UNIVERSAL TENSILE GRIP FOR UNI-AXIAL TESTING OF 3D PRINTED SPECIMENS

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Abstract: One of the main research areas in additive manufacturing (AM) no matter of the technology involved *(MEX – Material Extrusion, VPP – Vat Photopolymerization, BJT – Binder Jetting etc.) are the mechanical proprieties of the machined parts, especially the tensile strength. The aim of this paper is to highlight the most frequent problems that may appear during the tensile strength testing of MEX 3D printed parts and also to purpose a new sample clamping device - grip able to overcome some of the possible testing errors. Samples of three different materials (PLA - Polylactic acid, PLA+ - Enhanced Polylactic acid and PETG - Polyethylene terephthalate glycol) dog bone shaped type 1B according to ISO 527 were printed on a Creality CR 6-Se 3D printer. The results highlighted the importance of proper clamping during tensile strength testing of 3D printed parts.*

Keywords: *additive manufacturing, fused filament fabrication, tensile grips, device*

1. Introduction

Additive manufacturing is an emerging research area in the last decades. The main concern of the researchers and manufacturers in the field is related to the mechanical proprieties that additive manufactured parts exhibit and to establish the capability of these techniques to depose long time used cutting manufacturing technologies. Most of the studies carried out in the field addressed the tensile strength of parts generated by MEX / FDM (Fused Deposition Modelling) [1-4] and VPP / SLA (stereolitography) [5,6] technologies but also the specialized literature provides relevant information about metal AM [7], ceramic AM [8] etc.

As regards the tensile strength testing of MEX and VPP parts, the studies were carried out using industrial equipments and laboratory testing devices. An important issue observed in previous researches [9] and frequently overlooked is the clamping techniques of the tested parts. Incorrect clamping leads to potential errors caused mainly by the constructional variant of the grips used in the studies. The main possible problems are: 1. slippage of the piece between the device's grips; incorrect alignment of the specimen and 3. the appearance of plastic deformation of the parts in the clamping area especially in FDM specimens with low infill (Figure 1).

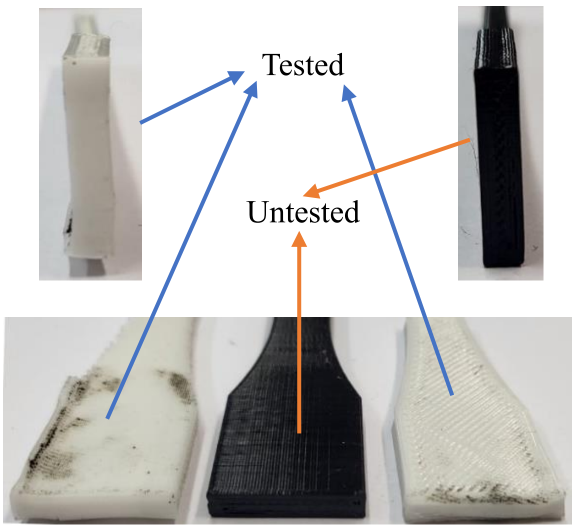


Figure 1: *Tested and untested specimens*

Usually, the slippage of parts between the wedge grip jaw inserts is due to the flat surface of the inserts, also in the case of serrated inserts the slippage of parts between the grips is caused by the plastic depositions (Figure 2).

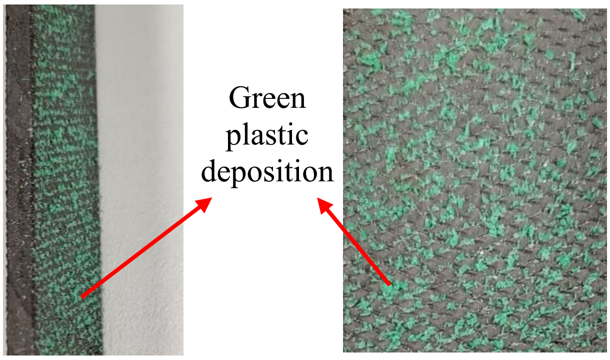


Figure 2: *Material deposition causing slippage*

Therefore, this article proposes the development of a new design for the tensile wedge grips that can eliminate these problems, and that is universal both in terms of the equipment used and the dimensions of the specimens indicated by the ISO 527-2 standard (Plastics — Determination of tensile properties — Part 2: Test conditions for moulding and extrusion plastics).

