Paper458

2017 17th International Conference on Control, Automation and Systems (ICCAS 2017)
Oct. 18-21, 2017, Ramada Plaza, Jeju, Korea

Development of an Extensible Back-Heating Parallel Cable Robot

Jinwoo Jung[1], Jinlong Piao[1,3], XueJun Jin[1,3], Jae Wook Park[2], Seong Yeop Kim[2], Jong-Sik Woo[2], and Jong-Oh Park[1,3*]

[1] Medical Microrobot Center, Robot Research Initiative, Chonnam National University, Gwangju, 61186, Korea, (jwjung@jnu.ac.kr)
[2] Automation R&D Institute, Daewoo Shipbuilding & Marine Engineering Co., Ltd., Geoje-si, 53302, Korea, (jwpark84@DSME.co.kr)
[3] School of Mechanical Engineering, Chonnam National University, Gwangju, 61011, Korea, (piaojinlong622@163.com, harkjoon27@gmail.com, jop@jnu.ac.kr) * Corresponding author

Abstract: Back-heating process is a heat treatment process to correct distortion induced by fillet weld for shipbuilding. The process is low-speed and high place work which requires repetitive setup and dismantlement of a scaffold like a swing stage and has high risk of serious injury by falling. Therefore, automation of the process can reduce the level of the risk and increase the effectiveness of the process. Several automatic mechanisms and devices have been introduced, however, they have limited use in back-heating process in terms of safety, efficiency, and size of workspace. To improve the efficiency of the work, an extensible parallel cable robot is developed utilizing the unique characteristics of a cable driven parallel robot, such as large workspace and high payload. An experiment was conducted to validate the workspace of the back-heating cable driven parallel robot. Through the experiment, it is shown that the extensible parallel cable robot system developed can successfully achieve the desired workspace for the back-heating process.

Keywords: Back-heating, extensible cable driven parallel robot, large workspace, shipbuilding

1. INTRODUCTION

Back-heating process in the shipbuilding industry has been manually performed by the workers. As shown in Fig. 1, due to the workspace is a vertical plane and the height can be up to five meters, the risk of falling and repetitive manual installation of a scaffold can lead to the increase of working hours and an experienced worker. Thus, automation of back-heating process has been continuously demanded.

For the back-heating automation, a few types of back-heating equipment are developed and patented. Back-heating device [1] using image processing recognizes lines and perform back-heating. There are other devices [2, 3] for back-heating the bottom lines, corners, or edges. All of them make use of magnet to maintain the contact or constant distance to a steel plate in order to effectively perform the back-heating. However, the use of magnet may cause safety issues of device falling in case of losing magnetic forces by debris on the plate or the shortage of the length of gas supply tube. Also, due to customization for specific back-heating conditions, the use of the device becomes considerably limited. Thus, to improve the safety and flexibility of the automatic process, we proposed an extensible back-heating cable driven parallel robot.

A cable-driven parallel robot (CDPR) is a novel type of parallel robot consisting of winches, pulleys, and lightweight flexible cables. Due to the use of cable, it has capability of high payload and large workspace. For high payload applications, NIST Robocrane [4] was developed for heavy part assembly and Pott developed a CDPR system [5] for large-scale installation of the solar power plant. For the applications of large workspace, FAST [6] was developed as a five hundred meter telescope and Skycam [7] for broadcasting football games has been widely used.

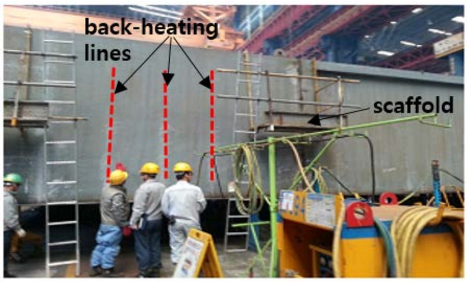

Fig. 1 Back-heating lines and scaffold on the wide steel plate in the shipyard

In this paper, we developed an extensible cable driven parallel robot to achieve large workspace of the back-heating process and improve the safety and working hours by the process automation.

This paper consists of the three sections. First, the kinematics of CDPR is briefly introduced and second the development of CDPR is described. Third, a workspace test was conducted to validate that the robot reaches the desired workspace.

