October 2021

Reinforced Line Infill Structure

Jiri Konvicny

Title: **Reinforced line infill structure (RELIS)**

Author: Jiri Konvicny, Ultimaker B.V. Utrecht, The Netherlands

Abstract: This publication relates to a new infill structure that works on the principle of interlocked lines infill structure, but adds reinforcements at the line crossings. The reinforcements can be created by changing of the filament flow or keeping the filament flow equal and changing the print speed.

The background

Lines/Grid/Triangular infill patterns are the cornerstones of current FFF print profiles. However all of them have flaws by design and the way they are implemented. This publication describes an infill structure to combat all the downsides and increase the strength of the part by reinforcing the joints (line crossings).

We refer to the following sites to explain the naming of different infill types across commonly used slicers:

Cura - https://support.ultimaker.com/hc/en-us/articles/360012607079-Infill-settings
Slic3r - https://manual.slic3r.org/expert-mode/print-settings

When printing Grid/Triangular type infill a phenomenon occurs when the flow of filament is temporarily stopped when the extruded line crosses previously printed line. After the line crossing, there's a gap where the infill is not printed. This gap is larger when the nozzle diameter goes up as well as printing speed goes up.
These unwanted gaps seriously weaken the structural properties of an object. This phenomenon is widely known and reported (e.g. https://reprap.org/forum/read.php?262,842235).

Our experience printing on an Ultimaker printer can be seen in Fig. 1.

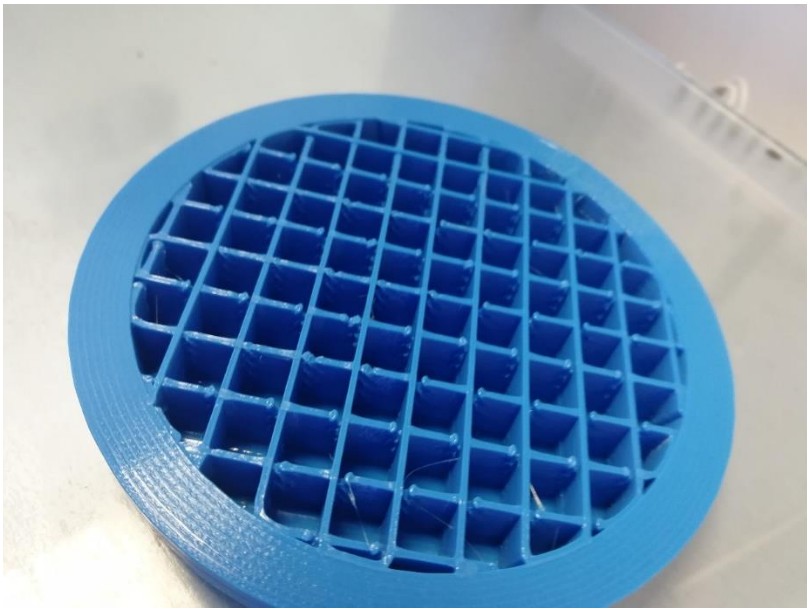

Fig. 1 – Grid infill as printed on Ultimaker printer and AA0.8 nozzle

Line infill is designed to be lightweight and functional as a support for the print's top layers, yet as can be seen in Fig. 2 there's an inherently bad layer bonding between the lines.

Fig. 2 – Lines infill showing circular extrusion lines not connecting with the previous layer (Figure source: https://rigid.ink/pages/ultimate-troubleshooting-guide#issue-deformed-infill-22)

It has been proposed by multiple sources to create line infill structure with different extrusion parameters effectively generating an interlocked lines structure (e.g. https://github.com/slic3r/Slic3r/issues/3032). This is illustrated in Fig. 3.

