New aspects of 3D printing by robots

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Abstract

Additive technologies are common field of industry and daily life. Almost everyone heard about 3D printing and rapid prototyping technologies. Dynamic evolution of methods gives us new possibilities and open new chances. Let's look on 3D robot printing, its limitation and advantages.

KEYWORDS: **Additive technologies**, **3D printing**, **robot**

General overview

Common 3D printing machines based on typical 3 linear axis construction, similar to 3-axis milling routers. Main mechanical difference between machines is that typical router have fixed table and Z-axis column, 3D printers have movable table (Fig. 1). Of course milling tool remove material, 3d printing tool – add material layer by layer.

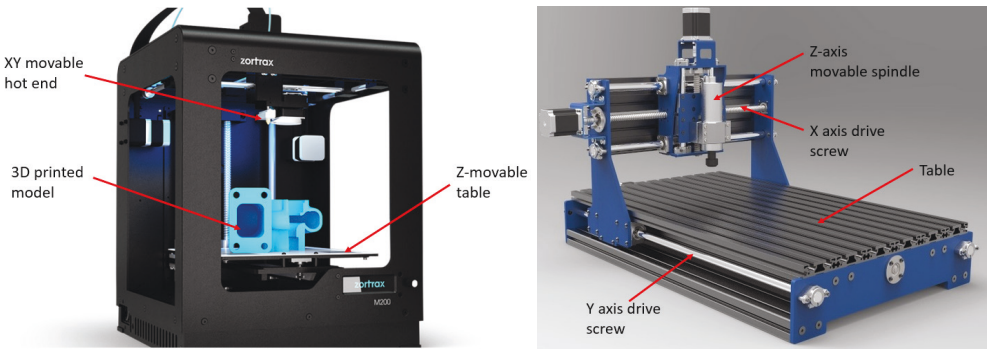

Fig. 1. *Example of FDM Zoltrax 3D printer (source: www.drukarki-3d.info) and 3D router*

Users don't care about machine control or programming – just put 3D virtual model on virtual table, sets technological parameters of process (if it is necessary and default are not enough to get satisfactory results) and click "Print" similar to conventional 2D printers. More advanced users know different methods (e.g. FDM, SLS, SLM, LOM), differences between them and they can predict printing result base on process parameters. If object is bigger than working area of 3D printer, we can print separated objects (parts for assembly) or divide individual parts to smaller ones and

then connect them (e.g. by glue). This way gives us possibility to print bigger object – e.g. 3D printed bicycle, using not popular LOM method (Fig. 2).

Fig. 2. *3D printed bicycle with Solido LOM 3D printer (source: www.drukarki-3d.info)*

How to make 3D printing more flexible? Just use robots for printing. General rule of model building is the same, but mechanical construction totally different – and it gives more possibilities.

Robotic arm as 3D printer

More advance construction is robotic arm – usually 4 or 5 axis (joints) with flat structure (Fig. 3). It means that end effector must be (without adding external axis or additional devices) perpendicular to the table. It is small limitation – but still robotic arm have bigger working area than 3D printer with similar high. It is also easy integrate rotary table changer, automatic line or just print or many separate tables around the robot arm. This solution can base on 3D model slicing by the software or G-codes like typical CNC machines.

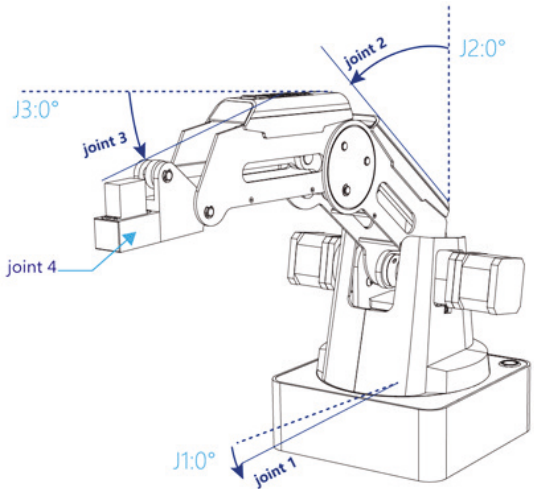

Fig. 3. *Schema of Dobot robotic arm (source: www.dobot.pl)*

In case of 3D model printing, robot arm controller convert XYZ point's position, calculated by the software, to corresponding joints position - so robot programming task is also out of user care. G-codes can be also generated based on 3D model

but as result we get program with open structure (just text file) and it can be easy modified or used on CNC machines (mounted hot end instead spindle). Functions for this kind of purposes should have additional information (besides positions), e.g. about extruder behavior or additional movement (because of technology). Example of G-code settings:

