由 M₇C₃ ([Fe,Cr]₇C₃)、Cr₇C₃、α-Fe、Fe-Cr、VC 等物相组成。
2) 与 Fe-Cr-C 堆焊层相比, Fe-Cr-C-V 堆焊层显微组织更加细化, 硬度增加, 磨损量降低, 且具有更加优良的冲击韧性。硬质相的细化、弥散分布以及 VC 新相的出现是堆焊层强化的主要原因, 而碳化物形貌的改善改良了涂层的冲击韧性。Fe-Cr-C 堆焊层的平均硬度为 HV_{0.5}710,

冲击韧度 6.2 J/cm^2 ; Fe-Cr-C-V 堆焊层的平均硬 $\text{HV}_{0.5} 810$, 冲击韧度 7.5 J/cm^2 , Fe-Cr-C-V 堆焊层具有更加优良的耐磨性能和冲击韧性。

与常用 65Mn、60Si2Mn 材质的旋耕刀相比, 有 Fe-Cr-C-V 堆焊层的旋耕刀耐磨性良好, 综合力学性能优良, 可通过堆焊 Fe-Cr-C-V 涂层提高旋耕刀耐磨性。

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Fe-Cr-C-V plasma surfacing layer improving wear resistance and impact toughness of rotary blade

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Abstract: In order to solve the problems of poor wear resistance and frequent failure of agricultural machinery contact soil components, Fe-Cr-C-V plasma surfacing layer was prepared on 65Mn steel matrix by plasma surfacing welding technology. Microstructure and phase composition of surfacing layer were analyzed by means of metallographic microscope and X-ray diffraction. Microhardness, wear resistance and impact toughness of surfacing layer were analyzed by means of microhardness tester, reciprocating friction and wear tester, self-made soil-bin wear tester and impact testing machine. The results showed that the cross-section of the surfacing welding specimen showed surfacing region, bonding region and substrate region, the substrate and coating diffused with each other, showing good metallurgical bonding, the coating dilution rate was low, and there were no defects such as porosity and slag inclusion. Fe-Cr-C-V series surfacing layer was mainly composed of α -Fe, Cr₇C₃, M₇C₃ ([Fe, Cr]₇C₃), Fe-Cr solid solution, VC, etc. The microstructure and hard phase morphology of Fe-Cr-C-V surfacing layer were improved. In addition to the original coniferous and hexagonal primary carbides, the dispersed spherical carbides, columnar crystals also appeared. Compared with 65Mn hardened steel, the Vickers hardness of Fe-Cr-C-V series alloy layer was improved by 75% and the wear quality was reduced by about 67%. Compared with Fe-Cr-C series alloy, Fe-Cr-C-V series alloy had finer microstructure, higher hardness, lower wear and better impact toughness. Fe-Cr-C-V surfacing layer had smaller wear quality, more stable wear curve and better wear resistance, this is because that the carbide hard phase dispersed on 65Mn matrix play the role of anti-wear skeleton, while the toughness phase in Fe matrix bonds and solidified the carbide, and the 2 interactions jointly improved the wear resistance of the coating. The refinement and dispersion of hard phase and the appearance of new VC phase were the main reasons for the coating strengthening, while the carbide morphology improved the impact toughness of the coating. The average hardness and impact toughness of Fe-Cr-C alloy were HV_{0.5}710 and 6.2 J/cm² respectively. The average hardness of Fe-Cr-C-V series alloy layer was HV_{0.5}810, and the impact toughness was 7.5 J/cm². Fe-Cr-C-V series alloy layer had better wear resistance and impact toughness. Compared with the commonly used 65Mn subsoiler tip, the wear quality of subsoiler tip with surfacing layer was reduced by 78%. Field experiments showed that the average wear quality of the rotary blade with surfacing layer was reduced by about 50% compared with the conventional 60Si2Mn rotary blade without surfacing layer. For the rotary blades without Fe-Cr-C-V surfacing layer, there were obvious wear marks in the intersection area between the cutting edge and the side cutting edge, and the blade passivation was serious, while the surfacing layer on the blade of the rotary blade with surfacing layer remained relatively intact, without serious wear and coating peeling. The average wear quality of rotary blade with surfacing layer was 32 g, and that of ordinary rotary blade without surfacing layer was 60 g. The hardness phase of Fe-Cr-C-V coating studied was uniformly distributed and there was no obvious hardness gradient, which has important reference value for extending the life of soil contact parts of agricultural machinery. In addition, plasma surfacing welding technology was used to prepare Fe-Cr-C-V series wear-resisting coating on the surface of the soil contact parts of agricultural machinery, which has low cost, high efficiency, flexible and convenient technology and high application and promotion value. Compared with the commonly used rotary blades with 65Mn and 60Si2Mn materials, the rotary blades with Fe-Cr-C-V surfacing layer has good wear resistance and excellent comprehensive mechanical properties.

Keywords: composite coatings; microstructure; plasmas; rotary blade; Fe-Cr-C-V surfacing layer; wear resistance; impact toughness