SDGs 8, 9, and 12

Influence of printing parameters on mechanical properties of recycled PET and PETG using fused granular fabrication technique

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Introduction

Additive manufacturing, also known as 3D printing, represents a revolutionary approach to production, enabling complex designs and reducing material waste, which positions it as a key player in sustainable manufacturing for the future. Among its various technologies, Fused Granular Fabrication (FGF) emerges as particularly promising for environmental sustainability, as it facilitates the reuse of plastic waste, converting it into new products and thus promoting a circular economy. This process not only diverts plastic waste from landfills but also reduces the need for virgin materials, making it a crucial tool in combating plastic pollution. However, current literature reveals a significant gap in research on the use of recycled plastics specifically in FGF, highlighting an area ripe for exploration.

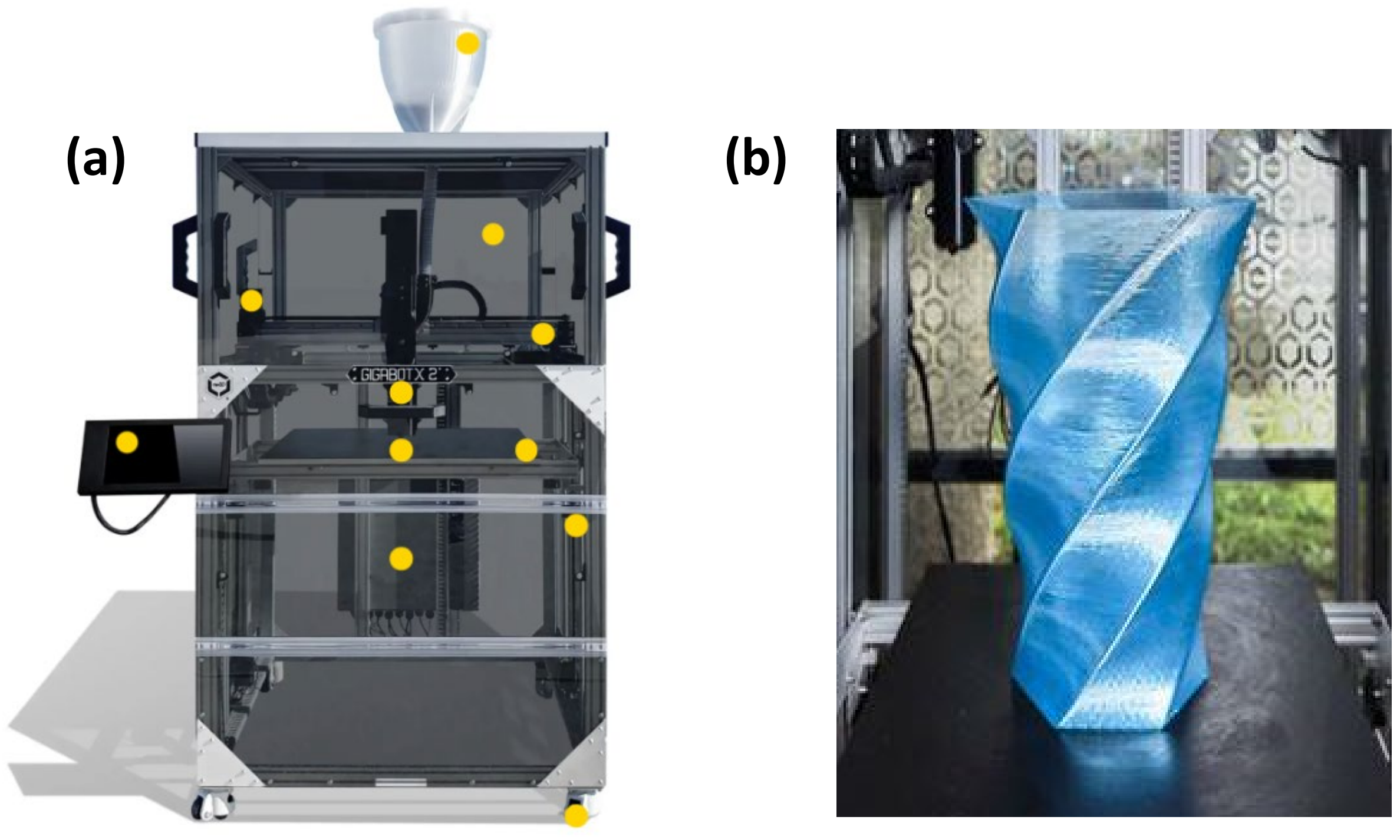
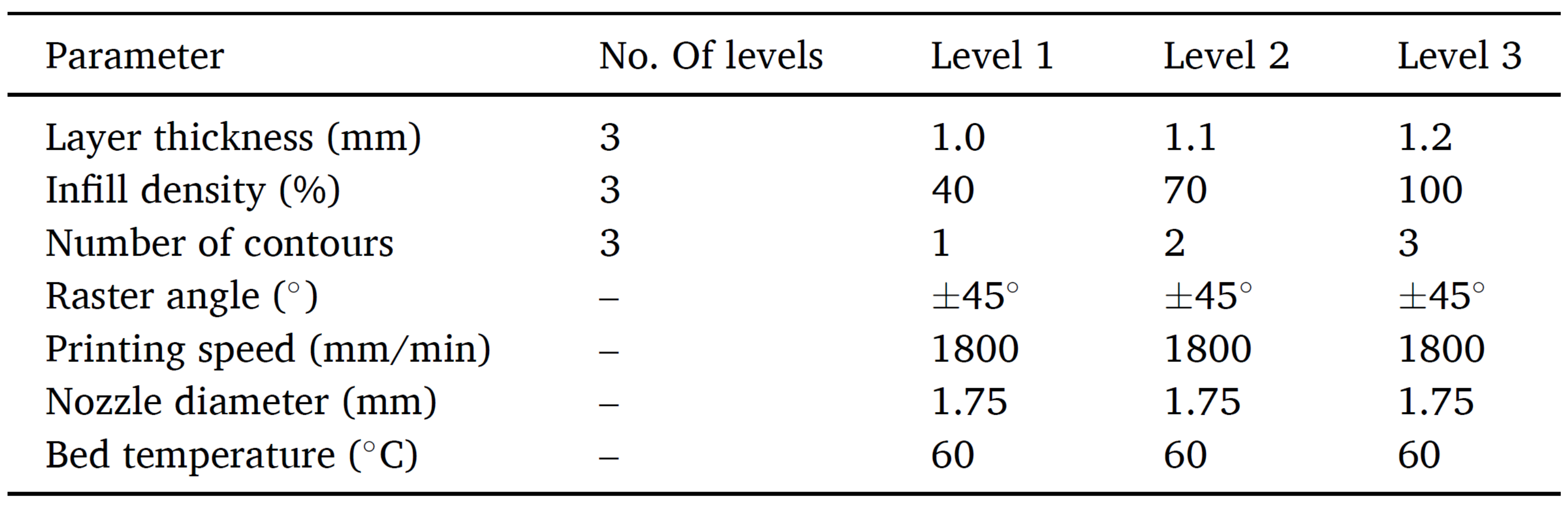


