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用小能量多冲击法测量烧结钢的断裂韧性

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摘要 采用小能量多次冲击法测量了尺寸为12mm×12.5mm×62.5mm 烧结碳钢的断裂韧性 K_{IC}值。考察了碳含量、冷却速度及后续退火工艺对粉末烧结钢的断裂韧性 K_{IC}值的影响。结果表明,烧结钢在小能多次冲击状态下的断裂韧性 K_{IC}值主要由烧结钢的强度决定。同时也需要一定的塑性与之相配合。

主题词 小能多冲 断裂韧性 烧结碳钢

引言

冲击韧性曾用来表征材料抵抗脆断的能力,这在当时曾一度解决了对工程材料的性能评价及设计问题。然而,一般机械零件并不是受到一次巨大冲击载荷就发生破坏,而是在单位体积内承受小能量载荷的多次冲击后才发生断裂[1]。因而,冲击韧性的测试条件并不与一般机械零件的服役工况相符合,采用它来对材料的断裂抗力进行评价也就失去了意义。为了正确地评价材料的断裂抗力,必须采用与其服役条件相一致或接近的测试方法。本文采用小能量多次冲击法来测定粉末烧结碳钢的断裂韧性,并考察碳含量、冷却速度及后续退火条件对烧结碳钢断裂韧性 K_{IC} 值的影响。

1 测量原理

在弹性范围内,金属受冲击后,变形仍遵循虎克定律,其弹性模量不因冲击载荷而改变[2]。对于直三点弯曲试样,其无量纲柔度为[3]:

$$BE\acute{C} = \alpha + \beta\tan^2[\pi a/(2W)] \qquad (1)$$

其中 $\alpha = 0.25(S/W)^3[1+3(1+\gamma)(W/S)^2]$

$\beta = 2/\pi[S/(4W)]^2[7.31+0.21(S/W-2.9)^{1/2}]^2$

式中S为试样跨距,W为试样宽度,a为裂纹长度,采用短跨距试样,取S/W=4,烧结碳钢的泊松系数 γ近似取为0.24,则

$$BE\acute{C} = 19.72 + 36\tan^2[\pi a/(2W)]$$

由该式计算出的 $BE\acute{C}(1-a/W)^{3/2}$值见表1。

表1 $BE\acute{C}(1-a/w)^{3/2}$的计算值

Table 1 Calculation values of $BE\acute{C}(1-a/w)^{3/2}$

a/w	0.1	0.2	0.3	0.4	0.45	0.5	0.6
$BE\acute{C}(1-a/w)^{3/2}$	17.588	16.840	17.025	17.966	18.316	19.669	22.156

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从表中可以看出，在$0.1 \leqslant a/W \leqslant 0.45$内，$BE\acute{C}(1-a/W)^{3/2}$值取17.63时所引起的误差在5%左右，故C可以表示为：

$$C = 17.63/[BE\acute{C}(1-a/W)^{3/2}] \quad (2)$$

在多次冲击试验中，若忽略在试样被冲击处的塑性变形及试样本身的弹性弯曲，冲锤以恒定的冲击能A冲击试样，即

$$A = P\Delta/2 = P^2C/2 \quad (3)$$

式中P为冲击载荷，Δ为试样在冲击载荷P时所产生的挠度。在小能量多次冲击载荷下，在试样的钼丝切割槽根部首先形成疲劳裂纹，并在随后的冲击下逐渐扩展。结合(2)、(3)式可得：

$$P = (ABE'/8.815)^{1/2}(1-a/W)^{3/4} \quad (4)$$

而应力强度因子K_I可表示为：

$$K_I = 3PS/(BW^2)a^{1/2}Y/2 \quad (5)$$

将(4)式代入(5)式，可以得到在小能量多次冲击条件下的应力强度因子K_I，即

$$K_I = [AE/(BW)]^{1/2}F(a/W) \quad (6)$$

式中F(a/W)为修正函数，当处于平面应变状态时，F(a/W)为：

$$F(a/W) = 2.082(1-a/W)^{3/4} \cdot (a/W)^{1/2} \cdot Y \quad (7)$$

而处于平面应力状态时，F(a/W)为：

$$F(a/W) = 2.021(1-a/W)^{3/4}(a/W)^{1/2} \cdot Y \quad (8)$$

式中Y为修正函数。对于三点弯曲试样，Y的表达式为[4]：

$$Y = 1.93 - 3.07(a/W) + 14.53(a/W)^2 - 25.11(a/W)^3 + 25.8(a/W)^4 \quad (9)$$

对于本试验所采用的试样尺寸及冲击载荷，很容易达到平面应变状态，故采用(7)式的修正函数F(a/w)。在一定的冲击能量A的条件下，对于给定尺寸的试样，当疲劳裂纹扩展到临界裂纹尺寸a_c时，裂纹将发生扩展而导致材料断裂，对应的应力强度因子K_I也达到其临界值K_{IC}。因此，K_{IC}可作为衡量材料在小能量多次冲击条件下本身所固有的抗力。通过在试样断面上测定临界裂纹长度a_c，便可通过(6)式来计算材料的K_{IC}值。

