MA3071 P3.15 Product Disassembly Report

ME18 Group B

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1 Abstract

This project aims to disassemble and evaluate the Electrolux Z1220 vacuum cleaner for adherence to both Design for Manufacturing (DFM) and Design for Assembly (DFA) guidelines.

A literature review is conducted to obtain the 8 DFM and 8 DFA guidelines, which are mainly obtained from [1]. The complementary and contradictory DFM and DFA guidelines are also elaborated upon to show how these guidelines fit together.

The vacuum cleaner is then evaluated based on the guidelines obtained, and specific parts, like the wheel holder, are selected for analysis in greater detail for their adherence to DFM and DFA guidelines.

The shortcomings of the vacuum cleaner parts are then discussed, along with other concerns, such as durability and repairability. Possible improvements are provided to improve the vacuum cleaner to be more adherent to DFA and DFM guidelines, as well as to address the other concerns brought up in the discussion.

Ultimately, the project is successful in meeting its main objective of disassembling and evaluating the vacuum cleaner for adherence to both DFM and DFA guidelines. Expectedly, the vacuum cleaner adheres to most of the guidelines, with a few exceptions.

2 Scope and objectives

This project focuses on evaluating the Electrolux Z1220 vacuum cleaner for adherence to both Design for Manufacturing (DFM) and Design for Assembly (DFA) principles and providing suggestions for improvements in areas where it falls short.

Figure 1: The disassembled Electrolux Z1220 vacuum cleaner.

The objectives of this project are:

1. Understand the key principles of Design for Manufacture (DFM) and Design for Assembly (DFA).
2. Analyse the vacuum cleaner's compliance with DFMA guidelines.
3. Identify contradictions and trade-offs between DFM and DFA.
4. Propose potential design improvements for cost, reliability, and ease of assembly.

3 Literature review

3.1 Design for Manufacturing (DFM) and Design for Assembly (DFA) principles

The DFM and DFA principles are [[1], [2], [3]]:

DFM	**DFA**
Use fewer parts	Minimise part count
Use standard part designs	Standardise and use common parts
Simplify geometry	Design for part symmetry
Modularise design	Design parts with self-aligning features
Match process to material chosen	Design parts with self-fastening features
Design for easy fabrication	Mistake-proofing (poka-yoke)
Design for realistic tolerances	Minimise re-orientation during assembly
Minimise secondary operations	Ensure accessibility and visibility

3.1.1 Injection moulding design guidelines [1]

1. Design the main wall of uniform thickness with adequate tapers or draft for easy release from the mould.
2. Choose the material and the main wall thickness for minimum cost.
3. Design the thickness of all projections from the main wall with a preferred value of half of the main wall thickness and not exceeding two-thirds of the main wall thickness.
4. Align projections in the direction of moulding or at right angles to the moulding direction lying on the parting plane.
5. Avoid depressions on the inner surfaces of the part.
6. Design external screw threads to lie in the moulding plane.

3.2 Complementary principles

3.2.1 Minimise part count

Reducing the number of parts reduces the cost for manufacturing while speeding up assembly. For example, an integrated water bottle cap hinge reduces the number of separate parts.

3.2.2 Standardise part designs

Making use of common parts like standard screws or fasteners reduces the manufacturing cost due to part availability, and reduces the need for special tools during assembly.

3.2.3 Modularise design

In DFM, modular parts can be reused in other products, removing the need to design and manufacture new parts. In DFA, modular parts are made to be easily joined and can be assembled quickly, as they are common parts used in multiple products. An example is IKEA's flat-packed furniture modules (Figure 2).

Figure 2: IKEA flat-packed furniture. [4]

3.3 Conflicting principles

3.3.1 Design parts with self-fastening features

Designing parts with self-fastening features like snap-fits greatly speeds up assembly time, but makes part geometries more complex, going against the principle of simplifying geometry in DFM. These features increase manufacturing time and costs.

4 Application

Overall, the vacuum cleaner generally adheres to most DFM and DFA guidelines. However, there are a few parts of interest that do not adhere to DFM guidelines that have been selected for analysis in greater detail.