Fig. 1 (a) Gigabot X2 - FGF printer (b) FGF printed spiral vase

Aim and Objectives

The aim of this study is to analyse the influences of FGF printing parameters on mechanical properties of FGF printed rPET and rPETG materials. The design of experiments (DOE) was performed considering the key FGF printing parameters such as layer thickness, infill density and number of contours. Subsequent experimental studies delve into the effects of these printing parameters on tensile properties, guided by the outcomes of the DOE. To further assess the tensile properties, the study evaluates the influence of interlayer bonding on the printed parts through finite element-based multiscale modelling. The fracture morphology and alterations in the chemical structure of post-3D printed products are observed using Scanning Electron Microscopy (SEM). This research provides valuable insights into the optimal processing conditions necessary for achieving high-quality 3D-printed parts using the FGF technique.

Methodology



Parameter	No. Of levels	Level 1	Level 2	Level 3
Layer thickness (mm)	3	1.0	1.1	1.2
Infill density (%)	3	40	70	100
Number of contours	3	1	2	3
Raster angle (°)	–	±45°	±45°	±45°
Printing speed (mm/min)	–	1800	1800	1800
Nozzle diameter (mm)	–	1.75	1.75	1.75
Bed temperature (°C)	–	60	60	60

Fig. 2 FGF process parameters and corresponding levels used in DOE for rPET and rPETG

