牙科用鑄造鈦鈮鐵合金之研削性及切削性研究

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摘 要

本研究中，進行探討一系列三元Ti-5Nb-xFe(X=1、2、3、4及5 wt %)合金之微結構、機械性質、研削性及切削性，並以商業用純鈦(Grade II)及Ti-6Al-4V作為對照組，期望能開發出適合作為牙科應用之鈦合金。實驗結果顯示，Ti-5Nb合金為α'繞射峰，添加Fe元素也開始觀察出體心立方(bcc)結構之β相，隨著Fe元素含量增加到4wt%或更高時，α'相完全消失只觀察到從高溫被殘留下的β相。由低掃描速度(0.5 deg/min)並觀察出Ti-5Nb-5Fe合金有微量ω相的出現，Ti-5Nb-4Fe合金則有大量的ω相。在微硬度方面，Ti-5Nb-4Fe合金因有ω相使得微硬度也是一系列Ti-5Nb-xFe合金中最高的，並且在研削性測試結果發現，微硬度與研削量有相似的趨勢。　　評估研削性為金屬每分鐘的移除量(研削量)及金屬被研削之切屑體積與砂輪直徑被磨削之體積的比(研削比)，而每個金屬之研削性都依賴著這些條件。當Fe元素添加入合金發現，在Fe元素含量較高時，使其更加容易加工，有助於改善研削性質。在1000 m/min 研削速率下，Ti-5Nb-4Fe合金之研削速率是c.p. Ti的1.9倍。　　切削性的評估為切削力，由刀具從試片邊緣切削進給，計算不同合金之平均切削力。實驗結果顯示，以目前的切削條件下，Ti-5Nb-xFe合金與c.p. Ti相比，當Fe元素含量遞增時，使其切削力有大幅提升的趨勢至Ti-5Nb-4Fe時下降。在Fe元素含量較高時，展現出更加容易之加工特性。Ti-5Nb-4Fe合金於110 m/min 切削轉速下，進給速度為30 mm/min時，切削力為5.09N；此外，添加切削液後會使Ti-5Nb-xFe合金之切削力下降1~4N。而Ti-5Nb-4Fe合金於110 m/min 切削轉速下之試片凹槽表面，顯示出沒有金屬切屑的黏附，且擁有最低的表面粗糙值(Ra)。