2. Constructive-functional description

Considering all the problems related to the tensile test presented above, the constructive variant shown in Figure 3 was proposed.

In the body (1) there are 8 M6 tapped holes for fixing the covers (4) and 4 M5 tapped holes for assembling the foot (6) that supports the grippers actuator (5). Also, within the body is a 'swallowtail' groove, which acts as a support and provides the possibility of vertical movement of the grippers (3). The wedge grip inserts of the device are moved by means of a lever (5). The lever is supported by the foot (6) and operated by two tension springs (8). The covers (4) are fixed with 4 screws (7) each, which are used to block the horizontal movement of the wedge grip inserts and to prevent impurities such as dust and oil from entering. The device is fastened to the machine by means of an M16 tapped hole. The design of the wedge grip inserts (3) includes a guide groove (14), which allows guiding of the pin (12) and the compression spring (13). The proposed design also allows positioning of the covers and the lever-foot subassembly on both sides of the body.

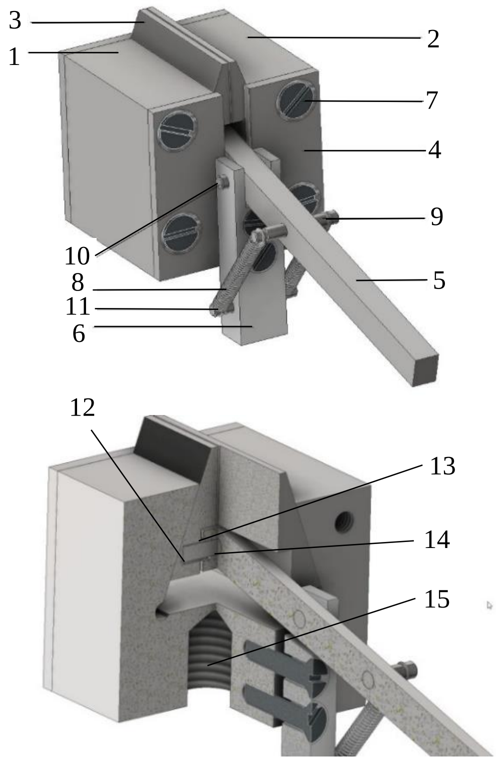
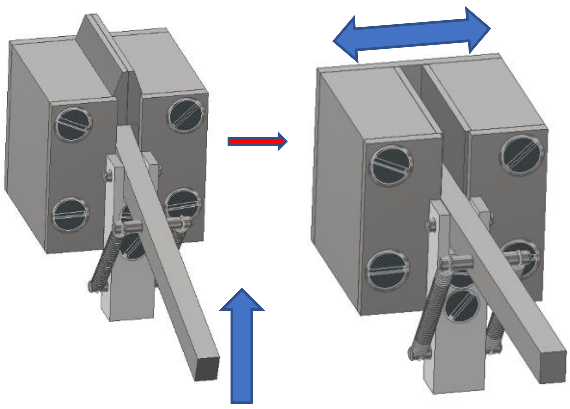


Figure 3: *Wedge grip elements*

By manually operating the handle 5, the device allows the wedge grip inserts to move across the surface of the body to the "open" position (Figure 4.b), and also to position the specimen parallel to the handle, thus making the alignment with the corresponding axis. When the handle is released, the tension springs allow the specimens to be locked for tensile testing.



a. closed b. open

Figure 4: *Gripping device positions*

The devices are designed with two types of springs: tension springs and compression springs. The purpose of the tension springs is to keep the lever always in the 'closed' position and to return it after the introduction of the sample.

The compression spring is fixed between the wedge grip inserts, mounted on the pin (12), in order to keep them apart when the device is in "open" position, eliminating the risk of self-locking and ensuring their spacing when the sample is inserted for testing.

In the composition of the device, there is also a pin guide channel (12) for locking the vertical movement of the inserts, and the locking of the horizontal movement is achieved by mounting the covers (4) on the device. The covers are fixed with standard screws (7). After the device has been mounted on the tensile testing machine, the lever support foot (6) shall be fitted to prevent the unscrewing of the assembly and the positioning of the other components.