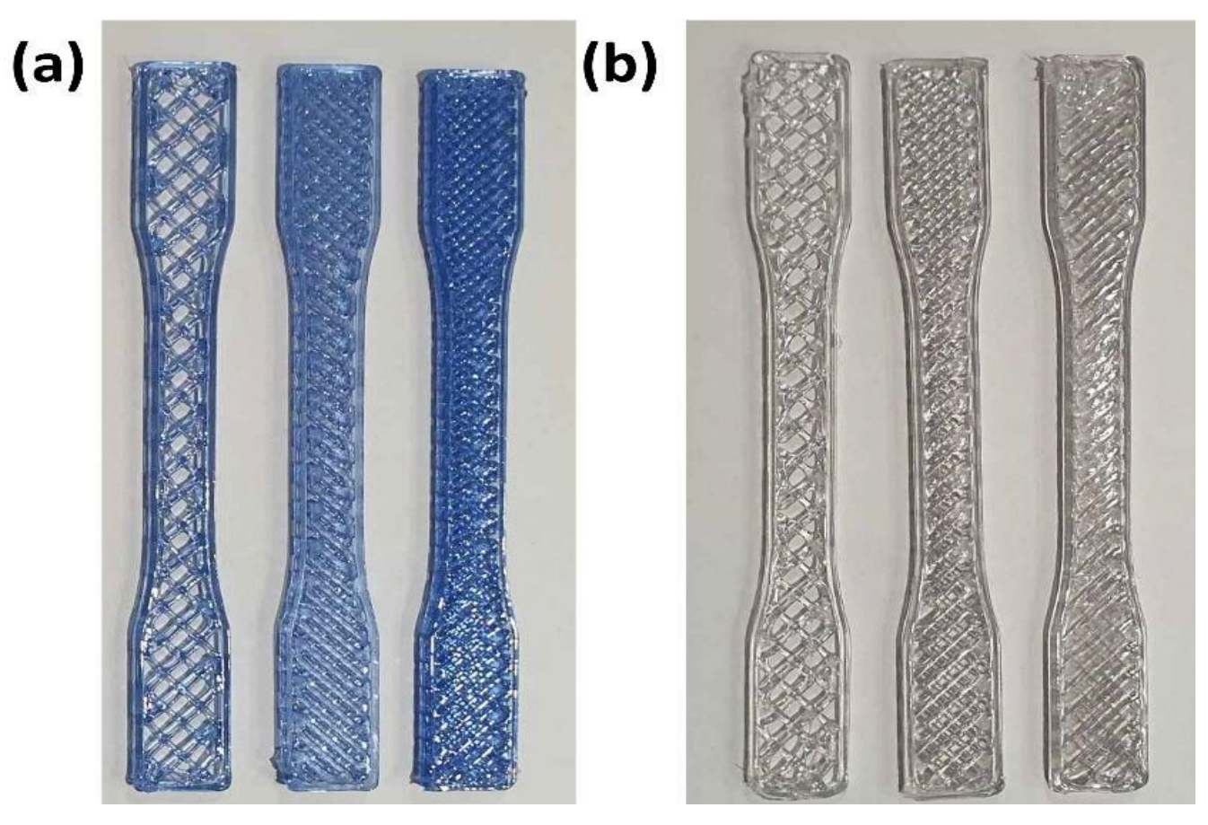


Fig. 3 FGF printed samples (a) rPET and (b) rPETG with 40% (left), 70% (middle) and 100% (right) infill percentages