- Start G-code: M106
- End G-code:
- M104 S0; turn off extruder
- G91; relative positioning
- G1 E-1 F300; retract the filament a bit before lifting the nozzle to release some of the pressure
- G1 Z+3 E-5 F {travel speed}; move Z up a bit and retract filament even more
- G1 Y+50
- G90
- M107

The biggest advantage of robotic solution is flexibility. We can easy change 3D printing robotic arm to laser engraving tool, writing or drawing kit, manipulating with gripper or suction cup (Fig. 4). The same equipment realizes totally different works. If we add great range of programming method and control the robot (by dedicated software, universal open source blocky programming by scratch, using mouse, joystick, handhold teaching, off-line programming in CAM software or even leap motion-control by gesture and EEG – using our mind signal amplitude detection as trigger signal of start playback), we get universal and powerful machine in reasonable price.

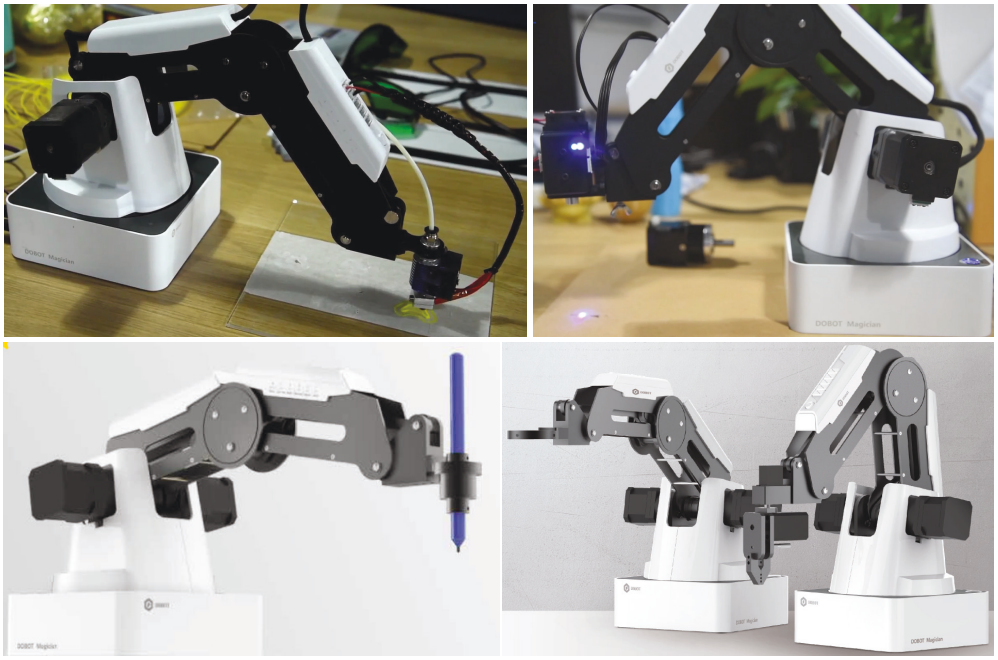

Fig. 4. *Different robot arm application: 3D printing, laser engraving, writing and gripper manipulating (source: www.dobot.pl)*

Additive technology on CNC industrial machines

Described methods of 3D printing based on simply machines construction, which add material (sequential layers) in one direction. Additional bridges and support material extend some features of shape aside, but it forces more effort to get ready model, change structure and strength (if something should works in different directions). So new idea is using multi-axis machine tools for 3D printing (Fig. 5).

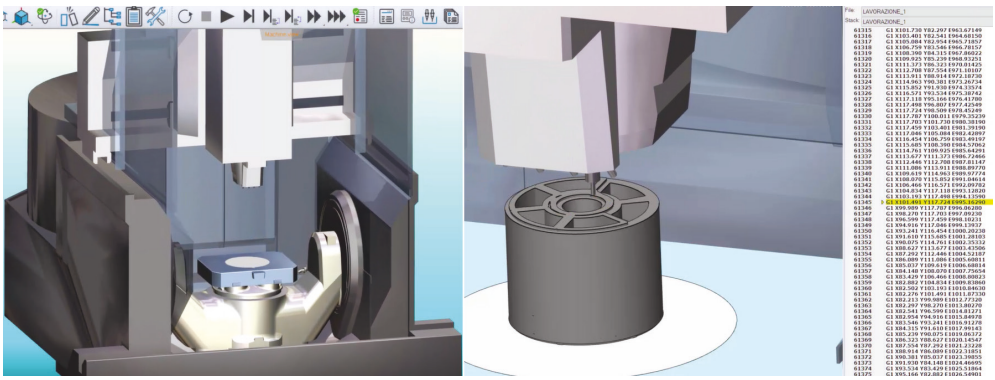

Fig. 5. *5-axis machine tool (table-table configuration) as 3D printer (source: www.roboris.pl)*