2 实验方法

2.1 试样制备

采用−200目还原铁粉为原料，其中碳含量为0.032%，配入−200目的石墨粉，使之构成的0.03%C、0.2%C、0.45%C、0.70%C及0.85%C五种成分，采用复烧工艺，使试样密度保持在7.30～7.35g/cm^{3}范围。用于考察冷却速度及后续退火条件影响的试样，其成分选择为0.45%C，分别采用水及一号锭子油作为冷却介质。最后机加工成尺寸为12mm×12.5mm×12.5mm的试样。

2.2 K_{IC}值的测试

在进行冲击试验之前，在电火花线切割机上开一条深度为2mm宽为0.10mm的槽。冲击试验在JD−125型小能多次冲击材料试验机上进行。试样冲断后，在断口上测出裂纹长度的平均值。本研究中冲击能量为1.1J。

3 实验结果与讨论

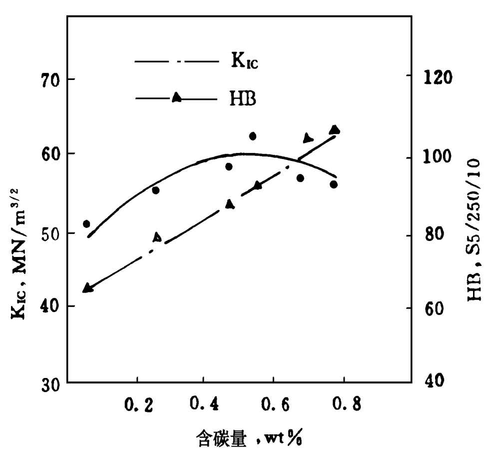

图1 碳含量对烧结钢断裂韧性及硬度的影响

Fig.1 Effect of carbon content on the fracture toughness and hardness of the sintered steels

图1示出了烧结碳钢的K_{IC}值、硬度与其中碳含量间的变化关系。从图中清楚地看到，烧结钢的K_{IC}值不象硬度那样与碳含量呈单调增加的关系，即在碳含量大约为0.55%处，烧结钢的K_{IC}值获得最大值，当碳含量低于

0.55%时，K_{IC}值随烧结钢中的碳含量的增加而升高，达到最大值后，又随碳含量的进一步增加而下降。在研究的碳含量范围内，烧结钢中珠光体的数量随着碳含量的增加而增多，从而烧结钢的强度、硬度也随之增大。在0.55%C 之前的 K_{IC}值随碳含量的变化关系与普通致密钢的 K_{IC}值的变化规律相反，即致密钢的断裂韧性随其强度的增加而下降。

表2为不同冷却及退火条件对碳含量为0.45%烧结钢断裂韧性、硬度的影响。从表中可以发现，随着冷却速度的提高，烧结钢的 K_{IC}值及硬度均升高。对于在930℃水冷试样，若进行退火处理且退火温度愈高，烧结钢的断裂韧性愈低。我们知道，冷却速度提高，有利于珠光体细化和分布均匀，烧结钢的强度也随之升高。退火温度升高，强度下降。这些与碳含量在低于0.55%时对烧结钢 K_{IC}值的影响规律一致，即与普通致密钢的断裂韧性随强度变化情形相反。

表2 断裂韧性与后处理工艺间的关系

Table 2 Relationships between fracture toughness and past-sintering processings of the sintered steels

	烧结态	油冷 T_o=870℃	水冷 T_o=930℃	退火(T_o=930℃，水冷)	
				T=200℃	T=600℃
K_{IC}，$MN/m^{3/2}$	58	60.4	69.3	67.6	63.7
HB(S5/250/10)	87	111	200	158	146

据 Rinehart[5]的研究，在静载下，应力与应变分布在整个受载物体上。而一次冲击试验由于激发的应力波相互干扰，使应力、应变分布表现出强烈的局部性。对于冲击韧性 α_K 的测量，由于应变的局部化和高的应变速度，材料若要抵抗这种破坏，不仅需要在狭小体积内吸收一定塑性变形能的足够塑性，而且也要求有能适应这种高应变速度的塑性。因而 α_K值主要取决于材料的塑性。反之，高强度则抑制了这种适应能力。相比之下，当材料承受小能量多次冲击载荷作用时，应变的局部化不如一次巨大冲击那么显著，亦即应变分布范围相对扩大了。小能多冲抗力是表征材料抵抗累积损伤的能力。塑性变形虽然能松弛应力，但它不能直接抵抗累积损伤。而材料强度则能抵抗这种累积损伤。另外，在含孔材料中，孔隙颈部材料的屈服强度 σ_s 决定了材料抵抗累积损伤的能力。因而，烧结钢的强度愈高，其断裂韧性 K_{IC}值也愈大，这一结论已为图1中当碳含量低于0.55%时及表2所列烧结钢的 K_{IC}值与强度的变化规律相吻合。然而，据报道[6]，试样缺口的存在导致材料小能多冲抗力在主要取决于其强度的同时，也要求一定的塑性与之相配合。图1中，当试样中的碳含量超过大约0.55%以后，断裂韧性 K_{IC}有所下降。这归结于烧结钢的塑性降低幅度过大，导致强度增加对断裂韧性 K_{IC}值的贡献低于塑性下降的贡献之故。断口形貌分析表明，较高碳含量烧结钢出现了解理断裂现象。