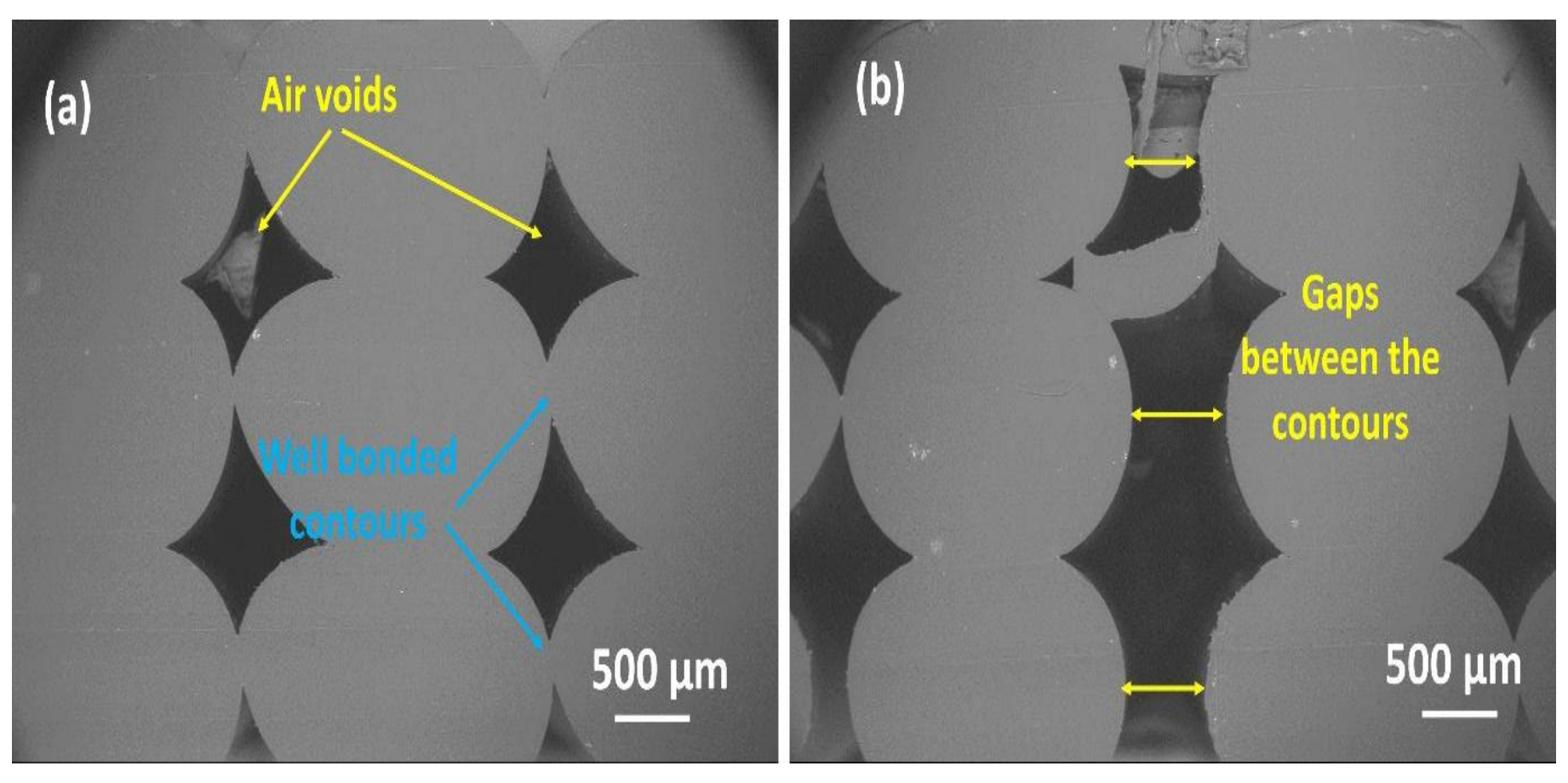


Fig. 4 SEM image of the 3D-printed rPETG specimen with 1.2 mm layer thickness, 100% infill and 3 contours

