Team 501: Functional Decomposition

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Introduction

Functional decomposition is important to break a system down into its simplest components. These components each perform an action and contribute to the system. To better understand the product being developed, a flow chart, hierarchal decomposition, and a cross reference table were used.

The purpose of the product being developed is to maximize the amount of metal powder recovered from a part after it has been printed in a laser powder bed fusion (LPBF) process. The product will support the part, manage the powder, and inhibit the powder.

The Current Process

The generalized functions were determined by breaking down the current process used to remove powder from the parts. This break down formed a function structure as seen in Figure 1. It is fundamental to analyze the current process to determine its functions. These functions will help further integrate our product using systems engineering. The structure diagram is effective because it determines the best fitment of our product in the current process. It also highlights weak points in the current process. We can then innovate to improve the weak areas.

The functional decomposition was constructed using both the existing process and the powder recovery product we are designing. The physics and functionality of the systems in the metal powder recovery method at AFRL were noted and broken down to the most basic operations. Many of AFRL's current powder-removal methods involve air. Air is used as a vacuum and a compressor to remove powder. These air-based systems were then decomposed to formulate the function structure of the existing process. Beyond that, the user is responsible for physically moving the plate/part to each phase of the existing process. The recovered metal powder enters a hopper system integrated in the LPBF printer if it is not contaminated.

A series of graphics were created to demonstrate the functional decomposition of both the existing method and the minimum required functionality of the powder recovery method our team is tasked with creating. In Figure 1, the functional decomposition flow chart of the process used at AFRL is broken down.

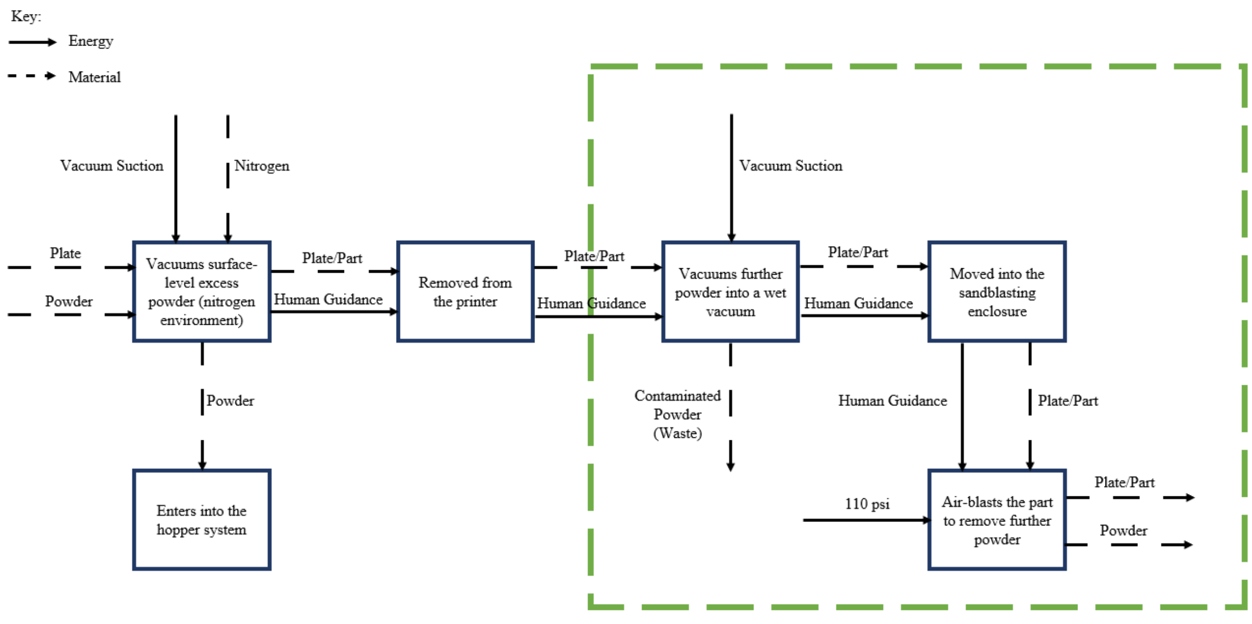

Figure 1: Functional decomposition flow chart of AFRL's existing process.

Figure 1 shows that the plate/part goes through a series of powder removal operations involving air suction, air pressure, and human guidance. The powder itself is typically taken out of the flow chart. The powder is either sent into a hopper system for collection or is contaminated in the wet vacuum stage. The area signified by a dashed green outline is likely where our powder recovery method will be implemented. This is where our method will be utilized because it is after the integrated recovery system of the printer. The "wet vacuum" stage is where most of the powder is contaminated and lost, and the sandblasting stage is where our sponsor believes the process can be most improved. In Figure 2, a hierarchical functional decomposition was created that breaks down the requirements of our powder recovery solution.

