Impact Dynamics of a 3D-Printed Piano Hammer

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The modern piano has remained largely unchanged since the 1800s. The currently used piano and its tonal system has subtle and obvious implications to Western music, such as its equal-tempered tonality. The modern piano is a popular instrument, but it has several limitations, including the need for frequent maintenance, a painstaking fabrication process, and an expensive price. It also has a subtle shortcoming: the modern piano was designed as an equal-tempered instrument. Equal temperament is a tuning system, which is constructed by setting the frequency interval between every pair of adjacent notes to have the same ratio. From an ethnomusical perspective, many pieces played on the modern piano are distorted in this equal temperament (e.g., J.S. Bach's *Well-Tempered Clavier*). To remedy these shortcomings, a three-dimensional (3D) printed grand piano action was manufactured by using a carbon fiber-reinforced thermoplastic. By simplifying the fabrication process and lowering the frequency of maintenance, the cost of the piano can be significantly reduced.

For this project, a standard grand piano action was disassembled manually by the author. Measurements of the small piano action pieces were recorded and drawings were created to turn the wooden design into a virtual design. The wooden action was also thoroughly examined by observing the motions between key components and the specific hardware used to fasten each component together. A computer-aided design (CAD) model was then reverse-engineered from these measurements. CAD models of all twelve parts of the piano action were modeled using SolidWorks™. Since the wooden piano action has many thin components, many of the parts are not suited for 3D-printing. For this reason, many of the parts were significantly restructured so that they could be 3D-printed. The assembled 3D-printed grand piano action is shown in Figure 1.

At this stage of the project, the strength of the carbon fiber-reinforced thermoplastic grand piano action components is found to be sufficient. The geometry of the parts has been successfully modified for effective 3D-printing. A 3D-printed piano action prototype has been designed and fabricated, which is much cheaper and easier to produce than a typical wooden action. With more modifications to the parts, a 3D-printed piano action is a viable option for a cheaper and more adjustable piano.

In the next stages of this project, the action will be improved by adding felt to the 3D-printed piano action. In the wooden piano action, felt plays a key role in adjusting the friction at the joints of the linkage and the density of the hammerhead. In addition, subsequent restructuring of the CAD files will likely be necessary to increase the stability of the linkage. In the final iteration, the hammer position will also be made adjustable in order to change the timbre of the string.

Statement of Research Advisor

During the course of this research, Rebecca completed the initial steps in a broader project, whose goal is to redesign the modern piano. These first steps were completed by reverse engineering a grand piano action in order for it to be effectively 3D-printed. This research has the potential to create a more versatile keyboard instrument.

– Edmon Perkins, Mechanical Engineering

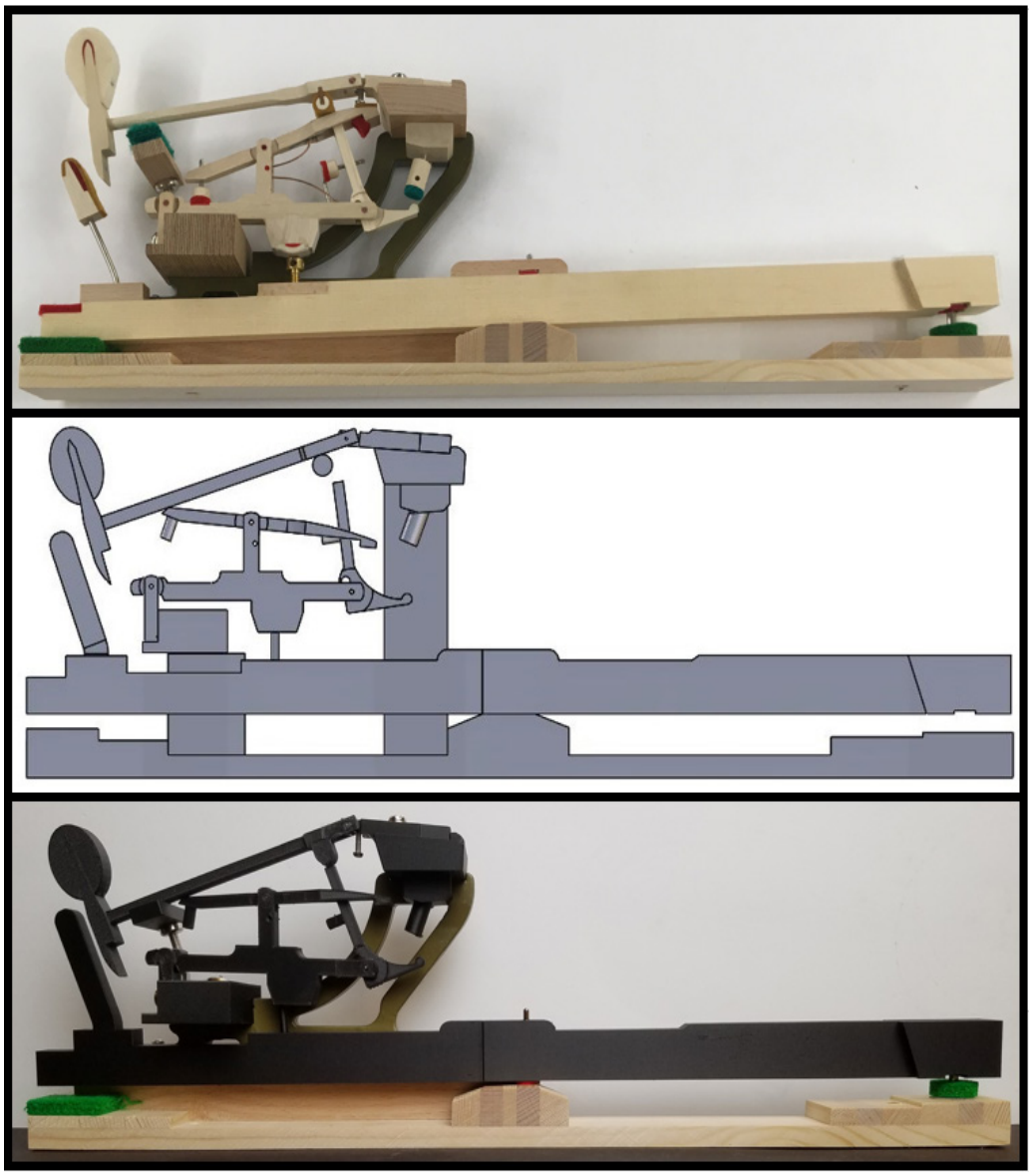

Figure 1.
Top: The original grand piano action is composed of wood with metal and felt components at connection points. Middle: SolidWorks™ CAD of piano action, modified in several ways to allow for 3D-printing. Bottom: The 3D-printed piano action prototype was produced from a Markforged™ printer; the material is nylon with chopped carbon fiber.