Techniques in Improving Quality and Speed of 3d Printing

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ABSTRACT: This research paper focuses on the improvement of print quality in 3D printing by analysing the variables that affect it. Six key elements were studied in detail: printing speed, nozzle size, operational temperature, bed levelling, material properties, and model construction. The research team conducted experiments with various combinations of these variables and measured the resulting print quality using a range of metrics. The findings indicate that adjusting these variables can significantly enhance print quality, with optimal settings dependent on the specific printer and printing medium being used. The results demonstrate that modifying these variables can greatly enhance print quality and that the best settings depend on the particular printing medium and printers utilised. Based on these observations, the paper offers suggestions for improving print settings as a conclusion. Overall, this research offers useful insights into the variables that affect the quality of 3D prints and offers helpful advice for getting better outcomes.

KEYWORDS: 3D printing, print quality, variable modification, print settings, material characteristics.

I. INTRODUCTION

Additive manufacturing technology, specifically 3D printing, has revolutionised the manufacturing industry by enabling the production of complex geometries and customized products. However, the quality of 3D printed objects can be affected by several factors, such as printing speed, nozzle size, operational temperature, bed levelling, material characteristics, and model construction. In order to achieve high-quality prints, it is crucial to understand how these variables affect the quality of the final product and to investigate ways to improve print quality.

In this research paper, we aim to investigate the variables that affect 3D print quality and to propose ways to improve print quality. To achieve this goal, we tested various combinations of the six elements mentioned above and used multiple measures to assess the resulting print quality. Our findings indicate that modifying these variables can significantly enhance print quality, and the optimal settings depend on the printing medium and the specific printer used. Based on our observations, we provide suggestions for improving print settings, which can benefit the 3D printing industry by enabling the production of higher quality prints.

This paper aims to investigate the variables that impact 3D print quality and explore ways to enhance print quality. The research team conducted several experiments to test different combinations of these variables and used a range of measures to evaluate the resulting print quality. The findings demonstrate that modifying these variables can significantly improve print quality, and the optimal settings may vary depending on the printing medium and printers used. This paper contributes to the existing body of knowledge by offering useful insights into the factors that influence 3D print quality and providing practical recommendations for improving print settings. The results of this study can be beneficial for individuals and organizations seeking to achieve high-quality 3D prints for various applications, including prototyping, manufacturing, and research.

II. RELATED WORK

Improved 3D print quality has been the subject of numerous studies. One study looked at the impact of printing speed and nozzle diameter on the quality of printed objects. [1] According to the study, the quality of the printed items was enhanced by reducing the nozzle diameter and speeding up the printing process. A different study that looked at the impact of bed temperature on print quality discovered that raising the bed temperature improved adhesion and print quality in general.

Another study focused on the influence of material viscosity and flow rate on the quality of printed items in order to better understand the relationship between material parameters and print quality. [2] The scientists discovered that materials with greater viscosity and flow rate produced prints with higher quality.

Additionally, some studies have concentrated on slicing and printing settings optimisation for certain materials. For instance, one study looked into the best printing settings for flexible materials, while another looked at the effect of different slicing settings on the calibre of printed parts.

III. METHODOLOGY

The methodology used for the research paper on improving the quality of 3D printing involved a series of experiments to investigate the effect of different variables on print quality. The six variables that were the focus of the study were printing speed, nozzle size, operational temperature, bed levelling, material characteristics, and model construction.

Hardware relation factors
1. **Printing speed**

Printing speed can have a significant impact on the quality of a 3D printing including the level of detail and accuracy (a). Generally, higher printing speeds result in lower quality prints, while slower speeds result in higher quality prints [3]. This is because when printing at higher speeds, the layers may not have enough time to properly fuse together, resulting in weak spots or gaps in the final print. Printing at higher speeds, the extruder has less time to lay down each layer of material, which can result in a rougher surface finish with visible layer lines. This can be especially noticeable in curved or angled surfaces, where the lines can become more pronounced and visible [4]. Moreover, printing at high speeds can also cause issues such as stringing, where small strands of plastic are left behind during printing, leading to inaccuracies and imperfections in the final print. The faster the print speed, the more likely it is for the extruder to leave these strands of plastic behind, resulting in lower print quality.

On the other hand, printing at lower speeds allows the extruder more time to lay down each layer, resulting in a smoother surface finish and more accurate details. This is because the slower speed allows for better fusion between the layers, resulting in stronger and more precise prints. However, printing at lower speeds can take longer and may not be suitable for larger prints.

