Applied Mechanics and Materials *Online: 2014-07-28*
ISSN: 1662-7482, Vol. 597, pp 95-98
doi:10.4028/www.scientific.net/AMM.597.95

The Microstructure and Mechanical Properties Research of FeCrWMoV-Series High Temperature Self- Compensation Lubricating Composite Materials

Ying Han[1,a], Yan Jun Wang[1,b*], Shou Ren Wang[1,c],Guang JI Xue[1,d]

[1] School of Mechanical Engineering, University of Jinan, Jinan, 250022, China

[a]abchanying@126.com, [b]me_wangyj@ujn.edu.cn, [c]sherman0158@tom.com, [d]xuegj.1990@163.com

Keywords: sinter; matrix material; microstructure; properties

Abstract：High temperature self-compensation lubricating composite materials were fabricated by vacuum sintering method in this work. The FeCrWMoV alloy powder was used as the basic material, the TiC and Co ceramic powder was used as reinforcing material and TiH_2 and $CaCO_3$ was used as pore-forming material. The changes of the crushing strength, micro-hardness and porosity were analyzed with the temperature. The pore structure and surface morphology of the preforms were analyzed using scanning electron microscope (SEM). The conclusion is that the most appropriate sintering temperature is 1250^{o}C in the process of sintering, and the formation of secondary organization has significant influence on the properties of composite materials.

Introduction

In the modern industry, high temperature self-lubricating composite materials are widely used in aerospace, biology, medicine and other industries, due to its superior mechanical performances [1]. It is added solid lubricant to the matrix materials in the composite. In the process of working, the solid lubricant can reduce the surface friction coefficient and wear. However, the way of adding solid lubricants into the metal ceramic matrix powder before sintering has undesirable side effects [2]. Such as the solid lubricants may be oxidized at high sintering temperature, which will damage its lubricating properties [3].

In order to overcome the negative aspect, a novel kind of high temperature self-lubricating composite materials has been developed. First of all, preform with orderly micro-pores was prepared by using high temperature vacuum hot pressing sintering process. Then, melting solid lubricant is infiltrated into the orderly micro-pores of preform by impregnation technology [4, 5]. The lubrication mechanism is that solid lubricant infiltrated to the friction surface to provide lubrication. These micro-pores function in a way similar to sweat glands of human beings [6]. The composite materials with high strength and toughness and has good self-lubrication property. The physical and mechanical properties of the composite material mainly depend on the preform with micro-pores. In this paper, based on TiC/FeCrWMoV metal ceramic matrix material and TiH_2/$CaCO_3$ pore-forming additives, the structure and mechanical properties of preform were analyzed.

Experiments

Test materials. The main function of the matrix in composite materials is to sustain load. To make the matrix has high strength and toughness is to ensure the composition design of matrix material. FeCrWMoV alloy powder was used as matrix material, TiC/Co ceramic powder as reinforcing material and TiH_2/$CaCO_3$ as pore-forming material. These powders were sintered under the vacuum degree at 10^{-1}-10^{-2} Pa. When the temperature rose to 400^{o}C, H_2 was resolved by TiH_2 and the micro-pores were formed in the process. While at 800^{o}C, CO_2 was resolved by $CaCO_3$. The release of the CO_2 and H_2 left orderly micro-pores in the preform, the strength of which was enhanced by the Ti.

Table1 shows the compositions and its volume fraction of the matrix material. And the chemical component of FeCrWMoV alloy powder was shown in table2.

Table1 The compositions and its volume fraction of the matrix material

Alloy powder	Ceramic powder	Pore-forming material	Lubrication	Additives
FeCrWMoV 79%	TiC+Co 7.5+2.5%	TiH_2+$CaCO_3$ +$C_{36}H_{70}O_4Zn$ 4.5%	graphite 0.5%	Cu_3P 6%

Table2 The chemical component of FeCrWMoV alloy powder

The chemical component (vol.%)							Average grading	Density	Compressib-ility factor	Mobility
C	Cr	Mo	W	V	Si	[O]	μm	g/cm^3	g/cm^3	s/50g
0.8-0.9	3.8-4.4	4.5-5.5	5.5-6.75	1.75-2.2	0.18-2.1	< 0.35	25/50	3.11	>5.0	<25

Material preparation. FeCrWMoV alloy powder was used as matrix material and TiH_2/$CaCO_3$ as pore-forming material. These powders were sintered under the vacuum degree at 10^{-1}-10^{-2} Pa. When the temperature rose to 400°C, H_2 was resolved by TiH_2 and the micro-pores were formed in the process. While at 800°C, CO_2 was resolved by $CaCO_3$. The micro-pores were come into cut-through in the surface during the process. The strength and toughness of preform were influenced significantly by the pore structure characteristics (such as porosity, pore shape, size and distribution).