2. ROBOT KINEMATICS

To manipulate the end-effector pose of CDPR with *n* cables, each cable length are obtained by solving CDPR inverse kinematics. As shown in Fig. 2, inverse kinematics can be derived as Eq. (1) using vector loop equation, where a_i and b_i are connection points of *i*-th cable on the base frame and the end-effector, respectively. R_θ is rotation matrix describing the orientation of the end-effector.

$$L_i = a_i - x - R_\theta b_i \ (i = 1, 2, \ldots n) \quad (1)$$

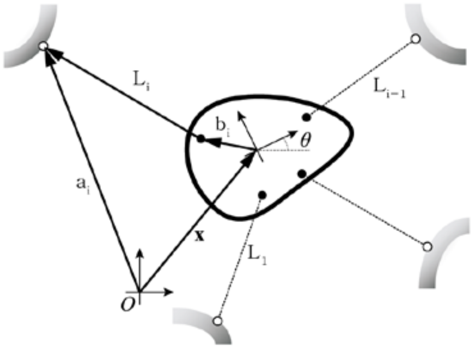

Fig. 2 Kinematics of a cable driven parallel robot

3. SYSTEM DESIGN

The concept of an extensible back-heating cable robot is demonstrated in Fig. 3. The prototype of an extensible back-heating cable robot 2 m(W)×5m(H) is developed based on the concept as shown in Fig. 4. In order to adjust the height of the robot for the different heights of the steel plates, two extensible lifts were utilized.

In order to validate the reachable workspace of the robot when the desired workspace is 3.2 m x 1.1 m, a test of reaching the boundary of workspace was conducted. As shown in Fig. 5, the robot successfully reached the boundaries of the desired workspace.

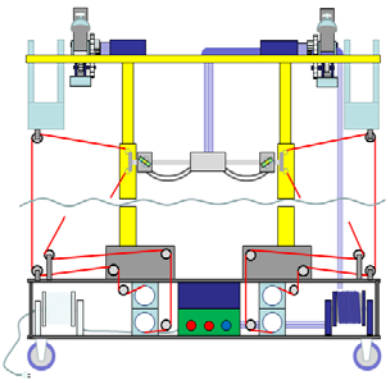

Fig. 3 Design of a back-heating CDPR

(a) (b)

Fig. 4 Prototype of an extensible back-heating CDPR; (a) The lifts extended and (b) the lifts stored.

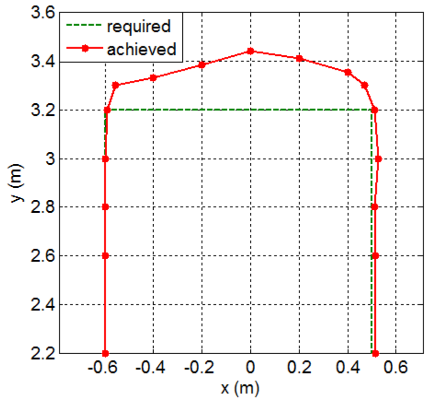

Fig. 5 Desired workspace (3.2 m×1.1 m) reached when the robot is extend to the height of 4.2 m

4. CONCLUSIONS AND FUTURE WORKS

A prototype of the extensible back-heating CDPR was successfully developed and its reachable workspace was validated. The accuracy of end-effector position will be validated and improved by considering the flexibility of the frame. Also, the back-heating process will be performed on shipyard as a field test to validate the effectiveness of the back-heating CDPR system.

ACKNOWLEDGEMENT

This research was supported by Leading Foreign Research Institute Recruitment Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT (MSIT) (No. 2012K1A4A3026740)

REFERENCES

[1] Y. H. Jung, H. S. Ryu, D. H. Lee, and H. K. Kim, "Back heating method using image," Korea Patent 10-1186839-0000, Sep. 24, 2012.

[2] J. H. Lee, "Automatic back heating apparatus on which side welding is available," Korea Patent 10-2012-0128917, Nov. 28, 2012.

[3] H. S. Lee, "Automatic back heating device along block edge," Korean Publicized Utility Model, Korea Patent 20-2013-0000298, Jan. 14, 2013.

[4] J. Albus, R. Bostelman, and N. Dagalakis, "The NIST robocrane," *Journal of Robotic Systems*, Vol. 10, No. 5, pp. 709-724, 1993.

[5] A. Pott, C. Meyer, and A. Verl, "Large-scale assembly of solar power plants with parallel cable robots," in *Robotics (ISR), 2010 41st International Symposium on and 2010 6th German Conference on Robotics (ROBOTIK)*, pp. 1-6, 2010.

[6] H. Jianlin, J. Fengshui, Y. Guodong, L. Zize, and Z. Lichun, "Modeling, control and software implementation of astronomical tracking of focus cabin suspension of FAST," in *Robotics and Biomimetics (ROBIO), 2013 IEEE International Conference on*, pp. 686-691, 2013.

[7] SKYCAM. (2015, Feb 3). Skycam. Available: http://www.skycam.tv/