![Graph representation effect of speed of printing on print quality](image)

(a) Graph representation effect of speed of printing on print quality

2. **Nozzle Size**

Nozzle size can have a significant impact on both printing speed and the quality of a 3D print. When it comes to printing speed, larger nozzle sizes can allow for faster printing because they can extrude more material per second. This means that larger nozzle sizes can be used to print thicker layers, which can reduce printing time (b). However, it's worth noting that printing at higher speeds with a larger nozzle can also result in lower print quality, as the extruded material may not have enough time to cool and solidify properly.

In terms of print quality, nozzle size can also have a noticeable impact. Smaller nozzles typically produce more detailed and precise prints because they can extrude finer lines of material. This is especially important for printing small or intricate details in a model. However, printing with a smaller nozzle size can also take longer, as it requires more passes to fill in a given area [5]. It's also worth noting that the nozzle size can impact the overall strength and durability of a 3D print. A smaller nozzle size can result in a stronger and more solid print, while a larger nozzle size can produce a more porous print that may be more prone to breakage.

![Graph representation effect of Nozzle Size on quality and Printing Speed](image)

(b) Graph representation effect of Nozzle Size on quality and speed of printing

3. **Temperature**
Bed temperature
The bed temperature of a 3D printer can affect the quality and speed of the printing process (c). A higher bed temperature can improve adhesion and result in a smoother surface finish, but if it's too high, it can cause warping and affect print quality negatively. A higher bed temperature can also allow the printer to print faster, but finding the optimal temperature for a particular material and printer is important for achieving high-quality prints at a reasonable speed.

<table>
<thead>
<tr>
<th>Bed temperature</th>
<th>Quality of print</th>
<th>comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Poor</td>
<td>No adhesion to bed</td>
</tr>
<tr>
<td>Moderate</td>
<td>Best</td>
<td>Perfect adhesion</td>
</tr>
<tr>
<td>High</td>
<td>Poor</td>
<td>Warping and strings</td>
</tr>
</tbody>
</table>

(c) Chart representing Effect of bed temperature on quality of 3D print

4. Extruder temperature
The extruder temperature of a 3D printer can also affect the quality and speed of the printing process (d). A higher extruder temperature can result in faster printing speeds, better adhesion, and smoother surface finishes. However, if the extruder temperature is too high, it can cause the filament to burn or become too liquid, negatively impacting the print quality. Finding the optimal extruder temperature for a particular material and printer is crucial to achieve high-quality prints at a reasonable speed.

<table>
<thead>
<tr>
<th>Extruder temperature</th>
<th>Quality of print</th>
<th>comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Poor</td>
<td>Nozzle clogged</td>
</tr>
<tr>
<td>Moderate</td>
<td>Best</td>
<td>Perfect extrusion</td>
</tr>
<tr>
<td>High</td>
<td>Poor</td>
<td>Filament burned</td>
</tr>
</tbody>
</table>

(d) Chart representing Effect of extruder temperature on quality of 3D print

5. Bed levelling
Bed levelling is crucial for ensuring high-quality 3D prints as it helps to ensure that the print bed is at the correct distance from the extruder nozzle. If the bed is not level, it can result in uneven extrusion and poor print quality [7]. Additionally, bed levelling can affect the speed of the printing process, as uneven beds can cause the printer to slow down or pause. Overall, bed levelling is an essential step to achieve high-quality prints at a reasonable speed.

1. Filament Properties
Filament type plays a critical role in the quality of the final printed object. The type of filament used can affect the level of detail, surface finish, colour options, and strength and durability of the printed object. For example, PLA filament is known for producing high-quality, detailed prints with sharp edges and fine details, while ABS filament may produce less detail due to its tendency to warp [8]. Filament type also affects the surface finish of the printed object, with some filaments producing a smooth and glossy finish, while others produce a more textured and matte finish [9]. Additionally, the range of colours available for different filament types can vary, which can impact the overall look and aesthetic of the printed object (e). Finally, the filament type used can also affect the strength and durability of the printed object, with some filaments producing prints that are stronger and more resistant to impact and wear than others.

<table>
<thead>
<tr>
<th>Filament type</th>
<th>Printing quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLA</td>
<td>Produces high-quality, detailed prints with sharp edges and fine details on all sizes.</td>
</tr>
<tr>
<td>ABS</td>
<td>May produce less detail due to its tendency to warp on larger sizes. Better printing quality on smaller sizes.</td>
</tr>
<tr>
<td>PETG</td>
<td>Produces high-quality, durable prints with good strength and flexibility on all sizes.</td>
</tr>
<tr>
<td>NYLON</td>
<td>Produces strong, durable prints with good impact resistance, but may require a heated bed for larger sizes.</td>
</tr>
</tbody>
</table>
TPU | Produces flexible, rubber-like prints with good strength and durability on all sizes.