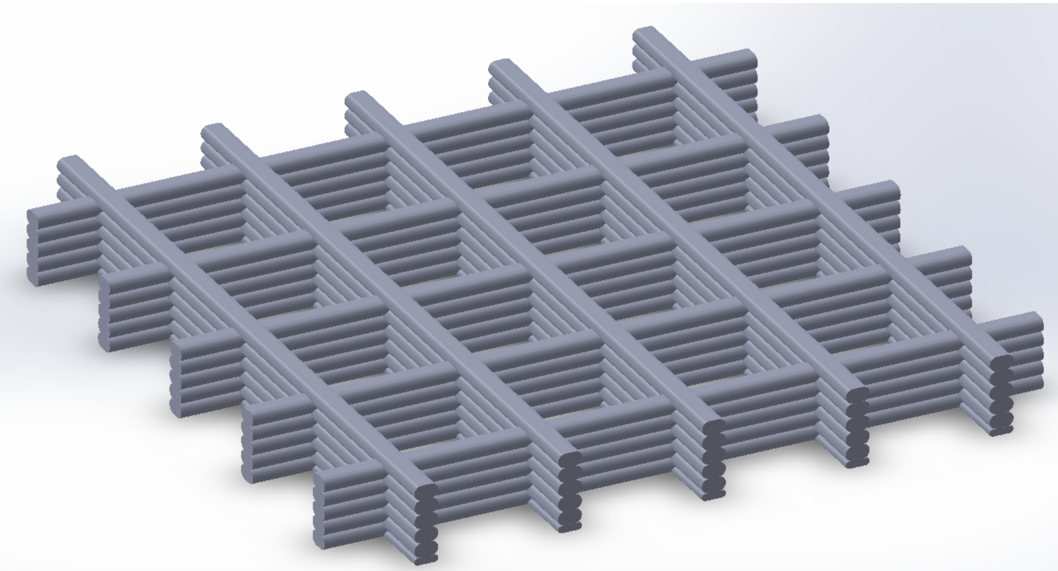

Fig. 3 – Interlocked lines infill structure acc. prior art

The proposed solution

The proposed RELIS infill structure works on a similar principle as infill from Fig. 3 but designs in reinforcements aligned with the lines crossings. These reinforcements can be created by changing of the filament flow or keeping the filament flow equal and changing the print speed.
This forms a series of bulged sections which form a stronger bond by increasing the contact area for layer bonding (Fig.7).

In the following section the principle of working is described with parameters such as line thickness, layer height, line spacing given as an example. These parameters give a frame of reference on the intended use, however are not intended to be seen as an exhaustive list.

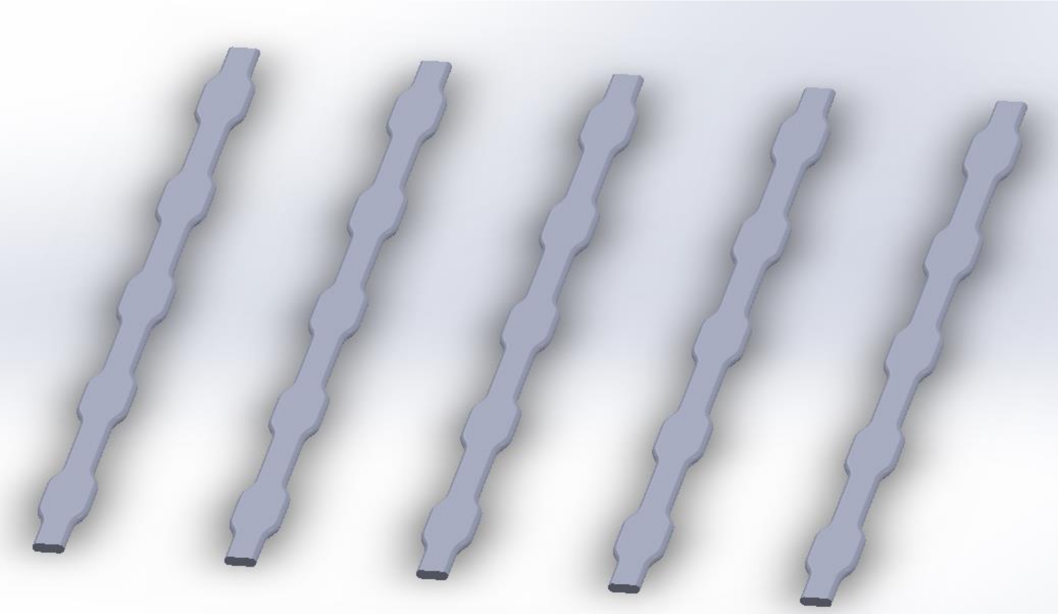

Fig. 4A – First layer of RELIS. Parameters [mm] – Infill line thickness 0.5, Layer Height 0.15, Reinforced parts line thickness 0.8, Line spacing 3