4.1 Wheel holder

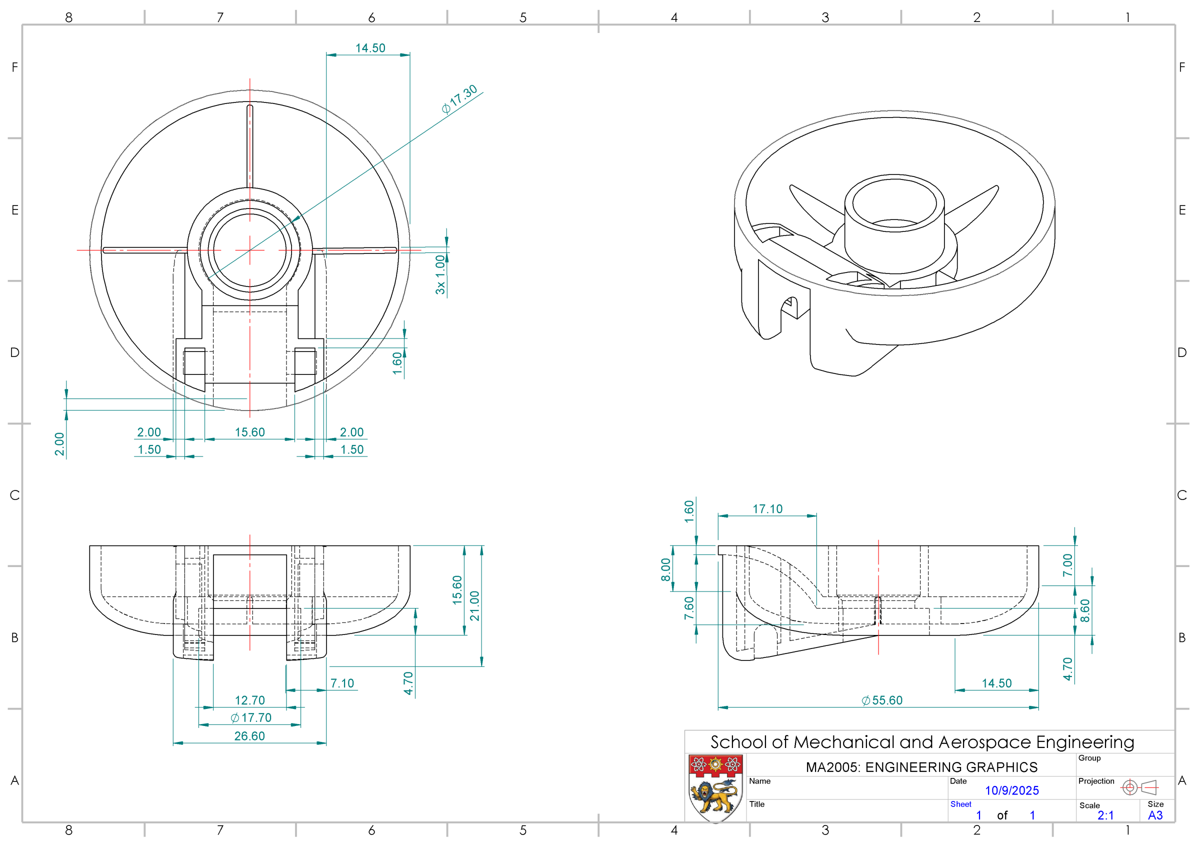

Figure 3: Engineering drawing of the wheel holder.

Figure 4: Outer finish of the wheel holder.

4.1.1 Adherence to DFM principles

The part has adhered to most of the design principles for DFM, as it is easily fabricated using a single core and cavity mould. However, the geometry of the inside is quite complex and can be further simplified.

The thickness of the walls surrounding the two rectangular holes, which are not as thick as the main wall (the 2 mm circular outer wall), but are also insufficiently thin to adhere to the guideline of keeping projections from the main wall between half and two-thirds of the thickness of the main wall (Section 3.1.1). It is difficult to tell whether this is due to bad tolerances in the mould, but it seems intended, as it is very clearly thicker than the three 1 mm ribs around the through hole in the middle, but it is thinner than the main wall.

Hence, these overly thick walls may result in cooling issues at the junction between the main wall and these walls due to the junction being thicker. Such cooling issues include sink marks, which form due to uneven cooling of plastic and plastic shrinking when cooled. These marks are not present in the part, but may be present in another part of the same run. Hence, these walls should be thinner to lower the chances of defects.

Furthermore, there is a stepped transition between the main wall and the bottom section that sticks out, which does not adhere to the design principle of having uniform wall thicknesses. Hence, it results in a greater risk of defects due to voids and sinks. The step transitions should be filleted or chamfered, so that there is a smooth transition between the main wall and the bottom section, keeping the wall thickness as uniform as possible to reduce the chances of defects.

Moreover, the outer finish of the part may not be needed (Figure 4), as it increases costs by 5%. However, it may be worth having due to the faster assembly time, thanks to workers having an easier time grabbing the part, but this will need to be empirically tested and verified.