There are free software to create NC code for model – but they not work in multi axis. Work with such big and have machines is also most danger than typical 3D printer job. Potential program bugs and crash cost much more. Mentioned problem solution is using CNC machine tools simulators for analyze, check and connect programs. On the computer screen we see whole process but also check machine collision with every parts (machine body, tool, clamps, tool holder), can switch machine working plane (indexial machining) to change printing direction. After changing the actuator in theory it is possible to mix 3D printing and milling operation on the same machine tool (Fig. 6). After simulation user just send ready code to the machine and get final model.

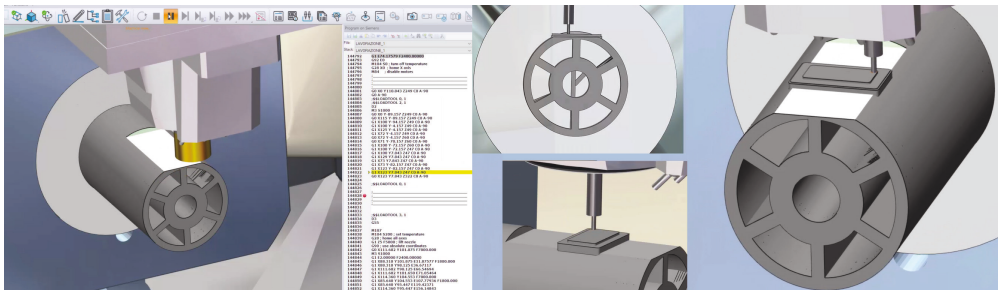

Fig. 6. *Milling and 3D printing simulation on the same machine tool (source: www.roboris.pl)*

It is possible for more complicated job use industrial CNC robots for 3D printing (Fig. 7). The rule is similar like with robotic arm, but typical CNC robot has 6 joints and works with external axis synchronization. We can decide if we use external axis like indexial (only change position of external axis without working movements) or full synchronization and maximum robot movements (min. using external if necessary), optimal division or minimize robot moves. There is also necessary to make simula-

tion for robot programming and read printer program prepared before as a base for working with robots.

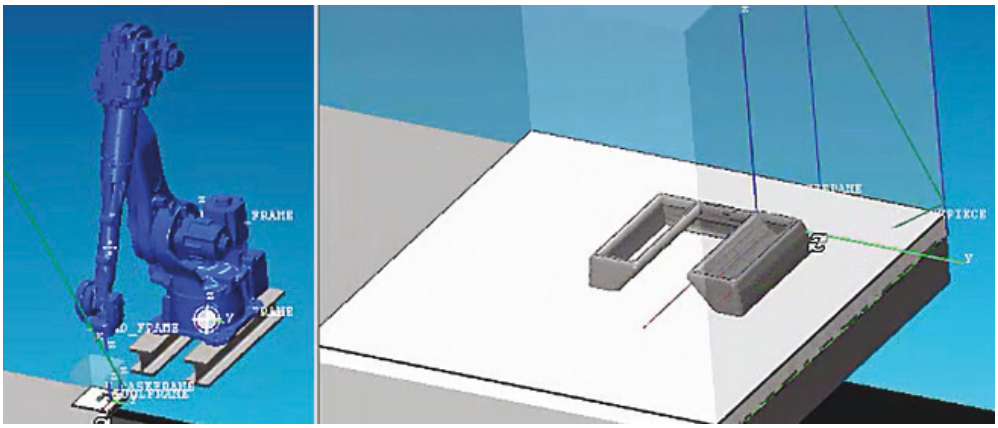

Fig. 7. *Industrial robot like 3D printer (source: www.roboris.pl)*

Conclusion

From all 3D printing technologies FDM is the most popular now and there are different ways to increase its capabilities. The easiest solution is transfer 3D printing methods to existing CNC machines, just add 3D printing equipment and software to control the machine. There are much flexible solutions: because of working area, multi axis, possibility to change end effector. But it is still the same technology with its advantages and disadvantages (e.g. problems with material float and deformation).

References

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