

铜含量对铁基烧结减摩材料组织性能的影响

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摘要 研究了铜含量对铁基减摩材料组织性能的影响。一方面铜是铁基材料的强化元素,能提高材料的力学性能;另一方面铁基烧结合金基体中的不少孔隙是由铜粉扩散后留下的,因而铜又间接削弱合金力学性能。研究认为含铜量为 5% 左右时,合金的力学性能最高,而且基体中有足够的孔隙起自润滑作用,即合金作为减摩材料综合性能最高。添加磷组元后,铜对合金力学性能特别是拉伸强度的负作用被削弱。

主题词 烧结铁基减摩材料 力学性能 显微组织

前言

在铁基烧结减摩材料中,铜是比较常用的元素,一方面,铜能起强化作用;另一方面,铜能形成孔隙,而孔隙能贮存润滑油,对提高材料的减摩性能有利。国内外对含铜铁基材料的研究主要集中于“铜的膨胀作用机理”^{[1][2]}及抑制“铜膨胀”的方法^{[3][4]}。文献[5]对铜的强化作用机理作了分析。本文就作为减摩材料的 Fe-Cu-C、Fe-Cu-P-C 系合金中铜含量对其组织性能的影响作了研究。

实验方法

(1)原料

鞍钢生产的还原铁粉,粒度 - 100 目,含氧量 < 0.08%,压缩性 6.25 g/cm^3 ,松装密度为 2.65 g/cm^3 。

磷铁粉含磷量为 15.6%,粒度为 - 200 目。石墨粉为鳞片状,灰分 < 2.0%,粒度 - 200 目。铜粉为电解铜粉,粒度为 - 100 目。

实验前对铁粉作了退火处理,以减少含氧量、消除粉末应力、提高压制性。退火规范为: 650℃ 保温 1h。

(2)压制

压制是在 60t 油压机上进行,压制压力为 500 MPa。

(3)烧结

试样的烧结是在实验室中自行设计的烧结炉中进行的。烧结温度分别为 1140℃ 和 1100℃,保温时间为 1h,采用分解氨作保护气体,试样埋在混有炭块的氧化铝粉中,密封装舟。烧结后炉冷至 900℃,出炉后对烧结舟喷水冷却。

(4)对试样作了金相观察、硬度和抗拉实验及磨损实验。磨损实验是在销盘式磨损试验机上进行的,测出材料油润滑下的摩擦系数和相对磨损体积。对磨盘为 45 号调质钢,硬度 HRB95,润滑油为 20 号机油。

研究结果

Fe-Cu-C 合金烧结温度为 1140℃,保温时间为 1h,最终烧结密度为 $6.4 \sim 6.5 \text{ g/cm}^3$ 。Fe-Cu-P-C 合金烧结温度为 1100℃,保温时间为 1h,最终烧结密度为 $6.2 \sim 6.4 \text{ g/cm}^3$ 。