4 结论

烧结碳钢在小能多冲状态下的断裂韧性 K_{IC}值在0.55%C 以下随着碳含量的增加而升高，达到最大值后又随碳含量的进一步增加而下降。说明烧结碳钢在小能多冲状态下的断裂韧性主要取决于其强度，同时也要求适当的塑性与之配合。

5 参考文献

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Manufacture of Fe-3Al_2O_3·2SiO_2 Composite Green by In-situ Coagulation Mu Baichun(Liaoning Institute of Technology, Jinzhou 121001)

The basic processing of Fe-3Al_2O_3·2SiO_2 composite green by in situ coagulation in slip casting is reported. The influences of the solid content and coagulant in composite slurry on the properties of composite green body are investigated. The results show that the in-situ coagulation of composite slurry is facilitated by the coagulant. By changing the contents of solid, coagulant and buffer in composite slurry, the coagulation time and strength of composite green body can be adjusted. The composite green body is characterized by high density and homogeneity, sufficient ejection strength and little dimensional change rate.

Key words: in-situ coagulation, Fe-mullite composite

Process of Bioceramic Coating with Laser-remelting Pretreatment Gao Jiacheng, Zhang Yaping, Tang Hua (Chongqing University, 630044)

The bioceramic coating was made by Lasser-remelt pretreating a layer of mixed powder $CaHPO_4$·$2H_2O$-$CaCO_3$-Y_2O_3 on the TC_4 substrate. Effect of laser-remelting preatment on microstuctures and properties was studied by SEM ESD XRD etc. The results show that laser-remelting pretreatment is favorable to improvement of the mechanical properties and biocompatibility of bioceramic coating.

Ker words: bioceramic, laser-remelting, coating

Continuous Production of Ultrafine Iron Powder Sun Weimin, Jin Shouri (Shenyang Prolytechnic University, 110023)

The DC electric arc plasma method of increasing generation rate of ultrafine iron powder is studied. The results show that the generation rate of ultrafine iron powder is increased about 50% with a inclined electrode and it is increased one time when the pure iron was substituted with a mixture of tungsten and iron.

Key words: ultrafine iron powder, generation rate

Microsturcture and Mechanical Properties of SiCp/Al Composites Made by Spray Co-deposition Zhang Liying, Wu Chengyi, Lin Yaojun, Wang Rui(University of Science & Technology in Beijing, 100083)

The SiCp/Al composites with 35 vol% SiCp have been made by spray co-deposition. Pores and distribution of Sic particles in the composites as-deposited has been observed with SEM. The stress-strain curves of SiCp/Al composites from seveal processes have been obtained in tensile apparatus. The chamber is vacuumized, nitrogen is filled before atomization and as-deposited composite is hotpressed then the morphology of the fracture surface has been investigated by SEM. The results show that the composite as deposited has low porosity, small pore dimensions and uniform distribution of SiC particles, the yield strength, tensile strength and elogation are elevated, and the fracture mechanism of the SiCp/Al composites is pore aggragation.

Key words: spray co-deposition, particle reinforced metal matrix composites

Influence of MoS_2 and C on the Properites of P/M Diamond Composite Material Wu Yikun(Chongqing Metallurgy Industry Administration office, 630010) Yu Qing (Yuzhou University, Chongqing 630036)

The influence of MoS_2 and C on the properties of diancond composite material have been studied. The results show that the hardness and transverse rupture strength of diamond composite material are increased, its antifrictional properties, emerging hight, grinding ratio were improved by addition of MoS_2 and C. The cutting rate and use life of the tools also increased.

Key words: composite material, diamond tool, properties

Development in Valve of Auto Shock Absorbers Wang Hongbin(Jiangmen P/M Factory Co LTD, 529000)

The process of design and manu facture, and some technological problems has briefly described.

Key words: P/M parts, sizing

Measurement of Sintered Steel's Fracture Toughness by Repeated Impact with Low Energy Cao Shunhua, Xu Renze (Central South University of Technology, Changsha 410084)

The repeated impact method with low energy, was adopted for measuring the fracture toughness of sintered carbon steels with sample size of 12mm × 12.5mm × 62.5mm. The effect of carbon content, cooling rate and anealing process on the sintered steels' fracture toughness was studied. The results shows that the fracture toughness, K_{IC} value of sintered carbon steels, is dominated by their strength, and their ductility is necessary for improving the fracture toughness of the sintered steels.

Key words: repeated impact with low energy, fracture toughness, sintered carbon steel

Functional Structure Materials Prepared by Spray Co-deposition Liu Yougchang, Yang Gencang, Lü Yili(Northwesten Polytechnic University, Xian 710072)

The typical characteritics of the spray co-deposition were summerized. It is promising to manufacture the material with high damping capacity, good friction-wear, high strength and high conductivity properties.

Key words: spray co-deposition, metal matrix composites