關鍵詞 : 牙科合金、鈦合金、微結構、研削性、切削性、機械性質

目錄

參考文獻

[1]Inglis AE, Advances in implant arthroplasty in the upper extremity, circa 1988, Clinical & Experimental Rheumatology, 7(3):141-144, 1989.
[2]Park JB and Lakes RS, Biomaterials: an Introduction 2nd ed., Plenum Press, New York, pp.2-3, 1992.
[3]Yen SK, Characterization of Electrolytic ZrO2 Coating on AISI 316L Stainless Steel, Journal of The electrochemical Society, 146(4):1392-1396, 1999.
[4]Yen SK, Huang TY, characterization of the electrolytic ZrO2 coating on Ti-6Al-4V, Materials chemistry and Physics, pp.214-221, 1998.
[5]Yen SK, Guo MJ and Zan HZ, Characterizaton of electrolytic ZrO2 coating on Co-Cr-Mo implant alloys of hip prosthesis, Biomaterial Publish, 2000.
[6]Silver FH and Doillon C, Biocompatibility : Interactions of Biological and Implantable Materials, Vol. 1, Polymers, VCH Publishers, New York, NY, Chap. 4, 1989.
[7]Silver FH and Doillon C, Organ and tissue structure in Biocompatibility, VCH Publishers, New York, NY, 27, 1989.
[8]Silver FH and Pin G, Cell culture on collagen: A review of tissue engineering using scaffolds containing extracellular matrix, J. Long-Term Effects of Medical Implants, 2, 67, 1992.
[9]Rateitschak KH and Wolf HF, Color atlas dental dental medicine, Thieme Medical Publishers, pp. 11-24, 1995.
[10]Block MS, Kent JN and Guerra LS, Implants in dentistry, Philadelphia: Saunders, pp. 45-62, 1997.
[11]Park JB and Lakes RS, Biomaterials: an introduction, Plenum Press, 2nd., New York, 1992.
[12]Davidson JA, Characteristics of metal and ceramic total hip bearing surface and the effect on long-term UHMWPE wear, Orthopaedic Research Report OR-92-08, Smith and Nephew, 1991.
[13]Tipper JL, Firkins PJ, Besong AA, Barbour PSM, Nevelos J, Stone MH, Ingham E., Fisher J,Characterisation of wear debris from UHMWPE on zirconia ceramic, metal-on-metal and alumina ceramic-on-ceramic hip prostheses generated in a physiological anatomical hip joint simulator, Wear 250 pp. 120-128, 2001.
[14]Wroblewski BM, 15-21 year results of the charnley low friction arthroplasty, Clin. Orthop., 211:30-35, 1986.
[15]Hench LL, Bioactive Glass and Glass-Ceramics:A perspective, CPC Hanbook of Bioactive Ceramics.
[16]黃世偉，高分子與醫療器材，科學發展455期，pp.14-19，2010。
[17]Park JB and Lakes RS, Biomaterials: an introduction, Plenum Press, 2th ed., New York, 1992.
[18]Branemark PI, Hansson BO, Adell R, Breine U, Lindstrom J, Hallen O, Ohman A, Osseointegrated implants in the treatment of the edentulous jaw, Experience from a 10-year period. Scand J Plast Reconstr Surg Suppl, 16:1-132, 1977.
[19]Branemark KP, Hansson B, Adell R, Intraosseous anchorage dental prostheses: I experimental studies, Scand J Plast Reconstr Surg Suppl, 16:1-4, 1977.
[20]Kokubo T, Nakamura T, Miyaji F, Bioceramics 9: Proceedings of the 9th International Symposium on Ceramics in Medicine. Otsu Japart, p.11, 1996.
[21]Moffat DL and Larbalestier DC, The competition between Martensite and Omega in Quenched Ti-Nb Alloys, Metall Trans., A19, (7):1677-1686, 1988.
[22]郁仁貽，冶金學概論(下冊)，徐氏基金會出版，1988。
[23]草道英武，????????用，日刊工業新聞社，東京，日本，1983。
[24]Collings EW, The physical metallurgy of titanium alloys, Met. Park, OH: Am. Soc. Met., pp. 3-5, 1984.
[25]Kahles JF, Field M, Eylon D and Froes FH, Machining of titanium alloys, J. Met., 37(4):27-35, 1985.
[26]Blenkinsop PA, High temperature titanium alloys, IMI Titanium Limited, Birmingham, England, pp. 189-198, 1986.