铜含量对合金烧结体积变化的影响如图 1。铜含量对合金力学性能影响如图 2~ 4。铜

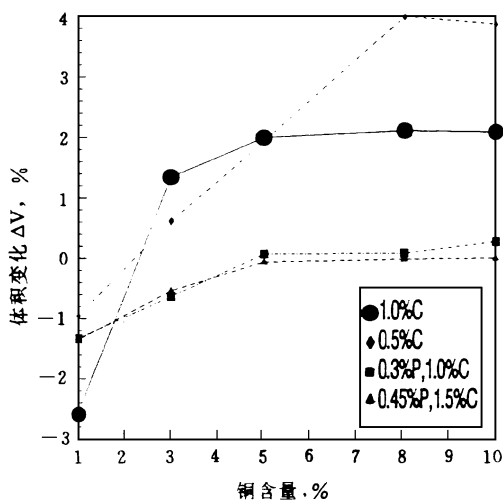


图 铜含量对烧结合金体积变化的影响

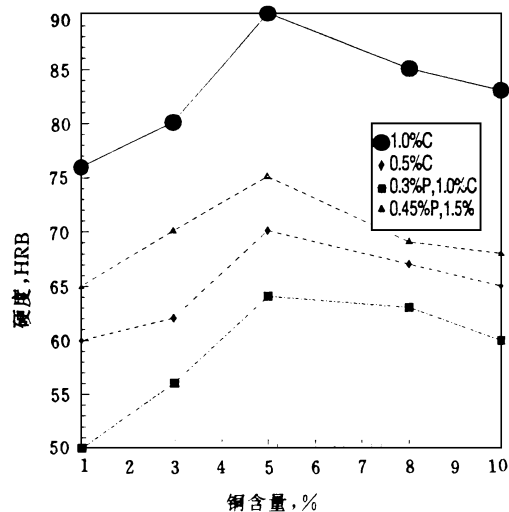


图 铜含量对烧结合金硬度的影响

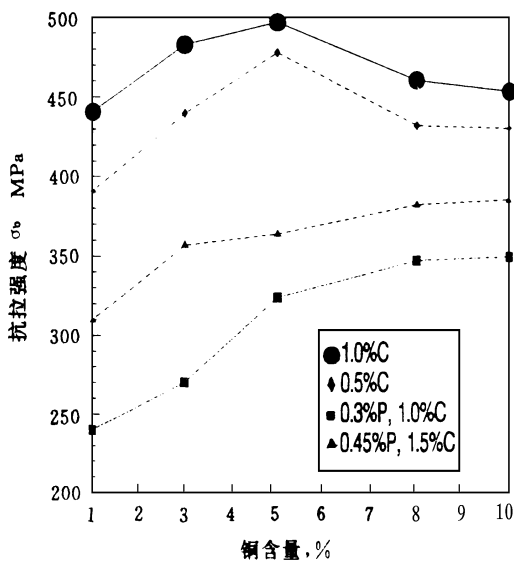


图 铜含量对烧结合金强度的影响

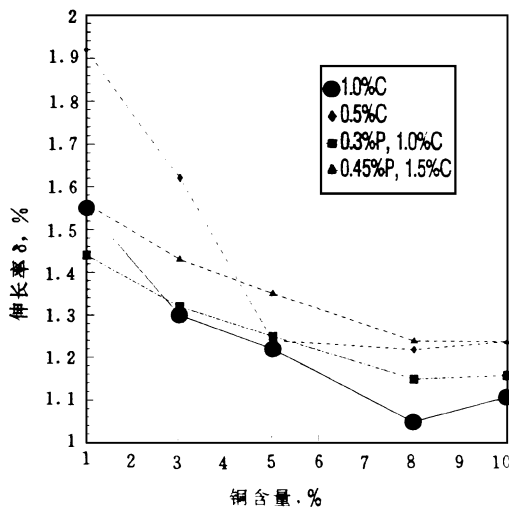


图 铜含量对烧结合金伸长率的影响

含量对合金磨损性能影响如图 5。

由图中结果可以看出：

(1) Fe-Cu-C 系合金, 随铜含量的增加, 试样体积由收缩变为膨胀, 铜量达到 8% 左右时, 膨胀达到最大, 随后体积膨胀有减小的倾向; Fe-Cu-P-C 系合金由于磷的作用, 试样的

膨胀受到抑制, 但随铜含量的增加体积膨胀趋势与 Fe-Cu-C 系基本一致。

(2) 合金硬度和抗拉强度随铜量增加变化趋势与不含磷材料基本一致, 在约 5% Cu 时达到最大值; 对含磷材料, 合金的抗拉强度在所作铜含量范围内, 基本随含铜量增加呈