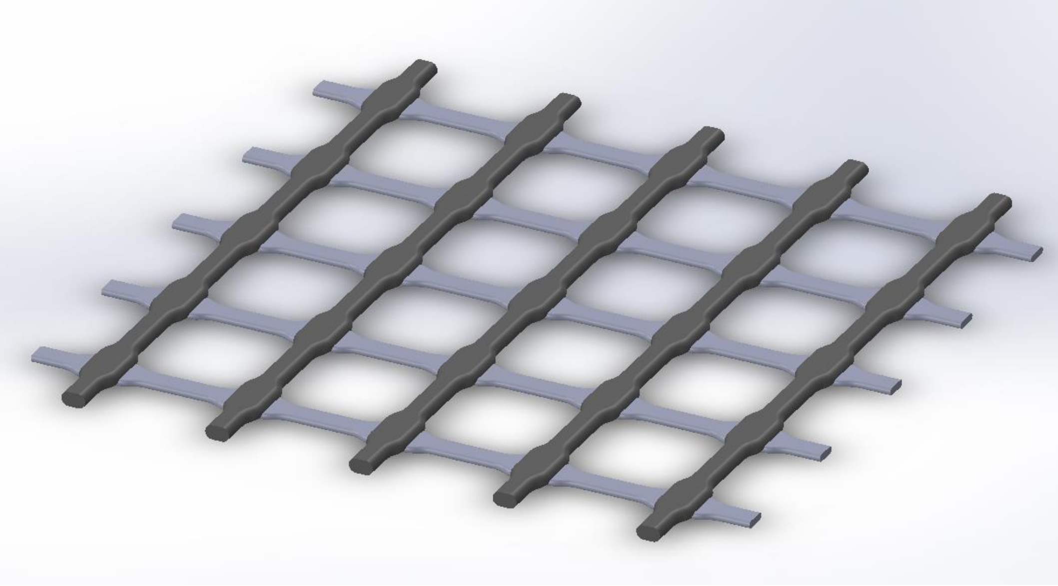

Fig. 4B – Second layer of RELIS. Parameters [mm] – Infill line thickness 0.5*, Layer Height 0.15*, Reinforced parts line thickness 0.8, Line spacing 3

*) The second layer is formed in a similar way how the first layer, except the extrusion needs to be calculated for two separate cases:

- 0.15 Layer height, 0.8 Line thickness (Reinforced part)
- 0.3 Layer height, 0.5 Line thickness (Regular line in between)

Other layers are created in the same way as the second layer always at the set angle offset (e.g. 90°) to the previous layer.

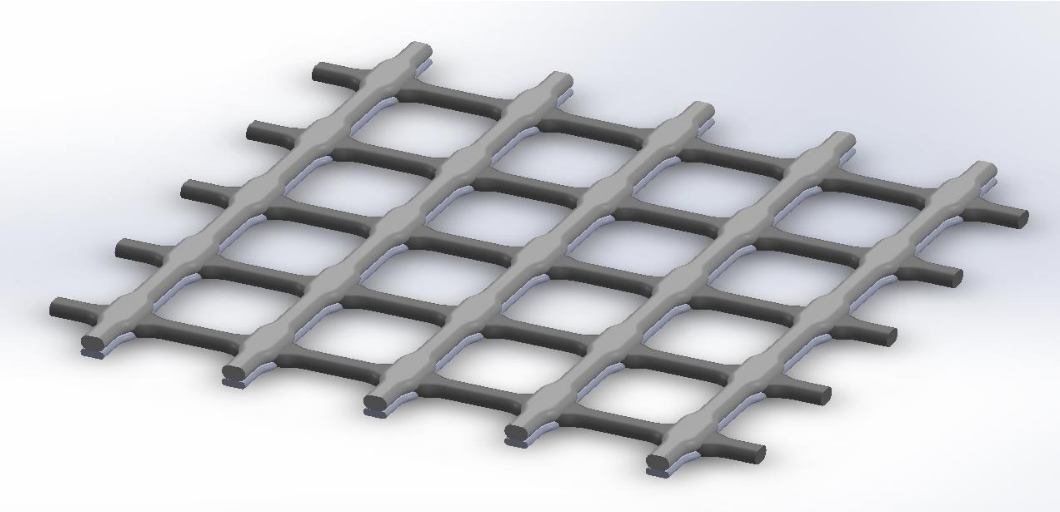

Fig. 5 – Third layer of RELIS. Parameters [mm] – Infill line thickness 0.5*, Layer Height 0.15*, Reinforced parts line thickness 0.8, Line spacing 3

