# Strengthening of Fused Deposition Modeling Printer Bed Adhesion Intensity using ABS Glue

**S.Maidin, J.H.U.Wong, N.M. Arif, A.S. Mohamed**

***ABSTRACT: Fused deposition modeling (FDM) technology enables the 3D printing of any complex geometrical parts or products easily using polymer based material such as ABS. In addition, FDM is also the future of sustainable manufacturing due to a small amount of wastes release, making it a valuable technology towards manufacturing sustainability. However, with all the significant advantages of FDM, parts printed with ABS material are occasionally found poor in printing quality due to warping or the printed part detached itself from the bed during printing leaving poor dimensional accuracy and mechanical failure. This affects the time to reprint and waste of material due to misalignment during the printing. This study provides an investigation of using ABS glue (ABS and acetone) to improve the adhesion between the FDM part and the printer bed. Various ratios of 1.75 mm diameter ABS filament chips were mixed with 50 ml of acetone and applied on the kapton tape. The results showed the test specimen warped 3 mm from the bed and ripped off when the ABS glue was not used. In addition, improvement of bed adhesion was with no warping when the ABS with acetone was used. Best surface quality results were found using 100 mm to 300 mm length of ABS filament chips with 50 ml acetone. These results proved that warping deformation can be prevented and allow quality parts to be printed easily.***

***KEYWORDS: Fused Deposition Modeling, Dimensional Accuracy, Bed Adhesion and Warp Deformation.***

## 1. INTRODUCTION

Additive manufacturing (AM) is a technology that is able to shape 3D objects by adding material layer by layer. The advancement of technology from various fields such as the 3D modeling software and computer numerical control (CNC), AM was successfully used in many industries such as aerospace, automotive, medical and even fashion [1]. Fused deposition modeling (FDM) is one of the vastly used AM technologies. It deposits an extruded thin filament of material from a heated nozzle onto the printer bed repeatedly layer by layer to form 3D parts. AM works differently compared to conventional manufacturing where it is capable of creating a custom complex parts in a short time and low cost without going through several manufacturing processes [2]. FDM offers huge design freedom and flexibility. FDM uses polymer material such ABS which is commonly available in the market to produce a solid 3D [3]. What makes FDM great is the minimal waste release during the entire process and aligned with the sustainable goal to be economically worth and environmentally friendly. However, ABS material tends to warp during the printing process and it causes the part or product to be rejected from bad dimensional accuracy and failure [4]. This is due to the nature of ABS material properties that shrink as much as one percent after cooling down to room temperature and poor bed adhesion that leads to warping.

This paper brings a study to improve adhesion between the 3D printed ABS part and FDM printer bed. Various methods have been introduced to improve the bed adhesion, but none were quite successful leaving slight warping issues. The use of ABS glue was discovered by 3D printing community but no in-depth research and experiment were carried out to get a comprehensive solution for the issue [5], [6]. ABS glue is a combination between ABS and acetone, for which in contact will dissolve the ABS, creating sticky glue. The glue will form a strong bond with the kapton tape on the bed. Acetone is a good solvent for plastics such as ABS and cleaning purposes in the laboratory [7]. This work investigates the correct mixture to be used effectively on FDM. Six different concentrations of 1.75 mm diameter ABS filaments chips, 100 mm, 200 mm, 300 mm, 400 mm, 500 mm, and 600 mm will be mixed with 50 ml of acetone inside each small HDPE plastic container and left for 12 hours or until the ABS completely dissoves. The glue was applied on top of a kapton-taped heated bed. A rectangular

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shape test specimen was printed by an open source FDM printer and the results of warping were recorded and tabulated.

## 2. BACKGROUND STUDY

FDM, an extrusion based method is categorised as one of the AM technology. Using polymer as a base material, it becomes popular and mostly used throughout the world. Originally developed and patented by Scott Crump in late 1980s, he as the co-founder of Stratasys, used the idea to mechanically extrude molten polymer layer by layer and was soon commercialized [8]. FDM starts with a development of a 3D CAD drawing file and converting it into a STL file. The file will be sent to the FDM printer software and this is where the user can freely decide the parameters (layer height, infill %, etc.) to edit for the appearance or the functionality. Then, the FDM printer will deliver filaments from the spool to the geared extruder and lastly into a heated nozzle. The nozzle will then extrude a thin layer of a filament according to the nozzle size onto a bed in two-dimensional axes (X & Y). The Z-axis will lift a gap to allow new layer to be deposited. The process is repetitive until the whole solid object is created [9].