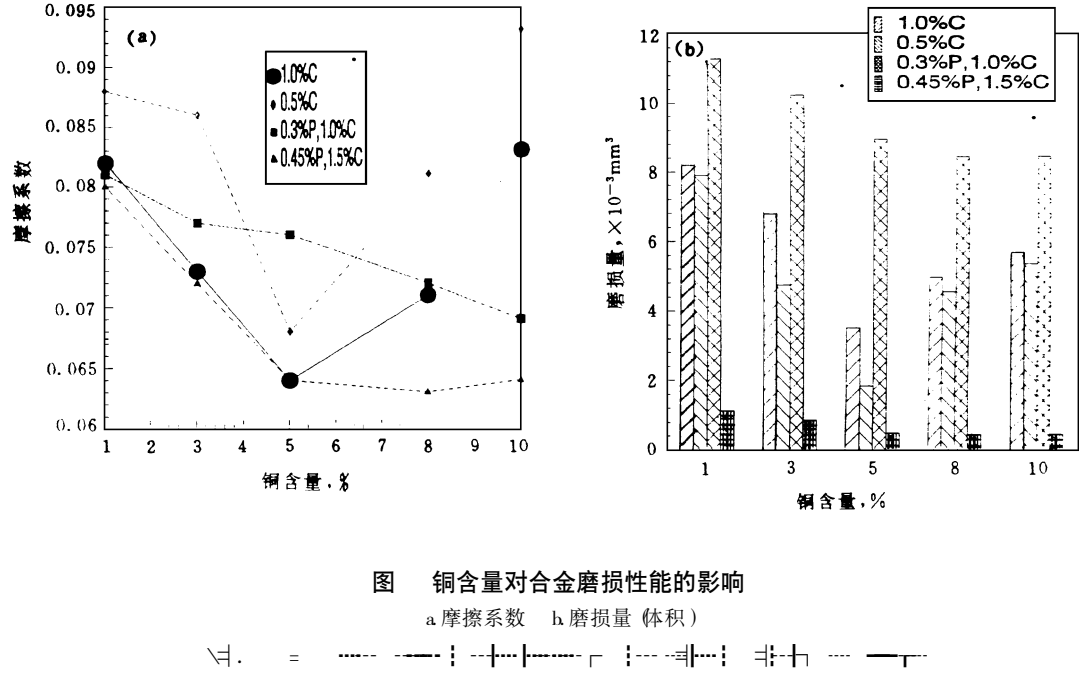


图 铜含量对合金磨损性能的影响

a 摩擦系数 b 磨损量 (体积)

—●— 1.0%C —○— 0.5%C —■— 0.3%P, 1.0%C —△— 0.45%P, 1.5%C

上升趋势。

(3)伸长率随铜量的增加而减小,在铜量达 8%时达到最小值。

(4)含铜量对合金磨损结果的影响较为复杂,在 Fe-Cu-C 系合金中,铜量达 5%时合金的耐磨性最高;对添加磷的合金,随含铜量的增加,耐磨性有提高的趋势。

讨论

在铁基粉末合金中,铜对材料力学性能的影响可归结为正负两方面的作用:

一是铜的强化作用,一方面铜增加珠光体量,细化珠光体片间距 (如图 6);另一方面,铜又有固溶强化和 ϵ -Cu 相的弥散强化作用^[5];其次,铜在烧结温度下奥氏体中的最大溶解度为 8%左右,当铜量大于 8%时,多余的液相铜有促进烧结的作用,从而提高了力学性能。

二是含铜合金中的不少孔隙是铜颗粒熔化扩散后留下的,随含铜量的增加,基体中的

孔隙数量增加 (如图 7),而孔隙削弱了合金的力学性能。

图 2 中含铜量对力学性能的影响可看作是 Cu 的正负作用综合影响的结果。一方面,随含铜量增加,铜的强化作用占优势,当铜量达 5%时,铜对基体的间接削弱作用开始占优势,当含铜量大于 8%时,由于液相烧结的作用,基体强度不再随铜量增加而下降。而添加磷元素后,由于磷的液相烧结作用,使基体中的孔隙球化,孤立化,从而使孔隙对基体的削弱作用减到最小,使铜对合金的负作用减小,即图 2 中含磷材料的抗拉强度随铜量增加而上升。但硬度对孔隙形状并不敏感,而与孔隙数量和分布有关。