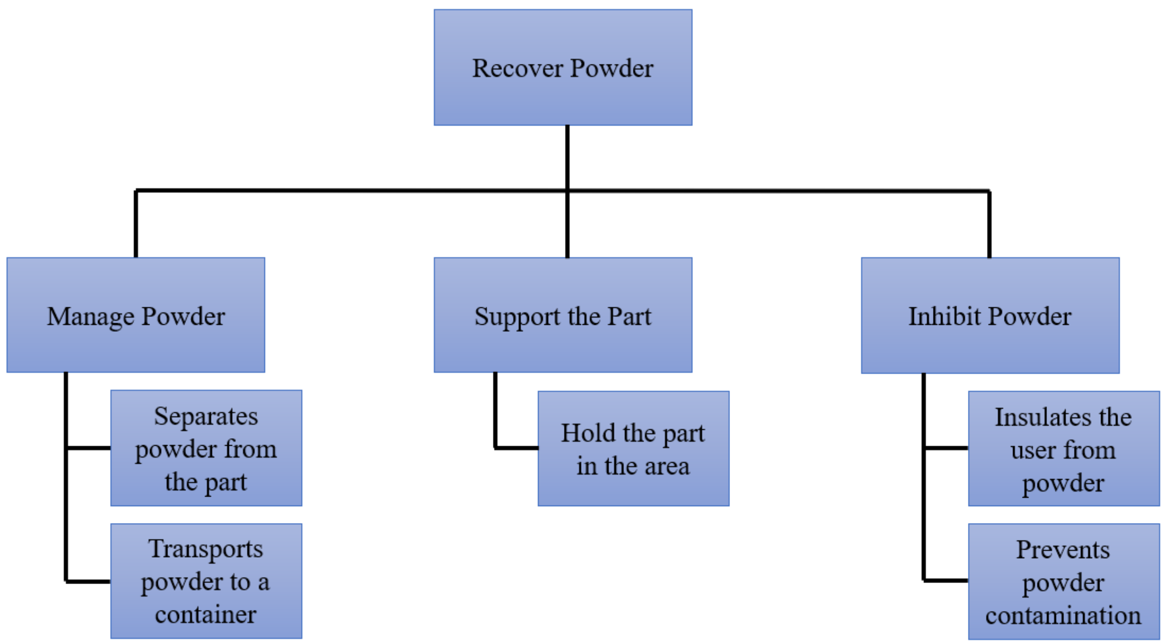

Figure 2: Hierarchical functional decomposition breakdown of the proposed product.

The Future Product

As described in the hierarchical chart above, the major functions required of the powder recovery system are to support the part, manage the powder, and inhibit the powder. The subfunctions of each of these major functions further describe the necessary performance expected for the powder recovery system.

The function of supporting the part has one key goal. The product can hold the part in place at the time of powder recovery. This can be something as simple as allowing the user to hold the part with their hands, or as complex as a holding cell containing the part. Managing the powder is a more complex operation, as the powder must be successfully separated from any lattices or crevices in the part, and then properly transported to a containment area. The last important function is preventing the powder from ending up somewhere it shouldn't be. Allowing the ability to insulate the user from the powder is a major safety concern, especially if the powder is subjected to compressed air. Such an action is performed in the current process in a sandblasting chamber to separate the operator from the powder. Additionally, preventing the powder from being contaminated is important for recycling purposes. Contamination occurs in the existing process during the wet vacuum stage so mitigating the contamination is an important function in powder recovery.

Function Integration

The functions of the product need to be designed to work with each other. For example, the part must be held to allow safe separation of the powder from the part. Supporting the part must not interfere with the transportation of powder to the final collection area. The powder collection should be insulated from the user, so the implementation of each of these functions is integral to having a successful product. Focusing on one more than the other may be detrimental.

Smart integration of the proposed functions could greatly increase the overall success of the project. Holding the part in the collection area shouldn't impede the overall goal of recovering powder. When it comes to managing powder, separating the powder and transporting the powder can be incorporated intelligently. The same process used to separate the powder can be used to implement the transportation of the powder. When inhibiting the powder, the same process which is used to insulate the user can also protect the powder from contamination.

Ranking Function Importance

A cross-reference table was constructed for each of the powder recovery functions described in the hierarchical chart. These functions were compared to each other in order to scale their relative importance. A "1" was assigned to cells in which the function in the row was more desired than the function in the column, and a "0" was assigned for the inverse. Across the diagonal axis from the top left to the bottom right, zeroes were assigned for all cells as the row and column functions were equivalent. The sum of each row was taken, and the row functions with the highest numbers were determined to be the most critical functions. The cross-reference table can be seen in Figure 3.

Functional Decomposition - Cross-Reference Table						
	Hold the part in the area	Separates the powder from the part	Transports powder to a container	Insulates the user from the powder	Prevents contamination of the powder	**Sum**
Hold the part in the area	0	0	0	0	0	**0**
Separates the powder from the part	1	0	1	1	0	**3**
Transports powder to a container	1	0	0	1	0	**2**
Insulates the user from the powder	1	0	0	0	0	**1**
Prevents contamination of the powder	1	1	1	1	0	**4**
Ranking	**5**	**2**	**3**	**4**	**1**	

Figure 3. Cross-reference table for the powder recovery device.

As determined from the summing of each function row, the ranking of the five functions from most to least critical is as follows: prevents contamination of the powder, separates the powder from the part, transports powder to a container, insulates the user from the powder, and holds the part in the area. The two highest ranking functions, preventing powder contamination and separating the powder from the part, are critical because the primary goal of this product is to recover as much powder as possible. Therefore, these two functions proved to be the most critical for the project to be successful. However, the prevention of powder contamination was found to be the most important function because it serves the purpose of keeping the recovered powder usable. This covers all stages of the powder recovery system, including potential improvements to the contamination-prone wet vacuum stage.

Powder transportation to a containment system was ranked third as it is an important part of the design for a recovery system. User insulation and part holding were deemed to be the least important functions because these could be manually done. The user can insulate themselves using other means if necessary (i.e. a respiratory system). The user could also hold the part in place manually. Performing these functions manually could be beneficial for some designs. Although these are the least critical functions, it is still beneficial to include them.