[27]Machado AR and Wallbank J, Machining of titanium and its alloys - a review, Proc. Inst. Mech. Eng. B, 204(1):53-60, 1990.
[28]Borradaile JB and Jeal RH, Mechanical properties of titanium alloys, Warrendale: Metallurgical society of AIME, vols. 1-3, 1980.
[29]Donachie MJ, Titanium: a technical guide, ASM INTERNATIONAL, Met. Park, OH 44073, USA, pp. 21-33, 1988.
[30]Molchanova EK, Phase Diagrams of Titanium, Isr. Pro. Sci. Trans., Jerusalem, 1965.
[31]Lee CM, Ju CP, Chern Lin JH, Structure-property relationship of cast Ti-Nb alloys, J Oral Rehabil 2002;29:314-322.
[32]Nishiyama Z, Transformation, Academic Press, New Tork, 1978.
[33]Louzguine DV, Kato H, Inoue A, High strength and ductile binary Ti-Fe composite alloy, J Alloy Comp, 384(1-2):L1-L3, 2004.
[34]何寶明，先進材料產業，中國，2003。
[35]Wang K, Gustavson L, Dumbleton J, The characterization of Ti-12Mo-6Zr-2Fe a new alloy developed for surpical implants, Beta titanium alloys in the 1990 ’ s, Warrendale:TMS-A1ME, 1993.
[36]Okazaki Y, Ito Y, Kyo K and andtateishi T, Corrosion resistance and corrosion fatigue strength of new titanium alloys for medical implants without V and Al, Mater. Sci. Eng., v213, pp. 138-147, 1996.
[37]Hamanaka H, Kinds and uses of titanium alloys in dentistry J. Quintessence of Dental Technology Extra issue. 1999; pp.140-145.
[38]王千億，王俊傑，機械製造(Ⅰ)，全華科技圖書股份有限公司，台北，pp.226-248，1986。
[39]簡文通，機械製造，全華科技圖書股份有限公司，台北，6-1至6-40，1997。
[40]Canteroa JL, Tardiob MM, Cantelia JA, Marcosc M, Migueleza MH, Dry drilling of alloy Ti-6Al-4V, International Journal of Machine Tools & Manufacture 45:1246 – 1255, 2005.
[41]Sun J, Guo YB, A comprehensive experimental study on surface integrity by end milling Ti – 6Al – 4V, Journal of Materials Processing Technology 209 : 4036 – 4042, 2009.
[42]Venugopal KA, Paul S, Chattopadhyay AB, Tool wear in cryogenic turning of Ti-6Al-4V alloy, Cryogenics 47 : 12-18, 2007.
[43]Yuan SM, Yan LT, Liu WD, Liu Q, Effects of cooling air temperature on cryogenic machining of Ti-6Al-4V alloy, Journal of Materials Processing Technology 211: 356-362, 2011.
[44]菊地聖史，奥野攻，?科用快削???合金?開?，第19回日本齒科??????術講演?，日本福島，pp.8-13，2006。
[45]竹山秀彥，切削加工，丸善株式?社，日本東京，1997。
[46]賴耿陽譯，現代外型研磨作業，復漢出版，台南，p.126，1989。
[47]何正義，姚威宏，鄭朝旭，蕭肇凱，聶國禎，機械製造，高立圖書有限公司，台北，p.388，2008。
[48]Ezugwu EO and Wang ZM, Titanium alloys and their machinability - A review, J. Mater. Proc. Tech., 68(3):262-274, 1997.
[49]Takeyama H and Murata R, Temperature dependence of tool wear, J. Jpn. Soc. Preci. Eng., Japanese, 27(1):33-38, 1961.
[50]Araki T and Yamamoto S, Nansaku zairyo to hisakusei, Kikai Gijutsu, Japanese, 21(8):22-27, 1973.
[51]Kikuchi M, Takahashi M, Okabe T and Okuno O, Grindability of dental cast Ti-Ag and Ti-Cu alloys, Dent. Mater. J., 22(2):191-205, 2003.
[52]Donachie MJ, Titanium: A technical guide, ASM. pp. 79-84, 2000.
[53]木村篤良，中村貞行，日本金????報，27:397-399，1988.
[54]Takahashi M, Kikuchi M, Takada Y and Okuno O, Mechanical properties and microstructures of dental cast Ti-Ag and Ti-Cu alloys, Dent. Mater. J., 21(3):270-280, 2002.
[55]Takada Y, Nakajima H, Okuno O and Okabe T, Microstructure and corrosion behavior of binary titanium alloys, Dent. Mater. J., 20(1):34-52, 2001.
[56]Ohkubo C, Watanabe I, Ford JP, Nakajima H, Hosoi T and Okabe T, Machinability of cast Ti and Ti-6Al-4V alloy, J. Dent. Res., 77:165, 1998.
[57]Watanabe I, Ohkubo C, Ford JP, Atsuta M and Okabe T, Cutting efficiency of air-turbine burs on cast titanium and dental casting alloys, Dent. Mater., 16:420-425, 2000.
[58]Koike M, ltoh M, Okuno O, Kimura K, Takeda O, Okabe TH and Okabe T, Evaluation of Ti-Cr-Cu alloys for dental applications, J. Mater. Eng. Perform., 14(6):778-783, 2005.
[59]Kikuchi M, Takahashi M and Okuno O, Mechanical properties and grindability of dental cast Ti-Nb alloys, Dent. Mater. J., 22(3):328-342, 2003.
[60]Okabe T, Kikuchi M, Ohkubo C, Koike M, Okuno O and Oda Y, Cost-Affordable titanium symposium dedicated to professor harvey flower, TMS, Warrendale, PA, 177, 2004.
[61]姜宗佑，生醫用鈦-鉻二元合金之結構及性質探討，大葉大學碩士論文， 2007。
[62]洪裕盛，牙科用鑄造鈦錫合金之結構及性質研究，大葉大學碩士論文，2009。
[63]Ohkubo C, Watanabe I, Ford JP, Nakajima H, Hosoi T and Okabe T, The machinability of cast titanium and Ti-6Al-4V alloy, Biomaterials, 21(4):421-428, 2000.
[64]Watanabe I, Kiyosue S, Ohkubo C, Aoki T and Okabe T, Machinability of cast commercial titanium alloys, J. Biomed. Mater. Res., A63 (6):760-764, 2002.
[65]Takahashi M, Kikuchi M. and Okuno O, Mechanical properties and grindability of experimental Ti-Au alloys, Dent. Mater. J., 23(2):203-210,