含铜量对材料的减摩性能也表现出一定的规律。材料的耐磨性一方面与基体组织有关,较小的晶粒度和细片状珠光体耐磨性最高;另一方面与材料的力学性能有联系,高的强度和硬度,材料的摩擦系数较小,耐磨性较

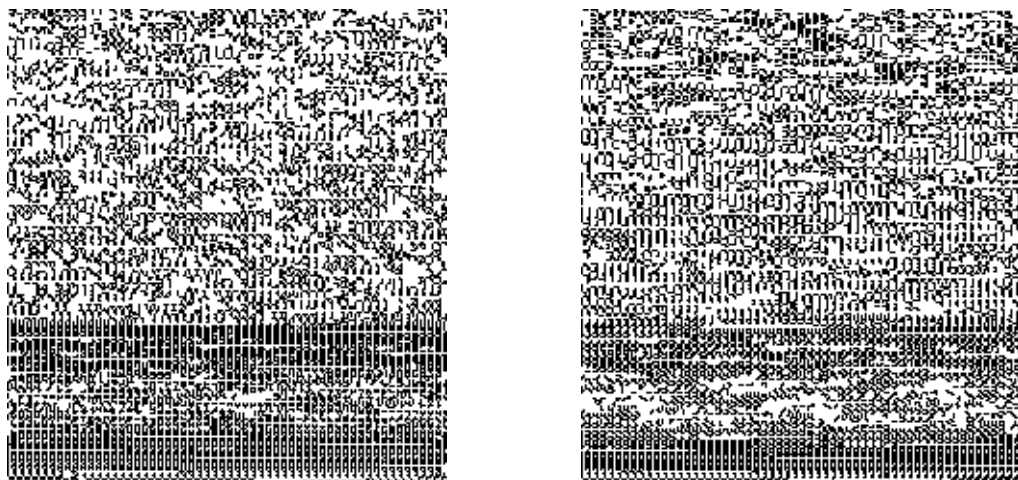


图 铜含量对合金显微组织的影响

a Fe 3 0% Cu 1 0% C **b** Fe 5 0% Cu 1 0% C

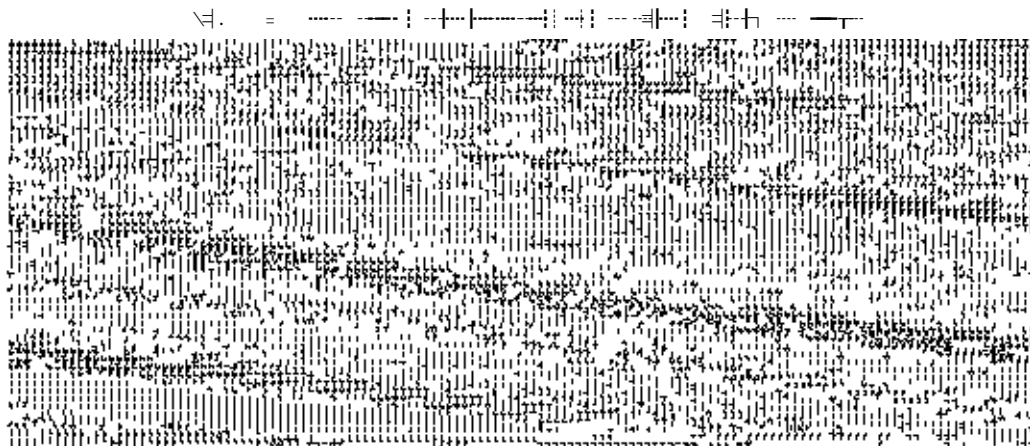


图 铜含量对合金基体孔隙度的影响 ×

$\cdot \setminus \gamma \quad \% < \dot{\gamma} \cdot \quad \% < \quad \cdot \setminus \gamma \cdot \quad \% < \dot{\gamma} \cdot \quad \% < \quad \cdot \setminus \gamma \cdot \quad \% < \dot{\gamma} \cdot \quad \% <$

