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Sustainability of 3D Printing vs. Machining: Do Machine Type & Size Matter?

Jeremy Faludi*[1], Rishi Ganeriwala[1], Brett Kelly[1], Toril F. Rygg[1], Chi Yang[1]
[1]*University of California Berkeley, USA*
*Corresponding author: faludi@berkeley.edu

1. Introduction and Background

3D printing is booming, now competing with CNC machining and other methods, particularly for prototyping [1]. However, its environmental impacts are still poorly understood. Here, impacts of four 3D printers were compared to two CNC mills to find if larger or smaller, or certain types of machine (FDM vs. SLA vs. polyjet) are more sustainable for general prototyping, or if such statements can even be made.

Some environmental impacts of machining have been well studied [2, 3]. Likewise, some environmental impacts of 3D printers have been well studied [4, 5]. However, most of these studies are single-issue (e.g. just energy use), and few of them compare different 3D printers, much less compare them to machining. Also, some 3D printing enthusiasm has led to misleading comparisons (e.g. solar-powered printers vs. grid-electric injection molding [6]).

3. Methods and Results

This study continues recent work [7] providing the first life-cycle assessment (LCA) of multiple 3D printers using comprehensive multi-variable impacts, and the first such comparison of additive manufacturing vs. machining. In this study, new machines were measured and the functional unit was adjusted from the making of two solid parts to making one thin-walled part, for more realistic comparison of the prototyping most often performed by 3D printers, according to industry sources. See Figure 1.

Machines measured were a Mori Seiki NVD1500 DCG ("small" CNC mill), a Haas VF0 ("large" CNC mill), an Afinia H480 ("small" desktop FDM printer), a Dimension 1200BST ("large" commercial FDM), an Objet Connex 350 ("large" commercial polyjet), and a Projet 6000 ("large" commercial SLA). Scoring used ReCiPe Endpoint H. Printer usage varies widely, so scenarios included theoretically making parts 24 hrs/day, 7 days/wk, as well as making just one part per week, either leaving machines idling or turning them off when not in use (except the Objet, for which shutoff is prohibitive).

Figure 2 shows maximum utilization results. Only one part was printed per machine, but SLA and polyjet machines can print several parts in nearly the same time as one part, so this was modeled, denoted by (*). The Mori Seiki had anomalously long operation time, which may have been due to operator inexperience. Thus, an alternative was calculated for it with more optimal operation time, denoted by (**).

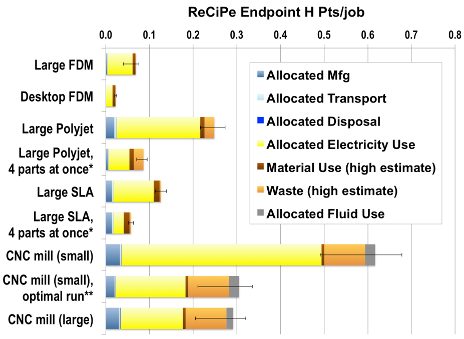

Figure 2. Impacts per part, operating at maximum utilization.

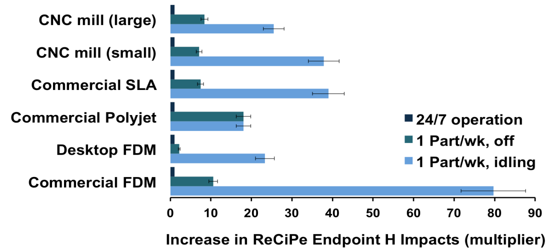

Figure 3. Impacts of idling vs. maximum utilization.

6. Discussion and Conclusion

Environmental impacts per part made depended much more on machine utilization than machine type or size (Figure 3 shows an 18x to 80x difference vs. Figure 2's 20% to 14x, or up to 27x if the anomalous datapoint is included.) Printing multiple parts at once in the polyjet and SLA also made larger differences than machine type (see Figure 2).

Thus, although some machine types do have lower impacts than others (e.g. the desktop FDM), sharing of machines to maximize utilization is the top-priority sustainability strategy for all machines, more important than machine type or size.

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