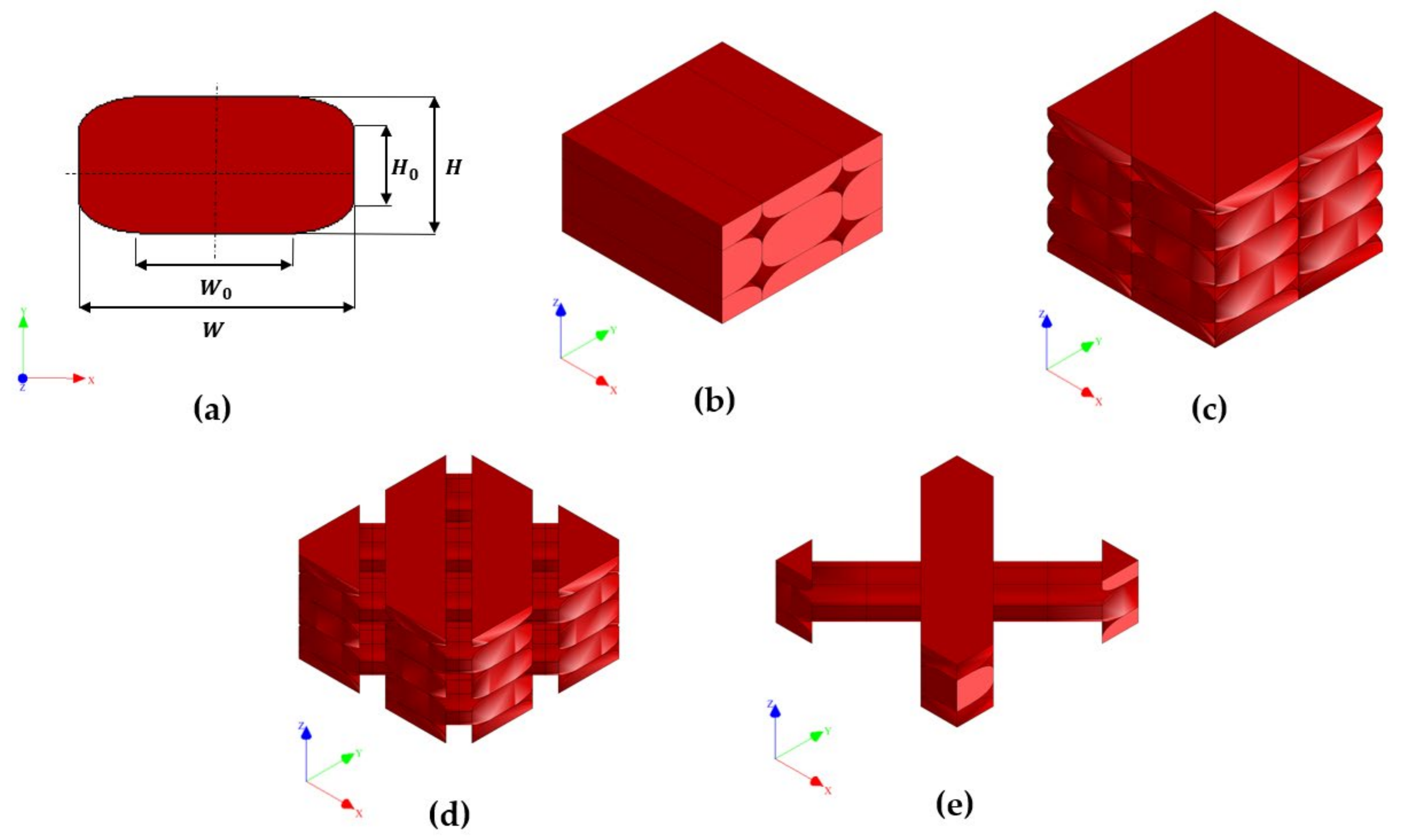


Fig. 5 a) Intrinsic element, b) Aligned model, c) Sparse model at 100% infill, d) Sparse model at 70% infill, and e) Sparse model at 40% infill.