Therefore, the factors (such as powder material, the ratio of components, the forming pressure and sintering temperature) of influence pore structure were considered at the process of preparing materials [7]. In this work, sintering temperature was selected as the main factors to analyze its impact on materials. The specific process of sintering metal ceramic material is as follows：

(1) Mixed material: every material powder was weighted respectively by electronic scales according to the ratio of composition. And then mixed powder was putted into the stainless steel tube of ball mill. In order to avoid the oxidation of powder in the process of ball mill, the stainless steel tube was filled with a certain amount of argon gas for protecting.

(2) The mold stress forming: the mixed powder was putted into the mold after ball mill. The size of the sample is Ø10×8mm by using press machine, forming pressure is 200-400MPa and the holding time is 5min.

(3) Sintering: the forming sample was putted into the vacuum sintering furnace for sintering. The sintering temperature is 1210-1260°C and the holding time is 60min. The pressure is 30MPa and the holding time is 30min. The sample was taken out at room temperature from the furnace.

Experimental method. The liquid static equilibrium method is used to test the density and the porosity of the preform. The crushing strength and micro-hardness of preform were tested using HVS-type micro-hardness tester and hydraulic testing machine respectively. Friction and wear properties of the composites were investigated using a high temperature XP-5 pin-on-disk wear tester. The samples microstructures and worn surface morphology were characterized using scanning electron microscope (SEM) equipped with an energy dispersive spectroscope.

Results and Discussion

Microstructure. Fig.1 shows the pore structure of metal ceramic preform. It can be seen that holes are homogeneously distributed and interpenetrated through the matrix. The release of the CO_2 and H_2 left orderly micro-pores in the preform, the strength of which was enhanced by the Ti. In the process, the liquid organization of the preform has been formed, so micro-pores can be formed. According to the theory of surface tension and surface energy, the shape of the pores is round in the process in order to maintain the lowest energy state [8]. Meanwhile, the formation of secondary organization in the process of sintering influenced the performance of matrix material. The wear degree of composite

materials is mainly depended on the performance of secondary organization in the process of material preparation [9].

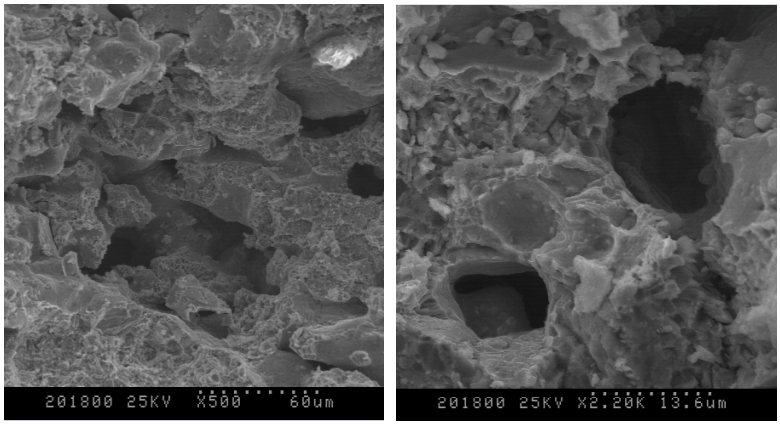

Fig.1 The pore structure of metal ceramic preform

Mechanical property. It can be seen that the porosity was decreased slowly with the rising of sintering temperature in Fig.2. In the process of sintering, in order to guarantee the preform with good strength and toughness, the porosity should controlled in the range of 15-30% [10]. With the rising of sintering temperature, every component in the preform was mutual diffusion. The forming of sintering neck leads to the decrease of porosity [11].