4.1.2 Adherence to DFA principles

Similarly, the part has adhered to most DFA principles, with it being very symmetric and having self-fastening features, like the indent at the bottom of the through hole for a snap fit. The installation of the part relies only on the vertical orientation being correct, where it is extremely asymmetric, making it clear which orientation it should be installed in. The part is also already at the theoretical minimum number of parts, so it has a perfect DFA index.

Nonetheless, one area of improvement would be to include self-aligning features, as proper alignment is needed before the snap fit can be passed through the centre hole. While the top hole 5 mm larger than the bottom hole and contains a countersink in the area where the transition between the two holes is, as it can still be challenging to fit the part into the snap-fit, as the part is fitted from the bottom.

Thus, having a top surface that is concave towards the centre hole would make it simple to assemble, as placing the snap fit anywhere on the top surface of the part will guide it into the centre hole.

However, this improvement may not be worth it, as it greatly compromises DFM principles. Adding a top surface to the existing part would increase the mould cost as it is far more complicated to make such a mould and would likely require moving cores. Alternatively, filling the entire part would be much worse, as it will result in far greater material costs and far longer cooling times. The risk of defects greatly increases too due to how thick the part is, greatly increasing the chances of sink marks and voids due to uneven plastic cooling.

Therefore, the part seems to be fully optimised for DFA, and it is highly unlikely that there is anything to further improve.

4.2 Crevice tool

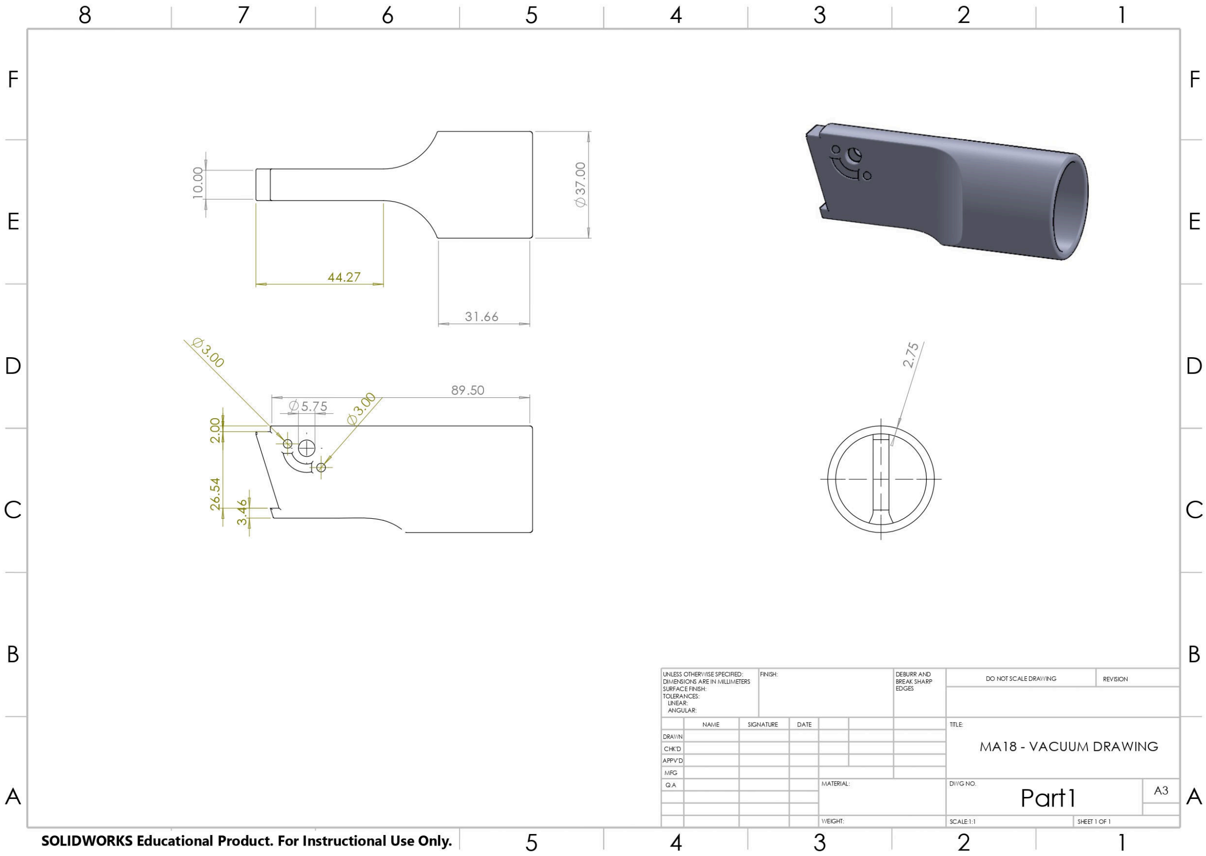

Figure 5: Engineering drawing of the crevice tool.