Results and Discussion

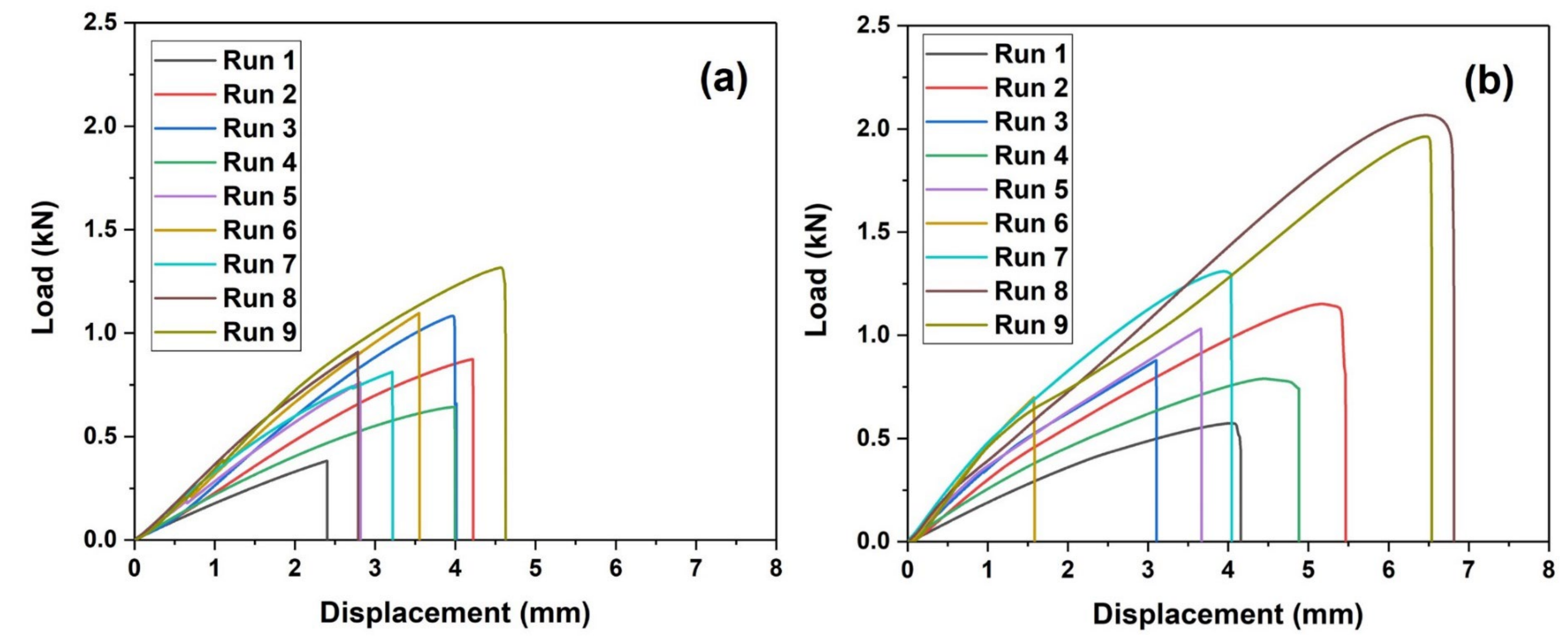


Fig. 6 Load vs displacement of 3D-printed (a) rPET and (b) rPETG at different printing parameters

