Design of a Remote Steel Pipe Cutting System for a High Place with Dual Arm Manipulators

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1. Abstract / Introduction

This paper describes a remote controlled dual arm manipulator system cutting a still pipe at high place. Remotely cutting work is one of the tasks with complicated working conditions. An overview and comparison of cutting techniques for piping is given in [1]. These include a plasma arc, arc saw, linear-shaped explosive charge, and 'conventional cutting methods' for metal cutting.

The dual arm manipulators consist of two LBR iiwa 14 R820's. LBR iiwa is a light weight 7 DOF articulated manipulator that weighs 29.5 kg with a payload capacity of 14 kg, and is able to move precisely with +/-0.1 mm repeatability. It assembles parts delicately and detects external forces using integrated torque sensors.

The dual arm manipulators are installed on the mobile platform. The mobile platform has a telescopic mast which can lift the manipulators to 10 m high from the ground. The telescopic mast is composed of the same shaped frames sliding synchronously with a cable driven mechanism. The dual arm manipulators are controlled as a slave robot by the mater device, Omega 7 of Force Dimension. The Omega 7 detects translational motion in the X/Y/Z directions, and rotational motion in the rx/ry/rz directions. In addition, it supplies the reflection forces, which are 12N for the translational motion and 8N for the grasping. Its linear accuracy is 0.01 mm, and its rotational accuracy is 0.09 deg. It supplies sufficient stability with a refresh rate of 8 kHz.

The slave robot will cut a 2 inch steel pipe with a 5 mm thickness at a place of 5m high. We adopted the 'conventional cutting methods' for metal cutting and developed a cutting tool suitable to a robot. In this case, robot motion induces a vibration of the mast and the reaction force from the pipe causes a vibration to the pipe and the robot system. The vibration of the mast acts as a disturbance in controlling the robot. It is very difficult to suppress the vibration for the operator remotely controlling the slave robot. First we will reduce the vibration with a shared control scheme so that the share controller controls the vibration internally and the operator only controls the aimed motion of the robot. This can be accomplished by using passive decomposition decomposing the original dynamics into the workspace along with null-space dynamics. Second we will use a dual arm system in which one manipulator will cuts the steel pipe and the other manipulator will grip the steel pipe to suppress the pipe vibration. To monitoring the working spot, a stereo camera (Zed mini) will be used and stereo view system will be developed.

2. Steel pipe cutting without vibration

We developed a very compact cutting tool for the slave robot arm. It weighs 5kg and uses 48V DC power. Figure 1 shows the cutting tool and a steel pipe cutting mockup.

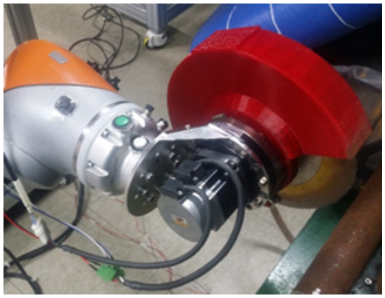
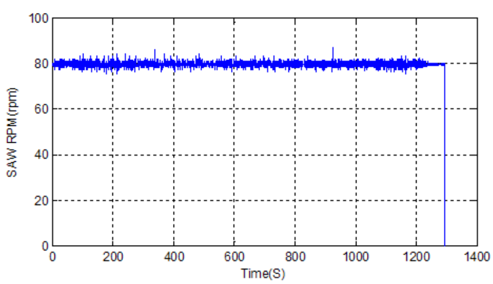


Figure 1 (a) Cutting tool (b) Steel pipe cutting mockup

We cut the steel pipe without vibration at the steel pipe cutting mockup at the ground. The rotating speed of the saw was controlled as 80 rpm. The current of the saw motor was set 6.4 A. The feed rate of the saw was 0.05 mm/s. Figure 2 shows the control response of cutting motor current



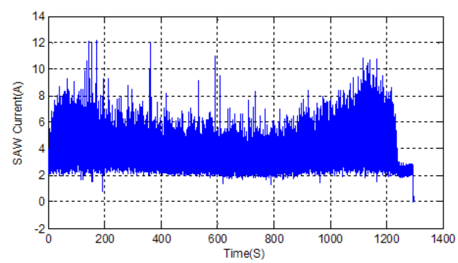
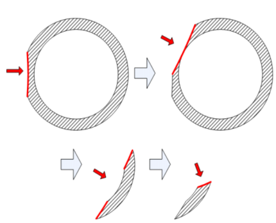


Figure 2. Control responses of cutting motor

It took 21 minutes to cut the target pipe. It is noted that the current curve has two picks at which the cutting part is the thickest. It need more torque at the end of the cutting. In addition, there is a current margin at the mid part. Thus we designed cutting strategy that feeds the saw straight to pass over the half of the pipe, moves the saw and then feeds the saw along the line inclined below a little. With the new strategy we cut the pipe with 15 minutes. Figure 3 (a) shows the cutting strategy and Figure 3 (b) shows the steel pipe cutting at the steel pipe cutting mockup on the ground.



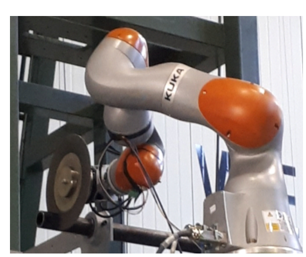
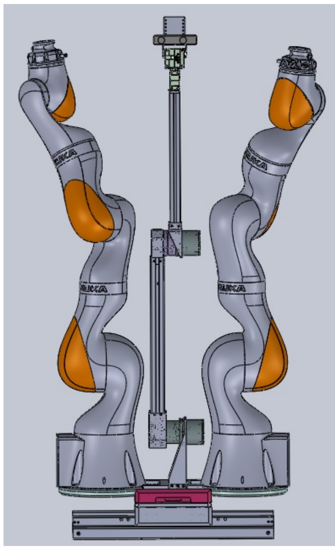


Figure 3. (a) Cutting path (b) Steel pipe cutting w/o vibration

We will develop a monitoring system which consists of a stereo camera on the two link positioner and install the steel pipe cutting mockup at a high place. Figure 4 shows the monitoring system and a high place mockup.



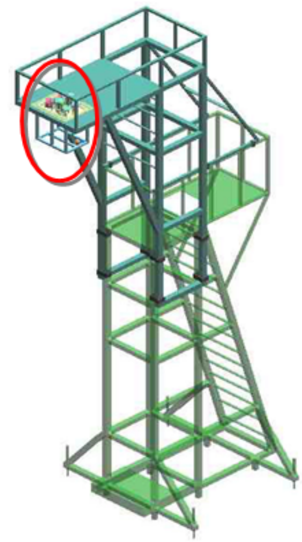


Figure 4 (a) Monitoring system (b) high place mockup.

References

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