An Experimental Study on Thermal Contact Resistance and Interfacial Pressure of Bolt-joined Aluminum Foams

張廷舜、葉俊良

E-mail: 9314536@mail.dyu.edu.tw

ABSTRACT

An experimental investigation of thermal contact resistance of aluminum foams (Al6061) was conducted. The aluminum foam with a diameter of 63.5 mm was sandwiched between two aluminum cylinders and the whole assembly was fasten by bolts. The heat was transferred through the sample by the one-dimensional thermal conduction. Two types of bolt patterns were used in this study: the first type has 3 bolts with the diameter of 5 mm, and the second type has 6 bolts of 5 mm in diameter. Effects of physical properties of Al foams, such as PPI (pores per inch), R.D. (relative density), and sample height on the thermal contact resistance of Al foams were studied. In addition, the influence of bolt pattern was also discussed. The torque applied on each bolt was in the range from 0.1 to 0.5 N-m. The heat flux through the test specimen was about 50~150KW/m2. In this study, the interfacial pressure between Al foams and Al cylinder was measured by the pressure measuring film. Results show that the interface pressure increases with the increase of applied torque. The contact surface area increases with the interfacial pressure. The variation in bolt pattern produced almost no effect on the interfacial contact pressure. Experimental results indicated that the temperature drop across the Al foam decreases and the total thermal conductance increases when the relative density of Al foam increases. The thermal contact resistance decreases with increasing applied torque, due to the increase of interfacial pressure and contact area. However, the increase of number of bolts from 3 to 6 produced nearly no influenceon the contact resistance. An increase in the sample height led to the increase of total thermal resistance, but the contact resistance was independent of the sample height. Among all of the properties, the PPI has most pronounced effect on the thermal resistance. Both total and contact resistances increase with an increase in the PPI value of the Al foam.

Keywords : Aluminum foam, Bolted joint, Thermal contact resistance, Total thermal conductance, PPI value, R.D. (relative density), Pressure measuring film.

Table of Contents

簽名頁 授權書.....iii 中文摘要.....v 英文摘要.....vii 誌謝.....ix 目錄.....xi 圖目錄.....xiii 表目錄.....xv 符號說明.....xvi 第一章 序論.....1 1.1 研究背景.....1 1.2 研究目的.....2 第二章 文獻回顧.....4 2.1接觸熱阻之相關研究.....4 2.2多孔性材料特性方面.....6 第三章 研究方法.....9 3.1 加熱器.....9 3.2 冷卻系統.....10 3.3實驗試片.....10 3.3.1 鋁合金試片.....10 3.3.2發泡鋁試片.....11 3.4界面壓力量測.....13 3.5螺栓接合面總接觸熱阻實驗數據量測.....14 第四章 結果與討論.....17 4.1溫度量測.....17 4.2界面壓力之量測.....19 4.3總熱傳導值與接觸熱阻的量測.....20 4.3.1相對密度的影響.....21 4.3.2試片高度的影響.....22 4.3.3試片 PPI 值的影響.....22 4.3.4不同螺栓組態的影響.....23 4.3.4界面壓力與接觸熱阻之影響.....23 4.3.5實驗誤差之影響.....24 第五章 結論.....26 參考文獻.....28

REFERENCES

1. Ramay, H. R. and Zhang, M.,“ Preparation of Porous Hydroxyapatite Scaffol -ds by Combination of the Gel-casting and Polymer Spongemethods,” biomate -rials, Vol. 24, pp. 3293-3302, 2003. 2. Fletcher, L. S.,“ Recent Developments in Contact Conductance Heat Transfe

