物理气相沉积热障涂层批量生产用球坑仪快速测厚法研究 *

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摘 要:为了满足热障涂层批量生产时对厚度快速、准确检测的需要,本文选用球坑测厚法对物理气相沉积热障涂层厚度进行了测量研究。首先在 GH3039 高温合金基体上分别制备厚约 120μm 的 NiCrAlYSi 涂层和 $ZrO_2 \cdot Y_2O_3$(YSZ)涂层,研究了研磨液粒径、研磨时间等参数与磨坑直径的关系,随后根据试验结果对高温合金试片涂覆的 NiCrAlYSi/YSZ 热障涂层使用球坑测厚法进行了厚度测量,并与金相测厚法结果进行了对比。结果表明:NiCrAlYSi 涂层和 YSZ 涂层磨坑直径与研磨时间均满足抛物线增加关系;相同条件下,所用研磨液粒径为 5μm 和 10μm 时获得的磨坑直径相当,均比 1μm 时的大;针对同一涂层,球坑测厚法与金相测厚法测量结果吻合度高,误差在 6%以内。

关 键 词:热障涂层;物理气相沉积;涂层厚度;球坑仪

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Research of Quick Measurement for PVD TBCs Thickness in Industrial Production Using Ball Crater Tester

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Abstract: In order to test the thickness of thermal barrier coatings quickly and accurately in industrial production, this paper discusses a method of thickness measurement for PVD NiCrAlYSi coating and YSZ coating by using ball crater tester. First, The NiCrAlYSi coating and YSZ coating with thickness of 120μm was deposited on GH3039 superalloy substrate by arc ion plating and EB-PVD respectively. The relationship of particle size in polishing slurry, grinding time and dimension of ball crater was obtained. Then, according to the above experimental results, the thickness of NiCrAlYSi and YSZ coatings on superalloy specimens was measured by ball crater tester, and the results of ball crater tester and metallographical measurement were compared. The results show that the dimension of ball crater has a parabolic relation with milling time for the NiCrAlYSi coating and YSZ coating. Under the same conditions, the dimension of ball crater is the same when the size of particle in polishing slurry is 5μm and 10μm, both of which are much larger than that of the particle size of 1μm. The result of ball crater tester is highly identical with that of metallographical measurement, and the relative error is less than 6%.

Key words: thermal barrier coating; PVD; coating thickness; ball crater tester

热障涂层技术作为延长发动机涡轮叶片使用寿命的关键技术[1-3],涂层厚度控制尤为重要,这是衡量涂层质量的一项重要指标。若涂层太薄,则无法满足隔热防护要求;若涂层偏厚,则会导致发动机性能下降。涂层厚度不仅影响涂覆产品的使用性能和可靠性,同时也影响着热障涂层生产的经济效益,在产品质量、过程控制和成本控制中都发挥着重要作用。因此,涂层的厚度检测是发动机涡轮叶片热障涂层的必要质量控制手段和必须进行的产品检验手段。

涂层厚度测量方法的种类繁多,大致可分为破坏性测量和非破坏性测量两大类[4]。破坏性测量方法有显微镜法、轮廓仪法、测微计法;非破坏性测量方法有磁性法、涡流法、超声法、红外热成像法、阻抗谱法等无损检测方法[5-12]。基于涂层类型、基体材料、涂层厚度范围及便捷性、准确性等

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