2004.
[66]Ohkubo C, Hosoi T, Ford JP and Watanabe I, Effect of surface reaction layer on grindability of cast titanium alloys, Dent. Mater., 22(3):268-274, 2006.
[67]Kikuchi M, Takahashi M, Sato H, Okuno O, Nunn M.E. and Okabe T, Grindability of cast Ti-Hf alloys, J. Biomed. Mater. Res. B. Appl. Biomater., 77(1):34-38, 2006.
[68]Kikuchi M, Takahashi M and Okuno O, Machinability of Experimental Ti-Ag Alloys, Dent. Mater. J, 27(2):210-220, 2008.
[69]Goeuriot D, Dubois JC, Merle D, Thevenot F and Exbrayat P, Enstatite Based Ceramics for Machinable Prosthesis Applications, J. Eur. Cer. Soc., 18(14):2045-2056, 1998.
[70]EZUGWU EO and WANG ZM, Titanium alloys and their machinability-a review, J. Mater. Process Technol., 68(3): 262-274, 1997.
[71]Silcock JM, An x-ray examination of the ω phase in TiV, TiMo and TiCr alloys, Acta. Metall., 6:481-493, 1958.
[72]Pack HJ, Kalish D and Fike KD, Stability of as-quenched beta-IIItitanium alloys, Mater. Sci. Eng., 6:181-198, 1970.
[73]Ohmori Y, Natsui H, Nakai K and Ohtsubo H, Effects of ω phase formation on decomposition of α"/ β duplex phase structure in a metastable β Ti alloy, Mater. Trans. JIM, 39(1):40-48, 1998.
[74]Bagariaskii IA, Nosova GI and Tagunova TV, Factors in the formation of metastable phase in titanium-base alloys, Sov. Phys. Dokl., 30:1014-1018, 1959.
[75]Combe EC, Notes of dental materials, Churchill Livingston, Edinburgh, 6th ed., 64, 1992.
[76]Ammen CW, The Metalcaster ’s Bible, McGraw Hill, PA, U.S.A., 1980.
[77]William DC, Materials science and engineering: an introduction, John Wiley & Sons, New York, 2003.
[78]Takeyama H and Murata R, Study on machinability of pure titanium, J. Jpn. Soc. Preci. Eng., 28(6):331-337, 1962.
[79]Miyakawa O, Reactivity of titanium with abrasive materials and its polishing, J. Jpn. Prosthodont Soc., 42(4):540-546, 1998.
[80]Narutaki N and Murakoshi A, Study on machining of titanium alloys, Annals CIRP, 321:65-69, 1983.
[81]Chandler HE, Machining of reactive metals, Metals Handbook 9th ed., v16 Machining, ASM Int., Metals Park, OH, pp. 844-846, 1989.
[82]Zoya, Z.A., R. Krishnamurthy, “ The performance of CBN tools in the machining of titanium alloys ”, Journal of Materials Processing Technology 100:80-86,2000.
[83]吳佩霖，在工件溫度限制下最大材料移除率之銑削條件探討，國立成功大學碩士論文，2000。