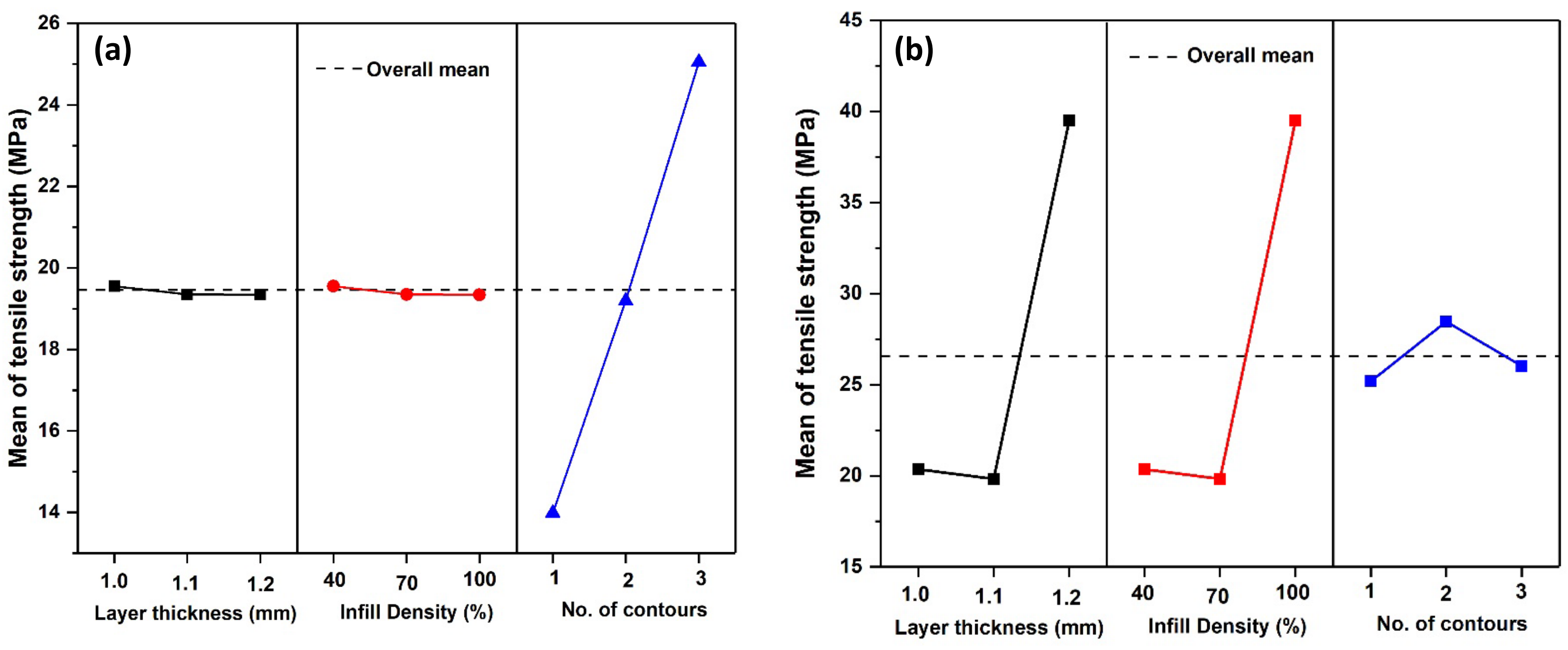


Fig. 7 Main effect plots for the tensile strength of (a) rPET and (b) rPETG

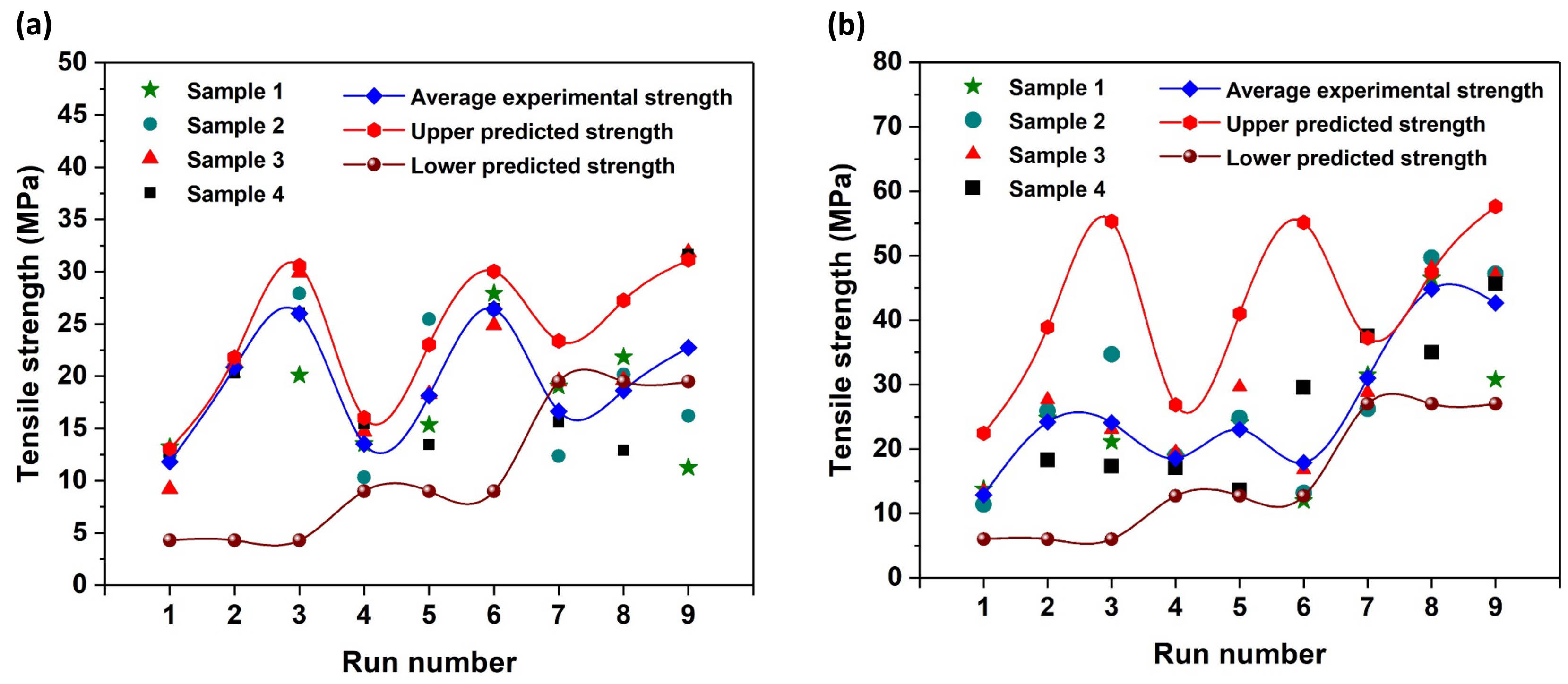


Fig. 8 Experimental and predicted modelling results for 3D printed (a) rPET and (b) rPETG