As mentioned, FDM works differently from conventional manufacturing such as milling, CNC and lathe. Conventional manufacturing removes the solid block of raw material into a desired shape and size. The unwanted scrap will be a waste of material. Injection moulding for another example, extra material is needed to fill in the mould. Therefore, FDM possesses the key advantage that is resource-efficient because the only material consumed is what came out from the extruder. Besides, FDM requires little manufacturing stages thus leading to low energy consumptions [10]. Furthermore, FDM does not require expensive tooling and frequent tool changing. All of the advantages reduce the environmental impact of a sustainable green manufacturing [11].

Although FDM produces less waste compared to conventional manufacturing, the failure of ABS product due to warping will result in waste production. This contradicts the term for sustainable manufacturing in AM technology. ABS material is very sensitive to temperature change. The temperature difference between the bottom and top part will create inner stresses, causing deformation, as well as warp and inner layer delamination or cracking. Worst, it will cause product failure and to be rejected. ABS is originally designed for the injection moulding process since shrinkage allows the part to pull away from the mould as they cool and fall into a container without any robot or human aid. Experienced by high to low-end users, FDM warping issues are common and many researchers have explored this problem. Wang et al. discussed the warping issues and developed a mathematical model. The results obtained from mathematical modeling showed that the produced ABS part with influencing factors such as a number of deposition layer, the length of stacking section, material linear shrinkage rate, operating ambient temperature and glass-transition temperature will contribute to the warp deformation [12]. Turner et al. explained that thermal stresses built during the printing process are essentially present since it is based on extrusion-based method. In order to combat the problem, the printing process was operated inside a temperature-controlled oven while low-end FDM machine uses the heated bed to reduce the warping, but not completely eliminating it [13]. Choi et al. discussed the ABS shrinkage based on the printer bed temperature. The results showed the higher bed temperature, the lower the warping effect on the test specimens. However, the printer bed temperature cannot exceed 120 $^{o}$C or poor printer bed adhesion will occur. Even at 110 $^{o}$C, the test specimen will still shrink and warp from 0.24 % to 3.44 % [14]. Ferro et al. studied about the characterization of ABS material specimen produced using FDM printer machine for drone structural component. The author mentioned ABS material has the tendency to warp and deform if it was cooled down too quickly. The suggested solution was to use printer bed to be heated to 90 $^{o}$C [15]. In the study of mechanical and thermal properties of ABS/montmorillonitenano composites for FDM printer machine, Weng et al. also mentioned that ABS material tends to shrink during cooling processes, causing warping deformation on the test specimens [16]. Sood et al. discussed the quality of FDM parts especially in dimensional accuracy could affect in sliding wear where sliding contact of mating surfaces such as gear, bearings, seals and cams. In order to improve the sliding wear, warping deformation that occurs more in bottom layers than upper layers must be resolved [17]. Warping deformation not only occurs in FDM only but to other AM technologies as well. Wang et al. studied warping issue in selective laser sintering (SLS) and proposed several effective measures to reduce the warping [18]. Jayanthi et al. explained how the scanning in stereolithography (SLA) affects part deflection and identified several parameter selections that were causing the magnitude of curl distortion [19].

Acetone is a colourless liquid and used as a solvent for plastic industries and other products. A lower concentration of acetone is also used in the household such as cosmetics and care products. It has been used extensively in laboratories as a solvent for plastics [20-21]. Issues regarding obtaining high part quality are important in FDM [22]. Thus, it is necessary to create a viable solution [23] to solve warping deformation issues.



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## 3. METHODOLOGY

Experiments were required in this study where several test specimens were printed on an open source FDM printer with different concentration of ABS glue. The experiment was conducted in an open air environment inside a laboratory with an average temperature of 22.5 $^{o}$C. One litre of acetone with 99% concentration, six empty HDPE bottles of 100 ml, syringe, and new 1 kg of 1.75 mm diameter ABS filament was used for the experiment. The acetone was handled with care since it was highly flammable. Each bottle was filled up with 50 ml of acetone and labelled. 100 mm, 200 mm, 300 mm, 400 mm, 500 mm, and 600 mm length of snipped ABS filament chips will be put into the acetone and mixed as shown in Figure 1a.