To eliminate the possibility of slippage of the specimens, the surfaces of the inserts were serrated to larger sizes (Figure 5). Choosing larger sizes ensures a grip with fewer contact points, reducing the chance of chipping (scraping) of the specimen surface. This eliminates both slippage due to lack of serrations and slippage due to plastic build-up between the teethes.

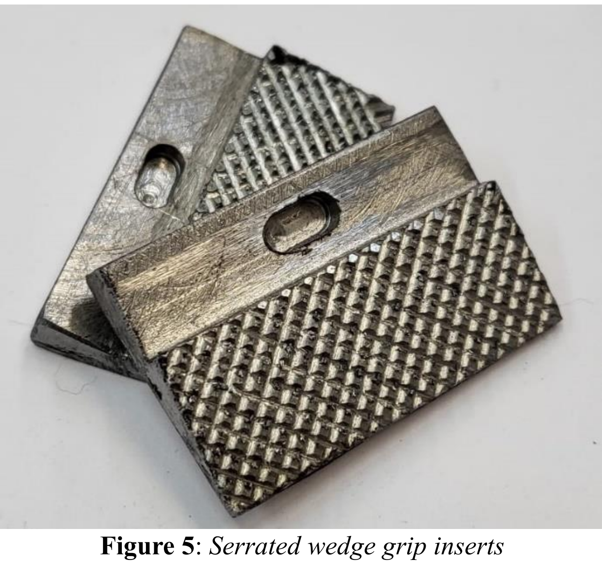


Figure 5: *Serrated wedge grip inserts*

Once the wedge grip is driven by the tensile testing machine, due to the construction of the surfaces, the inserts self-spread and provide a good hold on the specimen while the distribution of forces is ensured over the entire contact surface, preventing slippage.

3. Experimental validation

The above-described wedge grips were used for tensile testing of 3 standard ISO 527 type 1B test specimens made of 3 different materials (PLA - Polylactic acid, PLA+ - Enhanced Polylactic acid and PETG - Polyethylene terephthalate glycol). The tests were performed on the laboratory equipment shown in Figure 6.

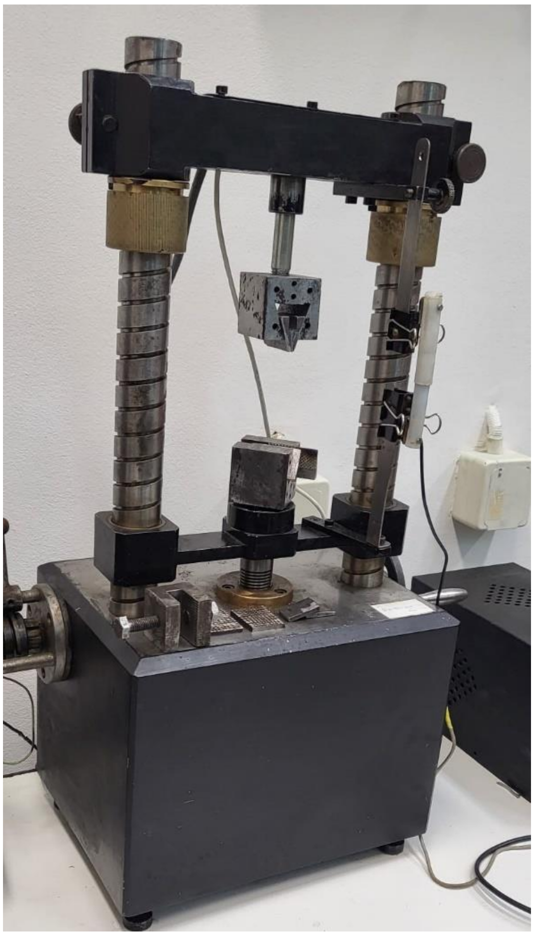


Figure 6: *Tensile testing laboratory stand*

All specimens were printed using a Creality Cr6-Se 3D printer with the machining parameters presented in Table 1. An infill density of 15% was used to visualize plastic deformations for all specimens.