$$\nabla_{\mathbf{f}} = \left[\frac{\partial}{\partial f_1} \quad \frac{\partial}{\partial f_2} \quad \frac{\partial}{\partial f_3} \quad \frac{\partial}{\partial f_4} \quad \frac{\partial}{\partial f_5} \quad \frac{\partial}{\partial f_6} \quad \frac{\partial}{\partial f_7} \quad \frac{\partial}{\partial f_8} \quad \frac{\partial}{\partial f_9} \quad \frac{\partial}{\partial f_{10}} \right]$$

高;另外,孔隙度也影响烧结材料的耐磨性。含 5%铜的合金具有较细片状珠光体组织,且其强度和硬度最高,故其磨损性能好。对于间断油润滑,孔隙能形成油的贮存容池,对于摩擦时形成油膜且保持油膜有重要作用。但孔隙太多,则不利于磨损性能的改善,一方面,接触面积的减少使单位接触压力升高,使磨损加剧,另一方面材料表面塑性变形抗力由于孔隙增多而减少,易于发生摩擦副间的咬合,堵塞孔隙,恶化材料的减摩性能。

当铜含量大于 5% 时,材料摩擦系数升

高,磨损量增加的原因除了孔隙太多外,还与富铜相的增多有一定关系,富铜相硬度低,它的存在一定会增大材料的摩擦系数。在铜量达 10%时,材料的摩擦系数增加较大,而磨损量增加较少,说明富铜相的出现对摩擦系数的影响较对磨损量的影响大些。

含磷材料孔隙球化、孤立化(链通孔隙数量减少),在铜含量较少时,孔隙保持油膜能力降低,不利于材料的减摩性能的提高。但当铜量增加时,孔隙保持油膜能力增强,且磷提高了基体的强度和硬度,使材料表面抗塑性

变形能力增强,摩擦时不易堵塞孔隙,故随铜量的增加,含磷材料在间断油润滑下减摩性能增强,表现在摩擦系数减小,磨损量降低。

结论

- (1)铜的正负两方面的作用即其强化作用和因形成孔隙而起到的间接削弱作用综合影响着含铜烧结铁基材料的力学性能。
- (2)铜含量对烧结材料的磨损性能的影响有一定规律,研究认为 Fe Cu C 合金铜含量达 5%时油润滑下其减摩性能提高;添加磷后材料的强度及耐磨性随铜含量的增加而提

高。

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北美粉末冶金持续增长

1995年,北美金属粉末销售量达 396623吨,增长了 2%,其中铁粉达 314538吨,增长 2 7%,铁基零件达 283544吨,增长 3 1%,预计铁粉市场将以 4~ 6%的平均增长速度增长,2005年将达 453000吨。但是,铜基粉末消耗量几乎没有增长 (21034吨)。

1995年,北美粉末冶金零件市场中,家用轿车占 66 5% (13 6kg),商用机械占 1 6%,家用设施占 5 3%,五金占 2 3%、工业马达和液压装置占 3 7%,手工工具、娱乐设施占 11 6%,其它占 9 0%。

1995年北美金属粉末销售量 (t)

铁粉和钢粉	314, 538
铜和铜基粉	21, 034
铝 粉	33, 562
钼 粉	2, 265 (估算)
钨 粉	1, 309
碳化钨粉	9, 826
镍 粉	9, 491
锡 粉	974
不锈钢粉	3, 624
总计	396, 623

摘译自《M PR》96 7, 26~ 27

Analyses of Statistical Characteristics of the Flexural Strength of an Advanced Ceramic Tool Material Xu Chong-hai, Ai Xing, Huang Chuanzhen (Shandong University of Technology, Jinan 250061)

The flexural strength of an advanced ceramic tool material and its statistical characteristics have been studied experimentally in this paper, according to which hot pressing parameters are optimized and the fracture feature is also analysed. Results of linear regression analysis and K-S distribution fit test show that the flexural strength of this kind of ceramic tool material obeys three-parameter Weibull distribution very well. A statistical model is built which can be used to explain the size effect of the flexural strength.