4.2.1 Adherence to DFM principles

The crevice tool generally adheres to the DFM principles, as it is manufactured using a single injection-moulded component with a simple and straightforward core-cavity design. The cylindrical shape, along with the uniform wall thickness provides symmetry, increasing suitability for fabrication and reducing the risk of cooling defects such as warping. The engravings and snap-fit features are integrated directly into the mould, which reduces secondary operations, keeping production time and cost low.

The only point of contention is that the transition between the cylinder and the flat-faced area could create a slightly uneven wall thickness, increasing the risk of localised voids. To avoid this, smooth fillets could be added to help achieve more even cooling. Overall, the part is well-designed for large-scale production and requires minimal post-processing.

4.2.2 Adherence to DFA principles

From an assembly viewpoint, the part also adheres to DFA principles. Its cylindrical design with uniform geometry makes orientation simple and naturally guides the crevice tool into its connecting part, simplifying insertion. The quick-connect and snap-fit features allow for tool-less assembly which significantly reduces assembly time compared to other fasteners like screws. It can only be assembled in one orientation due to the symmetry, which minimises assembly error.

A possible improvement could be enhancing the self-aligning features to make initial engagement smoother, particularly if tolerances between parts are tight. Introducing this feature might compromise the manufacturability as the mould complexity could increase, increasing the production cost. Although the part is optimised for both DFM and DFA, the multitude of snap-fit mechanisms could make it difficult to repair or service. Repeated disassembly could also reduce long-term durability due to fatigue. This highlights the common trade-off between DFA and repairability, designs that allow quick assembly are often not made for service after sale.

5 Discussion

5.1 Possible improvements

5.1.1 Plastic threads

Plastic threads in injection-moulded parts significantly increase manufacturing costs because they require threading cores in the mould. During the moulding process, these cores must physically unscrew from the part before ejection, which can add around 10 seconds per piece compared to non-threaded parts.

In high-volume production, this extra cycle time is a massive cost driver. Moreover, plastic threads are prone to wear, stripping, and cracking under repeated use, especially when exposed to torque or shock loads.

Making use of metal threaded inserts, which are press-fitted or heat-staked into the plastic body, eliminates the need for threading cores, improves strength, and provide durability and reliability compared to plastic threads. However, they also introduce tighter tolerance requirements and increase assembly costs due to press-fitting equipment and labour, and require the surrounding plastic design to be reinforced to avoid cracking under stress.

Despite the higher cost, metal inserts are preferred in applications where long service life, durability, and high torque resistance are critical.

5.1.2 Plastic wheels

The current plastic wheels are unreliable and noisy, hence, making use of rubber-coated wheels would decrease noise, improve durability and allow for smoother movement.

5.2 Durability

Snap-fit joints are widely used in the vacuum cleaner as they eliminate the need for fasteners, reduce part count, and allow for quick assembly. However, every time the snap-fit is flexed during assembly or disassembly, the plastic material experiences cyclic loading, which causes fatigue failure over long periods of time, leading to cracks or joint breakage.

The problem is exacerbated if the snap-fit is made from brittle plastics or the fit requires excessive bending. Once broken, the product becomes difficult or even impossible to reassemble, reducing serviceability and overall lifespan.

To mitigate this, designers can use tougher materials such as nylon instead of brittle ABS, make the structure more rigid using thicker roots and rounded fillets to reduce stress concentration. They can also limit the design to one-time assembly if repeated access is not required.

6 Conclusion

The 4 objectives have been met as our team now understands the principles of DFM and DFA. The vacuum cleaner complies with most DFA and DFM guidelines, except for the wheel holder, which has uneven wall thickness. Most DFA and DFM guidelines are complementary, except that the DFA principle of designing parts with self-fastening features conflicts with the DFM principle of simplifying geometry. The vacuum cleaner could also be more durable and repairable with the addition of metal thread inserts and rubber-coated wheels, as well as having snap-fit joints made out of less brittle materials.

7 References

[1] G. Boothroyd, P. Dewhurst, and W. A. Knight, *Product design for manufacture and assembly*. CRC press, 2010.

[2] B. Guns, "1: Design for manufacturing (DFM)." [Online]. Available: https://eng.libretexts.org/Courses/Northeast_Wisconsin_Technical_College/Design_for_Various_Manufacturing_Methods/01%3A_Design_for_Manufacturing_(DFM%29

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[4] P. IKEA, "The history of the revolutionary ikea flatpacks." [Online]. Available: https://www.ikea.com/ph/en/this-is-ikea/about-us/the-story-of-ikea-flatpacks-puba710ccb0/