Procedia Manufacturing
Volume 5, 2016, Pages 1143–1153
44th Proceedings of the North American Manufacturing Research Institution of SME http://www.sme.org/namrc

Development of a Desktop Hybrid Multipurpose Grinding and 3D Printing Machine for Educational Purposes

Farhad Ghadamli[1*], Barbara Linke[2†]
[1&2] Department of Mechanical & Aerospace Engineering University of California, Davis, U.S.A fghadamli@ucdavis.edu, bslinke@ucdavis.edu

Abstract
Manufacturing is a constantly changing field where new innovations and continuous improvements ensure competitiveness. Recent manufacturing revolutions include additive manufacturing and the empowerment of Do It Yourself (DIY) users. This paper reports on the development of a desktop hybrid machine that incorporates subtractive and additive manufacturing principles, in particular grinding and wire extrusion. Due to the small machine size of less than 1 m^3 and use of modular components it will be applicable in small scale operations and will have a low energy footprint. The article discusses the initial design and further improvements which have been done as senior design capstone projects, through summer internships and team work of graduate and undergraduate students. The first generation machine will be improved by stronger motor modules of up to 1.8Nm torque compared to 0.7Nm and new module connections that can be 3D printed instead of sheet metal connections. Future versions of the machine will have even more printable components. The machine control has been built on NI LabVIEW to enable path planning, machine control, manual steering, and integration of closed-loop algorithms on one standard platform.

Keywords: Desktop machine tool, hybrid machine, machine control, education

* Graduate student researcher
† Principal investigator

Selection and peer-review under responsibility of the Scientific Programme Committee of NAMRI/SME

doi:10.1016/j.promfg.2016.08.090

1 Introduction

Manufacturing continues to be an important pillar of economic growth in the United States (Webster, 2015). Nevertheless, industry has always been subjected to improvements and disruptive innovations changing the conventional methods of fabrication (Berman, 2012). Nowadays, additive manufacturing is attracting a lot of attention not only from industry but also from Do It Yourself (DIY) users and students. The integration of computing and manufacturing gives individuals with no background in manufacturing a chance to design, prototype and produce in their own garage (Fox, 2014). Desktop 3D printers, mills, and lathes will become accessible through community libraries or maker fairs.

To explore the idea of small scale manufacturing, a first generation modular desktop grinding machine was developed at UC Davis through a capstone project for senior students in mechanical engineering (Linke et al., 2015). The undergraduate team was tasked to develop and fabricate a machine with two major design requirements: configurability and affordability. It was necessary that the machine tool was easily assembled and disassembled by an end-user (e.g. engineering student or hobbyist). The configuration was adaptive by performing a change over from freeform grinding to cylindrical grinding within 15 minutes (Figure 1). Furthermore, the system had the potential for additional configurations. A modular, reconfigurable design gives tremendous flexibility and cost-effectiveness.

The mechanical design of the first generation machine included multiple subassembly groups: the base, motors, linear movement gearbox, power tool, power tool holder, and arm connectors. A major design component of the system were the Linkbot modules which were used as motors. These modules were invented in the Integration Engineering Laboratory at UC Davis and are now produced by the start- up company Barobo, Inc. The modules are pre-packaged with a GUI, which can connect multiple modules simultaneously. They are controlled through Bluetooth and have integrated batteries.

The torque output of 0.7 Nm (100 oz-in) was not high enough to move larger masses with high precision. Studies on the system where the tool tip had to follow a given path revealed inaccuracies reaching millimeters at times, which was mainly due to vibrations, low stiffness of the assembled arm, and motor slip.

The control of the first generation desktop machine was cumbersome and involved MATLAB programming, Barobo's ChIDE software and BaroboLink developed by Borobo, Inc. to control multiple Linkbot modules.

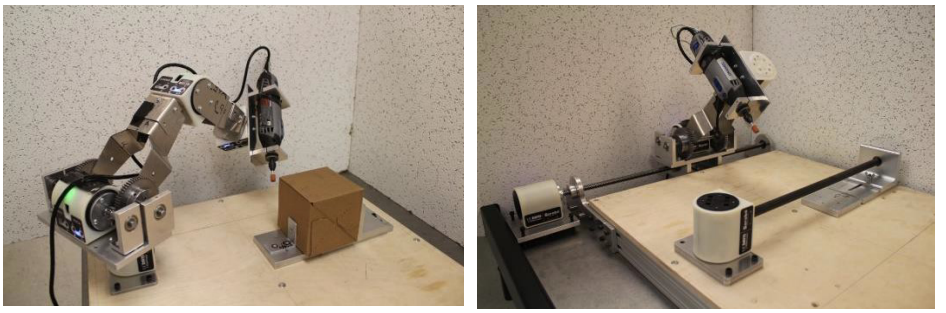

Figure 1: Desktop machine tool for freeform grinding (left) and cylindrical grinding (right) (Linke et al., 2015).

From the first machine generation, several areas of improvements were defined and tackled with the following steps:

- Higher precision of the whole system is needed. → This will be achieved by using a