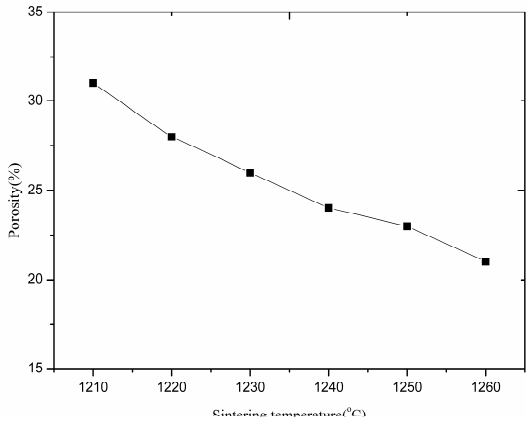

Fig.2 The influence of porosity with the changing of sintering temperature

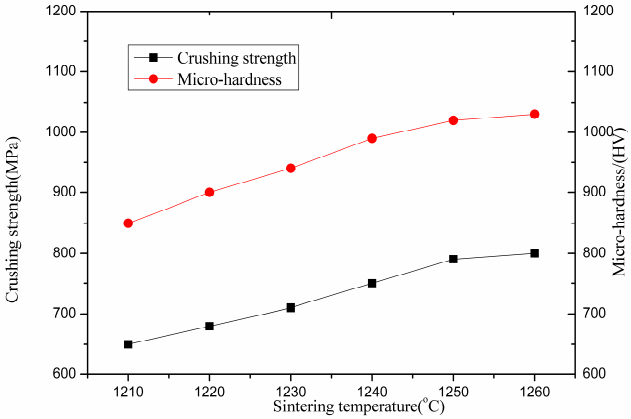

Fig.3 The influence of the crushing strength and micro-hardness with the changing of sintering temperature

The curve of crushing strength and micro-hardness with the changing of sintering temperature is shown in Fig.3. It can be observed that the crushing strength and micro-hardness were improved as the rising of sintering temperature. When the temperature reached to 1250°C, the curve began to change gently. When the range of porosity is 0-30%, the relationship between strength and porosity is as follows [12]:

$$\sigma = \sigma_0 \exp^{-B\varepsilon} \tag{1}$$

Where σ_0 is the strength of dense material (MPa), σ is the strength of porous material (MPa), ε is the porosity(%) and B is the scale factor.

It is evident that with the increasing of porosity, the strength of the material is reduced. Therefore, the porosity of preform is influenced by sintering temperature. With the increasing of sintering temperature, the strength of the material is improved and the porosity is reduced. Also, the crushing strength and micro-hardness were improved with the decreased of cut-through holes.

Conclusions

$TiH_2/CaCO_3$ was used as pore-forming material. The micro-pores were uniformly distributed and interpenetrated in the preform. Meanwhile, the formation of secondary organization in the process of sintering influenced the performance of matrix material. In the process of preparing FeCrWMoV-series high temperature self-compensation lubricating composite materials, as the sintering temperature rising, the crushing strength and micro-hardness were improved, while the porosity of preform was decreased slowly. So the most appropriate sintering temperature is at 1250^{o}C.

Acknowledgement

The authors would like to thank the National Natural Science Foundation of P.R. China for the financial support (ID: 51275208) and Science Foundation of Shandong Province of P.R. China for the financial support (ID: 2011GGX10321).

References

[1] Z.M.Liu, Elevated temperature diffusion self-lubricating mechanisms of a novel cermet sinter with orderly micro-pores, Wear. 262 (2007) 600-606.

[2] L.Y.Yang, Z.M.Liu, Microstructure and tribological properties of Ti-Al self-lubricating materials, Journal of Wuhan University of technology. 30 (2008) 118-120.

[3] X.L.Kong, Y.B.Liu, Y.Lu, P/M metal-matrix high-temperature solid self-lubricating materials, Powder metallurgy technology. 19 (2001) 86-92.

[4] Y.J.Wang, Z.M.Liu, Tribological properties of high temperature self-lubrication metal ceramics with an interpenetrating network, Wear. 265 (2008) 1720-1726.

[5] Y.B.Zhang, D.Z.Xing, Z.M.Liu, The study of high-temperature self-lubricating materials pore structure and lubricants driven, Lubrication engineering. 34 (2009) 5-8.

[6] F.Xie, Study on contact stability of high temperature sweating and lubricating cellular solids, Wuhan: Wuhan University of Technology, 2011.

[7] J.S.Han, W.M.Liu, J.J.Lv, Tribological properties of Fe-Mo-(MoS_2/PbO) high temperature self-lubricating material, Journal of material science and engineering. 26 (2008) 117-120.

[8] R.Zhang, Porosity and strength of SiC porous ceramics, Diamond and Abrasives Engineering. 4 (2000) 38-40.

[9] J.L.Li, D.S.Xiong, M.F.Huo, Friction and wear properties of Ni-Cr-W-Al-Ti-MoS_2 at elevated temperatures and self-consumption phenomena, Wear. 265 (2008) 566-575.

[10] F.L.Han, The brief introduction of criterion of MPIF(America) “the criterion of self-lubricating metallurgical materials” in 1998, Powder metallurgy industry. 10 (2000) 36-46.

[11] H.D.Ding, Sintering model about expansion and shrinkage, The Transactions of Nonferrous Metals Society of China. 11 (2001) 45-50.

[12] W.Duckworth, Discussion of ryshkewitch paper by winston duckworth, Journal of the American Ceramic Society. 36 (1953) 68-70.