地球物理学报 » 2009, Vol. 52 » Issue (5) :1280-1288 doi:10.3969/j.issn.0001-5733.2009.05.017

引用本文(Citation):
杨小秋;施小斌;许鹤华;徐行;李官保;郭兴伟;罗贤虎.双探针型海底热流计的结构优化. 地球物理学报, 2009,52(5): 1280-1288,doi: 10.3969/j.issn.0001-5733.2009.05.017

YANG Xiao-Qiu;SHI Xiao-Bin;XU He-Hua;XU Xing;LI Guan-Bao;GUO Xing-Wei;LUO Xian-Hu.Optimizing probe structure for dual-probe seafloor heat flow meter.Chinese J.Geophys. (in Chinese),2009,52(5): 1280-1288,doi: 10.3969/j.issn.0001-5733.2009.05.017

双探针型海底热流计的结构优化

杨小秋[1,2];施小斌[1];许鹤华[1];徐行[3];李官保[4];郭兴伟[5];罗贤虎[3]*

1 中国科学院边缘海地质重点实验室,南海海洋研究所,广州 510301
2 中国科学院研究生院,北京 100049
3 广州海洋地质调查局,广州 510760
4 国家海洋局第一海洋研究所,青岛 266061
5 青岛海洋地质研究所,青岛 266071

Optimizing probe structure for dual-probe seafloor heat flow meter

YANG Xiao-Qiu[1,2];SHI Xiao-Bin[1];XU He-Hua[1];XU Xing[3];LI Guan-Bao[4]; GUO Xing-Wei[5]; LUO Xian-Hu[3]*

1 CAS Key Laboratory of Marginal Sea Geology, South China Sea Institute of Oceanology, Chinese Academy of Sciences, Guangzhou 510301, China

2 Graduate University, Chinese Academy of Sciences, Beijing 100049, China
3 Guangzhou Marine Geological Survey, Guangzhou 510760, China
4 First Institute of Oceanography, State Oceanography Administration, Qingdao 266061, China
5 Qingdao Institute of Marine Geology, Qingdao 266071, China

摘要 本文在现有海底热流探针制作技术条件下,首先建立了脉冲式双探针海底测量单元的有限元数值模型,模拟获得多组参数下的温度-时间数据,作为“实测”数据,再用脉冲加热有限长线热源(PFLS)模型求解待测介质热导率及其相对误差上限($RE_{\lambda\text{-}UL}$),并以$RE_{\lambda\text{-}UL}$最小为原则,对双探针热流计的结构进行优化.结果表明:(1)在不同探针脉冲强度(q)、温度测量误差(ΔT_m)和探针长度(L)组合下,都存在最佳探针间距(Best_r),使得$RE_{\lambda\text{-}UL}$降到最低;(2)随着q增大或ΔT_m减小,Best_r逐渐增大;(3)当q、ΔT_m及探针半径(a)都给定时,Best_r与探针长度(L)呈线性正相关;(4)当a=1.0 mm,且q、ΔT_m分别取为628.0~1100.0 J • m^{-1}、0.5~1.0 mK,若L在20.0~42.0 mm之间时,则Best_r在18.0~30.0 mm之间,此时介质热导率相对误差上限可控制在5.5%以内,同时测量温度可在6 min内达到最大值,即脉冲加热开始后,温度测量只需约7 min,便可满足介质热导率的求解,这比目前常用的Lister型热流计所需海底测量时间缩短8 min左右.

关键词 双探针型海底热流计, 结构优化, 双探针脉冲法(DPHP), 脉冲加热有限长线热源(PFLS)模型, 有限元数值模拟

Abstract: This paper aims to optimize the probe structure for dual-probe seafloor heat flow meter. Firstly, with a constructed finite element model for seafloor pulsing dual-probe, a series of temperature-time data, which are used as the “observed” data, can be obtained by giving different probe structures and thermal properties. Then, we calculated medium thermal conductivity and its corresponding maximum relative error ($RE_{\lambda\text{-}UL}$) by using Pulsed Finite Line Source (PFLS) model, and optimize the probe structure in which $RE_{\lambda\text{-}UL}$ is minimized. Finally, we optimized dual-probe structure with the now available manufacture technique of seafloor heat flow probe. Our results show that: (1) under each distinct combination of probe heat pulse strength (q), temperature measurement error (ΔT_m) and probe length (L), there must be a best probe spacing (Best_r), at that position, $RE_{\lambda\text{-}UL}$ is least; (2) Best_r can be accordingly increased with q increasing or ΔT_m decreasing; (3) when q,ΔT_m and probe radius (a) are given, there is a significant linear positive correlation between Best_$r$and L; (4) when a is 1.0 mm, q is from 628.0~1100.0 J • m^{-1},ΔT_m is from 0.5 mK to 1.0 mK, and L is from 20.0 mm to 42.0 mm, Best_r ranges from 18.0 mm to 30.0 mm. In this case, the maximum relative error in medium thermal conductivity is within 5.5%, meanwhile, it reaches the maximum measurement temperature within 6 minutes, which means that the temperature measurement just needs about 7 minutes to calculate medium thermal conductivity after the beginning of pulse heating, which is about 8 minutes shorter than that of the Lister-type heat flow meter.

Keywords Dual-probe seafloor heat flow meter, Structure optimization, Dual-probe heat pulse (DPHP) method, Pulsed Finite Line Source (PFLS) model, Finite element numerical modeling

Received 2008-09-05;

Corresponding Authors: 杨小秋