Figure 1a: ABS glue preparation


Figure 1b: Different ABS filament dissolved

The solutions were left for 12 hours until the entire ABS fully dissolves. The lids were loose occasionally when the ABS filament began to slowly dissolve in order to release the fumes. In the end, ABS glue solutions were turned milky depending on the amount of ABS inserted as shown in Figure 1b. As observed, the solutions were more concentrated and viscous as the more ABS filament chips were used. Six different concentration of ABS glue was applied on a kapton tape with an open source FDM bed as shown in Figure 2. Kapton tape can withstand temperature up to 400 $^{o}$C and can prevent residues from ABS glue stuck on the bed. A rectangular test specimen with dimensions of 150 mm (L) x 15 mm (W) x 5 mm (H) was drawn from CAD software, saved into STL format and was produced to demonstrate the effect of warping. The rectangular test specimens were printed by 0.4 mm nozzle with 0.2 mm layer thickness, 25 % infill, 40 mm/s print speed, 220 $^{o}$C nozzle temperature and 90 $^{o}$C bed temperature. Each experiment run was conducted 3 times to ensure consistency of the data obtained. The level of warping, the quality of the plate and appearance of the plate were observed and documented.

Figure 2: ABS glue applied on a kapton tape

## 4. RESULTS AND DISCUSSION

All the specimen plates were printed to determine the level of warping deformation. The results were tabulated as follow in Table 1.

Table 1: Results on test specimens warping

| Exp run no | ABS length (mm) | Specimen warping | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | | 2 | | 3 | |
| | | L | R | L | R | L | R |
| 1 | None | Yes | Yes | Yes | Yes | Yes | Yes |
| 2 | 100 | No | No | No | No | No | No |
| 3 | 200 | No | No | No | No | No | No |
| 4 | 300 | No | No | No | No | No | No |
| 5 | 400 | No | No | No | No | No | No |
| 6 | 500 | No | No | No | No | No | No |
| 7 | 600 | No | No | No | No | No | No |

Experiment run no.1 was conducted without the use of ABS glue and after printing few layers, warping began to occur and at another 3 layer thickness, the whole test specimen was ripped off, resulting in failure as shown in Figure 3. The rectangular part warped approximately 3 mm from the printer bed [24]. For the second run till the seventh run, surprisingly all kapton-taped printer bed brushed with ABS glue does



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not warp at all. Both sides at the end of rectangular plate stuck properly [25]. Hence, the objective of this study was achieved to improve adhesion between the bed and the ABS filament.


Figure 3: Adhesion between 3D printed rectangular plate with bed

However, there were two noticeable differences between the different concentrations of ABS glue. First, the higher concentration of ABS (thick glue) such as 400 mm, 500 mm, and 600 mm was difficult to apply on the bed. The thicker glue dried quickly without covering the whole area while 100 mm, 200 mmm 300 mm (thinner glue) were able to cover all the area before the glue dried. The thicker glue left a thick and rough dried ABS on the surface while thinner glue left a thin and flat dried ABS. The reason was the amount of acetone present in each application. The thinner glue although contain lower ABS amount and with more acetone, it can apply evenly on the surface without the acetone dried too fast. On the other hand, the thicker ABS will dry quickly with higher ABS amount and less acetone. On the bright side, printed plate with thicker ABS was harder to be removed, thus suggesting at even bigger sized prints, thicker ABS will be preferable to be used to prevent warp deformation.

A second noticeable difference between different concentrations of ABS glue was the need for post-processing at the bottom of the plate's outline s shown in Figure 4. At 100 mm to 300 mm, the printed plate was easy to be removed and no post-processing required. Starting from 400 to 600 mm, the plate was harder to be removed and brims from the ABS glue were found at the outline of printed plate. The brims were removed using fingers and scrapper.

Figure 4: Thin brims at the outline of the printed plates

## 5. CONCLUSION

The use of ABS glue has remarkably improved the bed adhesion and prevented any warp deformations. The rectangular test specimen without the use of ABS glue was warped 3 mm from the printer bed and ripped off easily. The ABS glue that was made from ABS chips and acetone allowed the melted ABS to be applied on the kapton-taped printer bed leaving thin ABS layers behind to act as a bond between them. From the experiments conducted, the concentration of ABS glue played an important role. The thinner concentration of the ABS glue can be applied quickly and produced thin fine layers onto the kapton-taped bed while the thicker concentration ABS glue was harder to be applied on since it dried too fast and produced brims at the bottom outline of printed part. However, thicker glue provides more bed adhesion which makes it suitable to be used for larger print sizes. In this study, the use of ABS glue had prevented any prints from experiencing warp deformations and failed products. This will help FDM process to minimise time and material cost. For the future study, other safer chemical can be used other than acetone to dissolve the ABS material.

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