Key words: advanced ceramic tool, flexural strength, statistical characteristic, size effect

Investigation of Contact Materials for Microcrystal Cu₇Cr₅₀ Vacuum Breaker Cui Jiangguo, Yang Zhimao and Ding Bingjun (Xian Communication University, 710049)

CuCr₅₀ alloy powder was made by high energy ball-milling process and compacted into dense compact by hot pressing in vacuum furnace. The particle size, change of morphology, microstructure of hot pressed compact and its density change with temperature and time during milling process were reviewed by using scanning electronic microscope, X ray diffractometer, nely spectrometer, etc.

Key words: microcrystal, contact material, high energy balling milling, vacuum hot pressing

A Rudimental study on Manufacture of Cermented Carbide / Steel Composite Materials by HIP Sintering-Connecting Process Cheng Feixiong, Li Shikui (Central Iron and Steel Research Institute, Beijing 100081)

Composite adaptor of YG15C and 45[#] steel have been manufactured by HIP sintering-connecting method. The composite features, the elements diffusion and the binding strength in interface of the adaptor have been reviewed. The mechanism of HIP sintering-connection for YG15C and 45[#] steel has been analysed.

Key words: HIP (hot isostatic pressing), cemented carbide/steel composite material

Application of Solid lubricating Materials for Pantograph slide Plate Huang Hanzhong (Datong Locomotive Factory, Shanxi 037038), Li Mulin (Beijing Research Institute of Powder Metallurgy, 100078)

The weariness mechanism on the metal base pantograph slide plate and the contact network conductor of electric locomotive have been studied. A new type of solid lubricating materials have been developed.

The results show that after applying the solid lubricating materials to electric locomotive, the service life of the contact network conductor and slide plate have been obviously improved.

Key words: solid lubricating materials, pantograph slide plate

The Effect of Copper on Structure and Properties of Sintered Iron-based Anti-friction Materials Zhou Bide, Ci Lirjie (Harbin Institute of Tecnology, Box 434, 150001), Ma Xuezhu (Harbin Railroad Breau Institute of Sicence and Technology)

The effect of the amount of copper to iron-base anti-friction sintered materials were studied. It was concluded that effect of copper contains tow sides. Eirst, it is strengthening element and can increase mechanical properties. Second, it is the main cause of formation of porosity and decreases mechanical properties of matrix. However, porosity makes materials frictionizing under oil lubrication and has good anti-friction property. 5% copper was regarded as the best composition of iron-based anti-friction alloys. The negative effect on mechanical propertes, especially tensile strength of copper is lowered when phosphorus was added.

Key words: sintered iron-base anti-friction material, mechanical property, microstructure

Standard Emery Grit for Determination of Flowability of Powder Chen Mulan, Li Zhongquan (Central Iron and Steel Research Institute, Beijing 100081)

A standard emery grit for determination of flowability of powders has been developed which shall be used for calibrating of the funnel of the apparatus. We tested many materials, finally a sort of natural mineral was chose as to make emery grit. The emery grit has had success though dressing and sieving. The reference material has good wear resistance, chemical stability, homogeneity and is free of magnetic particles. All technical specifications of the emery grit accord with the demands of ISO 4490.

Key words: flowability of powders, reference material of emer grit (standard emery grit)

Development of Binders for Metal Powder Injection Molding Qu Xuanhui, Yan Hansong, Huang Baiyun (Central South University of Techology, Changsha, 410083)

The function and development of binders for metal powder injection molding are outlined. In addition, the suitability and cost of several typical binder systems and the debinding processes are discussed.

Key words: metal powder injection molding, binder