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论文

双重孔径泡沫金属材料的强度和热性能多目标优化设计

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摘要:

对双重孔径泡沫金属稳态热传导过程进行了数值模拟, 发现相同密度下双重孔径泡沫金属导热系数高于单一孔径泡沫金属, 但随着孔径比增大, 材料导热系数减小. 通过对有限元计算结果的多项式拟合得到了目标函数, 建立了包含强度 、隔热和轻质3个目标函数的多目标优化设计数学模型, 讨论了构件质量一定的情况下双重孔径泡沫金属材料设计参数的选取, 获得了满足强度要求, 同时隔热性能最优的泡沫金属孔径比、密度和构件厚度. 泡沫金属构件隔热参数—屈服应力图表明, 作为同时满足承载和隔热要求的泡沫金属板构件, 选用双重孔径泡沫金属的构件综合性能要显著优于单一孔径泡沫金属构件.

关键词: 泡沫金属 强度 热性能 多目标优化设计

MULTI-OBJECTIVE OPTIMUM DESIGN FOR STRENGTH AND HEAT INSULATION OF METAL FOAM WITH DUAL-SIZE CELLULAR STRUCTURE

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Abstract:

Finite element simulations are performed to study the steady state heat conduction of dual--size metal foams. Simulation results reveal that for a given density, the thermal conductivity of dual-size foams is higher than that of uniform cell size foam. However, the effective thermal conductivity decreases while increasing the cell radius ratio *r*/*R* in dual-size foams. A multi-objective optimum design model considering structure strength, heat insulation and light mass requirement is developed, where the objective function is obtained through polynomial fitting of the numerical results. The model is solved by the constraint method< and the optimum cell radius ratio, density and thickness of metal foam are obtained for dual-size metal foams. A comparison of the heat insulation capacity of the dual-size metal foam to the single-size metal foam having the same mass and yield strength shows that the heat insulation capacity of the former is much higher than that of the latter. Hence the dual-size foam structure is superior to that of the uniform cell foam when both load--bearing and heat insulation capacities are required.

Keywords: metal foam strength thermal property multi-objective optimum design

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参考文献:

[1] Ashby M F, Evans A G, Fleck N A, Gibson L J, Hutchinson J W, Wadley H N G. Metal Foams: A Design Guide. Woburn: Butterworth–Heinemann, 2000: 113
[2] Hanssen A G, Langseth M, Hopperstad O S. Int J Mech Sci, 2001; 43: 153
[3] Chen W, Wierzbicki T. Santosa, S. Acta Mech, 2002; 153: 183

[4] Steeves C A, Fleck N A. Int J Mech Sci, 2004; 46: 561
[5] Hanssen A G, Stobener K, Rausch G, Langseth M, Keller H. Int J Crashworthiness, 2006; 11: 231
[6] Magnucka–Blandzia E, Magnucki K. Thin–Walled Struct, 2007; 45: 432
[7] Evans A G, Hutchinson J W, Ashby M F. Prog Mater Sci, 1998; 43: 171
[8] Zhu H, Sankar B V, Haftka R T, Venkataraman S, Blosser M. Struct Multidisciplinary Optimization, 2004; 28: 349
[9] Gu S, Lu T J, Evans A G. Int J Heat Mass Trans, 2001; 44: 2163
[10] Li L X, Li Y M, Hong L, Yan G R, Chen C Q, Shen S P. Adv Mech, 2008; 38: 256
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[11] Rakow J F, Waas A M. AIAA J, 2007; 45: 329
[12] Kou D P, Li J R, Yu J L, Cheng H F. Scr Mater, 2008; 59: 483
[13] Calmidi V V, Mahajan R L. J Heat Transfer–Transactions ASME, 1999; 121: 466
[14] Gibson L J, Ashby M F. Cellular Solids: Structure and Properties. 2nd ed, Cambridge: Cambridge University Press, 1997: 283
[15] Lu T J, Chen C. Acta Mater, 1999; 47: 1469
[16] Carbonell R G, Whitaker S. In: Bear J, Corapcioglu M Y eds., Fundamentals of Transport Phenomena in Porous Media. Boston: Kluwer, 1984: 123
[17] Hsu C T, Cheng P,Wong K W. ASME J Heat Trans, 1995; 117: 264
[18] ASTM. ASTM Standard Methods of Fire Tests of Building Construction and Materials. West Conshohocken, PA: ASTM, 1988: E119

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2．刘再华;赵东立.采用环状裂纹圆棒试样测定中低强度钢的断裂韧度[J]. 金属学报, 1988,24(6): 426-431

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4．郭树启;韩圭焕;姚忠凯.SiC_w/Al复合材料的微观结构与性能[J]. 金属学报, 1988,24(6): 499-504

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7．陈黄浦;邓增杰.高强度结构钢的韧性启裂和稳态扩展[J]. 金属学报, 1989,25(6): 49-54

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9．李光福;吴忍畊.高温淬火改善超高强度钢应力腐蚀断裂抗力的研究[J]. 金属学报, 1989,25(6): 70-73

10．金柱京;于力;戴少侠;于志明.添加元素Al,La改性IP-TiN膜性能研究[J]. 金属学报, 1990,26(1): 96-101
