RESCOLL & the 3D printing: summary of the objectives of the SPECTRAL project

SPECTRAL: low-coSt Printing of high-pErformanCe Thermoplastics foR structurAl appLications

The technology known as Fused Filament Fabrication (FFF) is one of the oldest known 3D printing methods. Until recently, FFF was largely limited to polymers with fairly low melting points: less than 280°C. This has limited its success from an industrial standpoint, where high-performance polymers such as ULTEM and PEEK are needed in order to provide thermal and mechanical performance in extremely demanding scenarios.

In the aerospace market, PEEK has become the reference high-performance engineering thermoplastic and is being widely investigated for replacing titanium and other metals in order to reduce the overall weight of aircrafts and bring their overall carbon cost down.
As a result, FFF has not seen a great deal of success in aerospace applications. Electron beam melting remains the one method currently available on the market for the production of PEEK 3D printed parts.
In this context, the Clean sky project named SPECTRAL (low-coSt Printing of high-pErformanCe Thermoplastics foR structurAl appLications) aimed at providing new affordable and reliable technologies and materials for the additive manufacturing of high added value polymers.
The key objectives of the project were:
- To develop a low-cost industrial grade FFF 3D printer
- To develop, manufacture, validate spools of high quality filaments
- To develop, manufacture, and validate a bespoke breakaway support matrix
- To develop a database for automatically importing print job processing parameters and correlating with post print data
- To perform prototype testing and validation of printers using both sample coupons and pulsed jet actuator models
- To define a model for the exploitation of the project results.

Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far

1. Development of 3D printers
In total, three generations of printers were issued during the SPECTRAL project.
The first generation (G1) enabled the consortium to demonstrate the feasibility of printing high temperature polymers such as PEEK, PEKK, Ultem. The G1 printer was delivered to RESCOLL for material validation. Mechanical coupons and calibration cubes were produced to validate the quality of the process and the robustness of the printer.
Some technological limitations were identified. 3NTR then developed a second printer

generation (G2) with more powerful and more precise mechanical features, more reliability in terms of thermal control
The G3 printer is currently being produced for commercialization in the near future.

2. Development of high quality materials
In order to evaluate the feasibility of printing PEEK polymers, first tests were done with a special grade of PEEK and a 'low temperature' printer. Rapidly, issues with the crystallization of PEEK and interlaminar adhesion were observed.
Several grades of PEEK and fillers were selected. Formulations of PEEK and PEKK filaments filled with carbon fibres and glass fibres were developed and characterized. Among these formulations, four formulations based on CF PEEK and PEKK show good promise for further development.
Special attention was paid at producing high quality filament spools (i.e. non porous, constant diameter) with:
- the set-up of an on-line monitoring device to control filaments diameter and ovality
- their packaging to avoid moisture absorption.

A comparative study of injected polymers vs. printed polymers was performed to obtain their intrinsic thermal and mechanical properties.
The impact of the print path and directions was evaluated to better understand the relation between process and properties. Overall a 20% decrease of mechanical properties was observed, attributed to the influence of interlaminar adhesion and the presence of porosity.

3. One of the objectives of the project was to develop breakaway support materials compatible with high-temperature printing conditions and PAEK polymers. Adhesion tests were carried out to evaluate the affinity of support materials with the print polymer. Preliminary formulations of support materials were obtained and show a good thermal behaviour.

4. RESCOLL developed a database interface architecture capable to create 3D print data sheets, store materials testing data, correlate print parameters to results and allow materials usage tracking.

5. The main stakeholders, competitors and applications were identified by means of a market study. 3NTR and RESCOLL identified their commercial strategy based on key exploitable results. Their offers were positioned on the market to insure a potential market penetration. FFF Spectral printer and PEEK filaments from RESCOLL are well positioned on the market in terms of performances and price.

During the project, partners attended 17 fairs and conferences to disseminate the results of the project and presented one webinar. The G3 printer was unveiled at the Formnext show held in November 2019. Several articles were issued in specialized websites, magazine as well

as on partner social media

The main key exploitable results are:
- a FFF printer and replacement parts capable of standing 250°C in the chamber and 500°C at the extrusion head.
- PEEK and PEKK filaments, not reinforced, and reinforced with glass fibers and carbon fibers. These have been fully characterized and can be produced on demand.
- Preliminary formulations of support materials
- A database allowing the storage of original models, the storage of data related to print quality and materials, and the storage of post-print analyses
- A service offer dedicated to FFF additive manufacturing by RESCOLL : filaments custom development, materials characterization and validation, printability/prototyping, and pre-series manufacturing.

Progress beyond the state of the art and expected potential impact (including the socio-economic impact and the wider societal implications of the project so far)

The SPECTRAL project ensured the development of a printer with beyond the art performances. The printer was developed to answer the limitations of high temperature printers currently on the market: lack of reliability, cost…
The unique characteristics of the high-temperature FFF printer developed in the project are:
• a print volume with excellent thermal capabilities
• 4 nozzles that can reach up to 500°C
• the possibility to print small and large parts
• a high temperature printing chamber in order to minimize warping and ensure interlaminar fusion
• self-calibrating system
• an excellent price-print volume ratio
• quick to operate system.

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Most of all, the printer has an open materials system.

Although there now seems to be a wide offer of printers which claim PEEK capacity, there are only very few capable to print with an industrial quality level.
Last but not least, on-demand PEEK and PEKK filaments, unfilled or filled, are also now available for high-performance applications with a controlled production process.

Potential impact
The technology developed in the frame of SPECTRAL was targeting high added value applications such as non-structural parts or aeronautic. The outcomes of the project will provide manufacturers with the tools needed to efficiently produce low-weight parts reducing the overall CO2 equivalent footprint.
The SPECTRAL developments could benefit several applications in a wide range of sectors apart from aerospace notably:
• Metal replacement for light weighting, coupled with excellent fatigue, chemical resistance, thermal and mechanical performances
• Retrofitting or replacing legacy parts
• Functional prototyping