Table 1: Process parameters

Parameter	PLA	PLA+	PETG
Layer height	0.2 [mm]		
Nozzle	0.4 [mm]		
Infill	15%		
Infill type	Cubic		
Printing temperature	210 [°C]	210 [°C]	240 [°C]
Build platform temperature	60 [°C]	60 [°C]	80 [°C]
Retraction distance	6.5 [mm]		
Print speed	50 [mm/s]		

Intentionally, the specimens were fixed at one end with the designed wedge grip and at the other end with a screw wedge grip. Figure 7 represents the tested specimens where the nature of the breaks can also be seen, where PLA and PLA+ had material-specific instantaneous breaks. It can be also seen the elastic nature of the PETG.

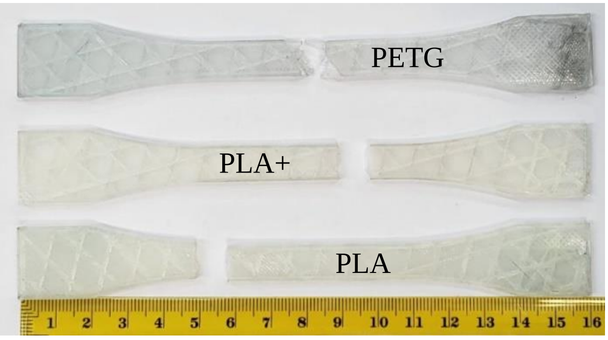


Figure 7: *Tested specimens*

Regarding the plastic deformation in the gripping area, figure 8 shows the ends where the specimens were clamped with the new device and figure 9 shows the ends clamped with another device.

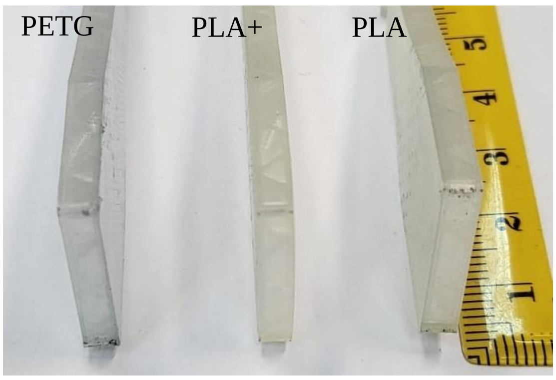


Figure 8: Specimens with no deformation

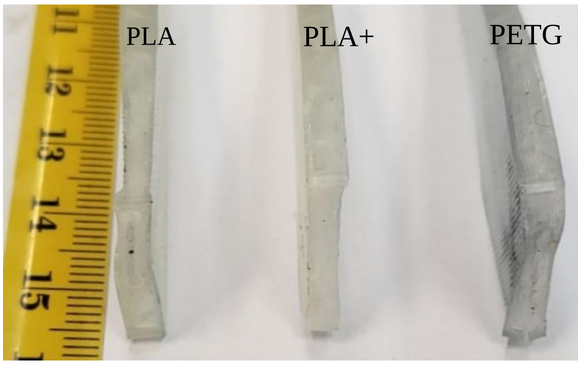


Figure 9: *Specimens with plastic deformations*

Comparing the images, it can be clearly seen that by using the new clamping device the specimens did not undergo plastic deformation, despite the low infill density, while in Figure 9, plastic deformation caused by incorrect clamping of the specimens can be seen. The values recorded for the 3 specimens are shown in Table 2.

Table 2: Tensile strength of the tested specimens

Parameter	PLA	PLA+	PETG
Tensile strength	9.22 MPa	10.00 MPa	9.06 MPa

However, the focus of the article is on the wedge griping device, with tensile force studies being topics for future research.

4. Conclusions

Tensile testing of plastics manufactured by the MEX method, if the test conditions are not appropriate, may lead to erronate values. The aim of this paper was to present a constructive variant for a wedge grip device used mainly for specimens made of plastic materials.

In the designing the device, special consideration was given to the types of problems that can appear during tensile tests. The possibility of specimen embedded area deformation due to uneven force distribution or too big clamping forces, the possibility of slippage of the specimens between grip inserts and the possibility of plastic deformation has been eliminated. Also, the improper alignment of the specimens have been eliminated.

The device was validated through a series of tests on three materials commonly used in the MEX processes, where the results showed the need for specially designed wedge grips for these types of materials. In the future, the devices will be used to properly study the tensile strength of plastics regardless of how they are manufactured.

Acknowledgments

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