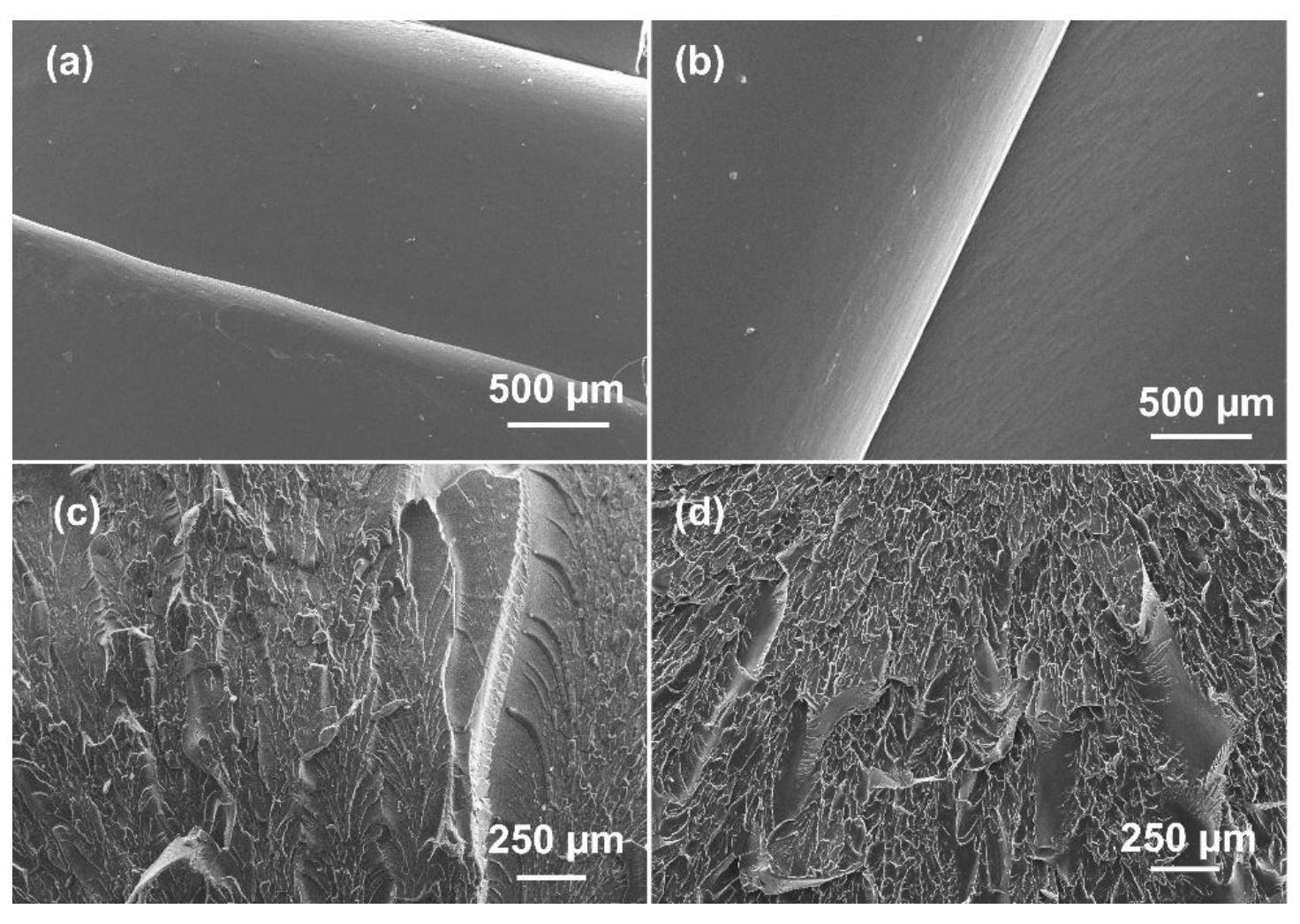


Fig. 9 SEM images of the side (a and b) and fracture surfaces at intersections of multiple layers (c and) of rPET and rPETG, respectively

Conclusions

In this study, the effects of FGF printing parameters on the tensile strength of the FGF-printed rPET and rPETG were studied:

- The maximum tensile strength of 26.4 MPa for rPET was achieved with a layer thickness of 1.1 mm, an infill density of 70%, and 3 contours.
- The maximum tensile strength of 44.8 MPa for rPETG was attained at 1.2 mm layer thickness, a 100% infill density, and 2 contours.
- The mesoscale modelling approach effectively established the upper and lower bounds of tensile strength for both rPETG and rPET.
- The fracture surface characteristics of both rPET and rPETG exhibited typical brittle fracture behaviour.
- No indications of voids are observed on the fracture surfaces of both rPET and rPETG, demonstrating the excellent quality of the 3D-printed specimens produced through the FGF method.

Research Outcomes

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