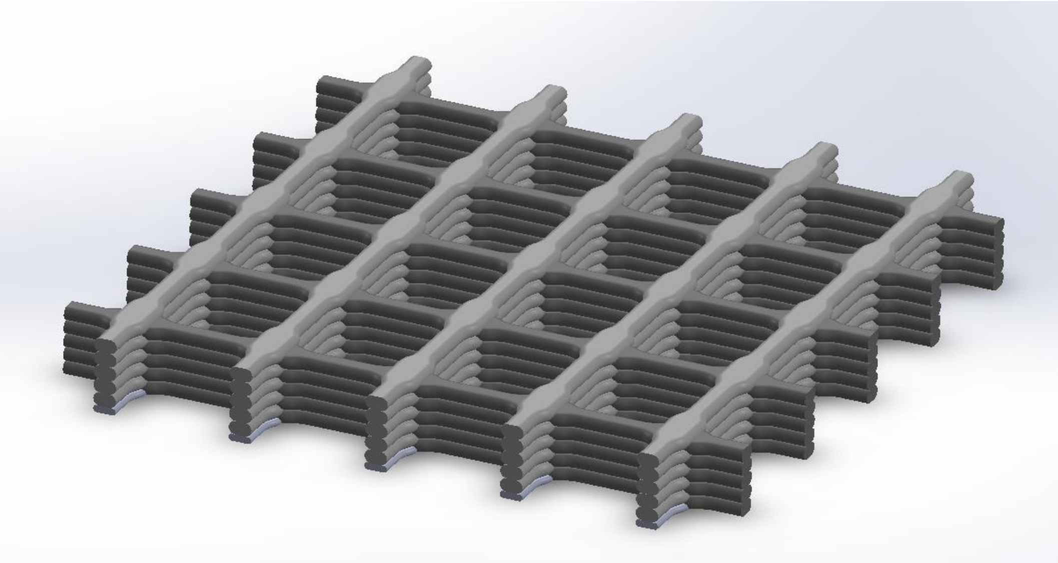

Fig. 6 – Multiple layers of RELIS.

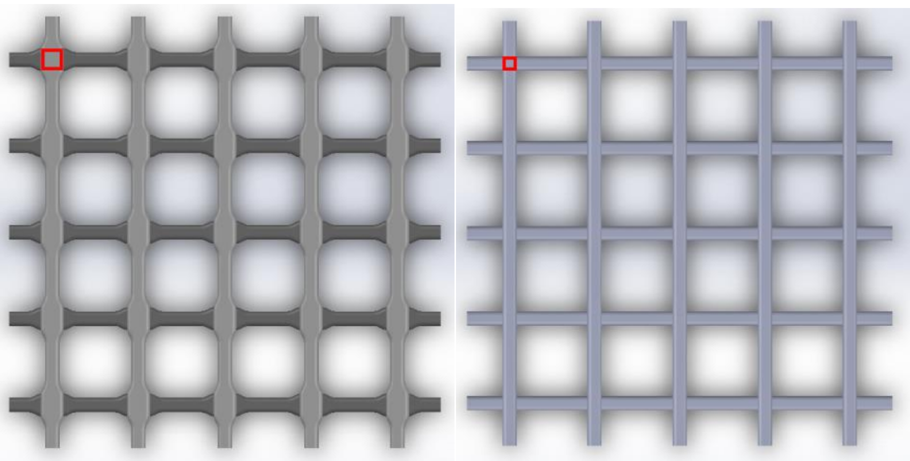

Fig. 7 – Comparison of bonding surfaces in the infill line intersections (RELIS on the left, Line infill on the right)

Application remarks:

1. The lines for this method don’t need to be parallel to each other (e.g. Triangle infill, rhomboid structure)
2. The layer to layer angular offset can be any angle, not necessarily 90°
3. For creating the current layer, an information about the crossing with following layer must be known. This is very easily predictable for repeating patterns (i.e. Non-random)
4. The geometry of the reinforced sections can be optimized w.r.t. designed intent, extrusion and motion system capabilities (dynamic step response etc.)
5. The sections shape does not necessarily need to be symmetrical – Extrusion rate increase/decrease section can be designed to be asymmetrical
6. The sections don’t necessarily need to be aligned to intersect symmetrically w.r.t. each other.