PC | Produces strong, heat-resistant prints with good impact resistance, but may require a heated bed and enclosure for larger sizes.

(e) Chart representing Various filament type and their printing quality

Filament size is another critical factor that affects the quality and speed of 3D printing. Smaller filament diameters, such as 1.75mm, allow for faster printing speeds because they require less energy to heat and melt. However, smaller filament diameters may produce weaker prints, which may not be suitable for some applications. In contrast, larger filament diameters, such as 3mm, may produce stronger, more durable prints that can withstand more stress, but may require more energy and time to heat and melt, which can slow down the printing process.

Filament size can affect the quality of 3D prints in a few ways:

- Extrusion Consistency: The diameter of the filament affects the amount of plastic that is extruded from the nozzle. Inconsistent filament diameter can result in inconsistent extrusion, leading to visible defects and inconsistencies in the print.
- Layer Adhesion: The diameter of the filament can also affect the adhesion between layers. If the filament is too thick, the layers may not adhere properly, resulting in weak or delaminated prints. If the filament is too thin, the layers may fuse together, resulting in a loss of detail and definition.
- Flow Rate: The diameter of the filament can also affect the flow rate of plastic through the nozzle. If the filament is too thick, it may not melt properly or may require a higher temperature to melt, resulting in slower printing speeds. If the filament is too thin, it may melt too quickly, resulting in stringing and other defects.

Software relation factors

1. Complexity to compile

Compiling software does not have a direct effect on 3D printing. However, the software used to generate the 3D model, slice it into layers, and generate the G-code that controls the printer can have a significant impact on the quality and accuracy of the final print [10].

Three major types of settings that can be controlled in a slicer software—

- Print Settings: layer heights, shells, infill per cent, and speed
- Filament Settings: filament diameter, extrusion multiplier, the temperature of the extruder, and print bed.
- Printer settings: nozzle diameter, print bed shape (L x W), and Z offset.

The slicing software determines how the 3D model will be sliced into layers and how each layer will be printed. It also generates the G-code that controls the printer's movement and extrusion during printing. If the slicing software is not properly configured, it can lead to problems such as under-extrusion, over-extrusion, stringing, or warping.

Some ways that the slicing software can affect the 3D print include:

- Layer height: The slicing software determines the layer height, which directly affects the resolution of the print. A lower layer height generally results in higher resolution but slower printing speeds.
- Infill density: The slicing software controls the infill density, which affects the strength and weight of the print. A higher infill density results in a stronger but heavier print.
- Support structures: The slicing software generates support structures for overhangs and bridges, which affect the print's overhang quality and overall stability.
- Printing speed: The slicing software can control the printing speed, which affects the time it takes to print the object. Higher printing speeds can result in lower quality prints, while slower speeds can lead to higher quality prints.

Overall, using a high-quality slicing software and adjusting the settings appropriately can significantly improve the final print quality. It is important to experiment with different settings to optimize print quality and printing speed for each specific 3D print.

IV. EXPERIMENTAL RESULTS

In this research, we conducted experiments to investigate the impact of various factors on the quality of 3D prints. We tested different combinations of printing speed, nozzle size, operational temperature, bed levelling, material characteristics, and model construction, and evaluated the resulting print quality using measures such as layer height, dimensional accuracy, surface finish, and strength.

The results showed that each of these factors had a significant effect on print quality, and that modifying them could lead to significant improvements. For example, increasing the printing speed generally resulted in lower print quality, but could be
compensated by using a smaller nozzle size or increasing the temperature. Bed levelling was found to be critical for achieving good adhesion and preventing warping, while material properties such as viscosity, melting point, and shrinkage had a major impact on the print quality.

We also found that the optimal settings for each factor depended on the specific printer and material used, and that there was often a trade-off between different quality metrics. For instance, reducing the layer height could improve surface finish, but could also increase print time and decrease strength.

Overall, these experiments provided valuable insights into the factors that influence 3D print quality and demonstrated that careful selection and adjustment of these parameters can lead to significant improvements.

Image representing the difference between quality before and after applying the improvements

V. CONCLUSION

In conclusion, this study investigated the impact of various factors on the quality of 3D prints. Through extensive experimentation, we found that printing speed, nozzle size, operational temperature, bed levelling, material characteristics, and model construction all have a significant impact on the final print quality. Our results demonstrated that by optimizing these variables, it is possible to achieve significantly improved print quality. However, we also found that the optimal settings depend on the specific printer and printing medium used. Therefore, we recommend that users experiment with these settings to find the best combination for their needs. Overall, this research provides valuable insights into the factors affecting the quality of 3D prints and offers practical advice for achieving better results.

REFERENCES