

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
5 July 2007 (05.07.2007)

PCT

(10) International Publication Number  
**WO 2007/076357 A3**

(51) International Patent Classification:  
*E04B 1/00* (2006.01) *G06F 17/50* (2006.01)  
*G06F 17/10* (2006.01)

(21) International Application Number:  
PCT/US2006/062302

(22) International Filing Date:  
19 December 2006 (19.12.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
60/751,500 19 December 2005 (19.12.2005) US

(71) Applicant (for all designated States except US): **THE BOARD OF GOVERNORS FOR HIGHER EDUCATION, STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS** [US/US]; 301 Promenade Street, Providence, RI 02908 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **TAGGART, David, G.** [US/US]; 13 Tamarack Circle, North Kingstown, RI 02852 (US). **DEWHURST, Peter** [US/US]; 376 Dugway Bridge Road, West Kingston, RI 02892 (US). **NAIR, Arun, U.** [IN/US]; 3595 Post Road, Apt. 17208, Warwick, RI 02886 (US).

(74) Agents: **HILTON, William, E.** et al.; GAUTHIER & CONNORS, LLP, 225 Franklin Street, Suite 2300, Boston, MA 02110 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

**Published:**

- with international search report
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

(88) Date of publication of the international search report:  
21 December 2007

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: SYSTEM AND METHOD FOR FINITE ELEMENT BASED TOPOLOGY OPTIMIZATION

(57) Abstract: A method is disclosed for providing an optimal topology for a structure based on a set of design criteria including at least one support point and at least one force to be applied to the structure. The method includes the steps of identifying a plurality of nodes within a structure design domain, and assigning an initial density value to the plurality of nodes. The method also includes the steps of conducting a finite element analysis on the nodes, determining a stress intensity value for each node, ranking the nodes by relative stress intensity values, and adjusting the density value for each node. The method also includes the step of repeating the steps of conducting a finite element analysis on the nodes, determining the stress intensity value for each node, ranking the nodes by relative stress intensity values, and adjusting the density value for each node until a termination criteria is realized, thereby providing an optimal topology.



WO 2007/076357 A3

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 06/62302

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - E04B 1/00; G06F 17/10; G06F 17/50 (2007.01)  
USPC - 703/1

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8): E04B 1/00, G06F 17/10, G06F 17/50

USPC: 703/1

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

IPC(8): G06F 15/18, G05B 13/02, G06G 6/00, G06E 3/00, G06E 1/00

USPC: 700/30, 700/31, 700/32, 706/19

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PubWest (USPB, USPT, USOC, EPAB, JPAB), DialogPro, GoogleScholar; method optimal topology nodes density finite element analysis stress strain energy ranking intensity map iteration tension compression stiffness fiber force 3D CAD support point mass assign maximum minimum distributing uniformly initial reduce penalize elastic

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/0199365 A1 (WASHIZAWA) 07 October 2004 (07.10.2004), Figs. 2,6-7; para [0002]-[0003]; [0010]; [0012]; [0018]; [0032]; [0034]-[0035]; [0054]-[0060]; [0065]; [0071]-[0074]; [0077]; [0097]; [0115]; [0125]; [0132]-[0134]; [0142]-[0145]; [0148]-[0150]	1-14 and 17-20
X	US 2005/0216237 A1 (ADACHI et al.) 29 September 2005 (29.09.2005), Figs. 1,4a-4c; para [0029]; [0031]-[0038]; [0042]; [0064]-[0067]	15-16

 Further documents are listed in the continuation of Box C.

\* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&amp;" document member of the same patent family

Date of the actual completion of the international search

22 September 2007 (22.09.2007)

Date of mailing of the international search report

18 OCT 2007

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents  
P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-3201

Authorized officer:

Lee W. Young

PCT Helpdesk: 571-272-4300  
PCT OSP: 571-272-7774