-r, ” Transactions ASME Journal of Heat Transfer, Vol. 110, pp. 1059-1070, - 1988. 3. Lambert, M. A. and Fletcher, L. S., “ Review of the Thermal Contact Conduc -tance of Junctions with Metallic Coatings and Films, ” J. Thermophysics a -nd Heat Transfer, Vol. 4, pp. 547-554 1993. 4. Knight, R. W., J. S. Goodling and D. J. Hall, “ Optimal Thermal Design of -Force Convection Heat Sink – analytical, ” ASME J. Electronic Packaging ” -Vol. 133, pp. 313-321, 1991. 5. Sridhar, M. R. and Yovanovich, M. M., “ Review of Elastic and Plastic Cont -act Conductance Models: Comparison with Experiment, ” J. Thermophysics a -nd Heat Transfer, Vol. 4, pp. 633-640, 1994. 6. Bhattachary, A., Calmidi, V. V. “ Thermophysical properties of high porosi -ty metal foams, ” Heat and Mass Transfer, Vol. 45, pp. 1017-1031, 2002. 7. 陳逸凡, “ 螺栓接合面接觸熱阻與鋁蜂巢板熱傳導特性之研究, ” 大葉大學機械與自 動化工程學系碩士論文, 2002. 8. 林建通, “ 鋁合金與鋁蜂巢間接觸熱阻及界面壓力之實驗研究, ” 大葉大學機械與自 動化工程學系碩士論文, 2003. 9. Nishino, K., Yamashita, S., and Torii, K., “ Thermal ContactConductance un -der Low Applied Load in a Vacuum Environment, ” Experimental Thermal and -Fluid Science, Vol. 10, pp. 258-271, 1995. 10. Chung, K. C. and Sheffield, J. W., “ Enhancement of Thermal Contact Condu -ctance of Coated Junctions, ” Journal of Thermophysics and Heat Transfer, - Vol. 9, No. 2, pp. 329-334, 1995. 11. Fletcher, L. S., Blanchard, D. G., and Kinnear, K. P., “ Thermal Conducta -nce of Multilayered Metallic Sheets, ” Journal of Thermophysics and Heat - Transfer, Vol. 7, No. 1, pp. 120-126, 1993. 12. Lewis, D. V., and Perkins, H. C., “ Heat Transfer at the Interface of Stai -nless Steel and Aluminum – the Influence of Surface Condutions on the Dire -ctional Effect. ” Heat Mass Transfer, Vol. 11, pp. 1371-1383, 1968. 13. Cooper, M. G., Mikic, B. B.and Yovanovich, M. M., “ Thermal Contact Condu -ctance, ” Int. J. Heat Mass Transfer, Vol. 12, pp. 279-300, 1969. 14. Roca, R. T., and Mikic, B. B., “ Thermal Conductance in a Bolted Joint, ” -AIAA 7th Thermophysics Conference, AIAA, pp. 272-282, 1972. 15. Bevans, J. T., Ishimoto, B. R., Loya, B. R., and Luedke, E. E., “ Predict -ion of Space Vehicle Thermal Characteristics, ” Air Force Flight Dynamic -Laboratory Technical Report, AFFDL-TR, pp. 65-139, 1965. 16. Yip, F. C., “ Theory of Thermal Contact Resistance in Vacuum with an Appl -ication to Bolted Joints, ” AIAA 7th Thermophysics Conference, AIAA 72-28 -1, 1972. 17. Oehler, S. A., Mcmordie, R. K., and Allerton, A. B., “ Thermal Contact Con -ductance across a Bolted Joint in a Vacuum ” , AIAA 14th Thermophysics Co -nference, AIAA 79-1068, 1979. 18. Lu T.J., Stone, H. A. and Ashby, M. F., “ Heat transfer in open-cell metal - foams, ” Acta mater. Vol. 46 pp. 3619-3635, 1998. 19. Gibson L. G., and Ashby, M. F., “ Cellular Solids: Structure and Propertie -s, ” 2nd edn. Cambridge University Press, Cambridge, 1997. 20. Daracy, H. “ Les Fomtains Publiques Dela Ville de Dijon, ” Paeis, Victor D -allmint, 1856. 21. Chou, S. F. and Yang, C. H., “ Heat transfer Characterisitic of Alumin Foa -m Metal, ” Transfer Pransfer Phenomena in Thermal Engineering, pp. 709-71 -4, 1995. 22. Calmidi, V. V., ” Transport Phenomena in Figh Porosity Fibrous Metal Foam -, ” Department of Mechanical Engineering, pp. 105-115, 1998. 23. Lee, S. L. and Yang, J. H. “ Modeling of effective thermal conductivity fo -r a nonhomogeneous anisotropic porous medium, ” Int. J. Heat and Mass Tra -nsfer, Vol. 41, NO. 6-7, pp. 931-937, 1998. 24. Miller, R. G. and Fletcher, L. S., “ Thermal Contact Conductance Correlati -on for Porous Metals, ” AIAA 12thAerospace Science Meeting, AIAA, pp. 74-1 14, 1974. 25. C.L. Yeh, C.Y. Wen, Y.F. Chen, S.H. “ Yeh, C.H. Wu, An experimental invest -igation of thermal contact conductance across bolted joints, Exp. ” Therm -al Fluid Sci.(6) (2001) 349-357