Case study

Additive manufacturing for spare parts in the rail industry

Structural performance validation & cost optimization of FDM printed replacement parts

Digimat for structural FDM validation

One of the crucial topics for rail operators is maintenance and obsolescence management as rail vehicles can stay in service for over 30 years.

Angel Trains identified additive manufacturing (AM), especially Stratasys' FDM technology with the rail compliant Ultem™ 9085 resin filament, to be potentially beneficial on lead times as well as cost reduction for many spare part applications. Engineering & Consulting companies like DB ESG face new challenges coming along with the validation of these additively manufactured parts. Anisotropy in stiffness & failure due to the slicing strategy require new solutions as finite element simulations with traditional approaches lead to overly conservative designs. A combined effort of Stratasys, DB ESG, Angel Trains and Hexagon showed that Integrated Computational Materials Engineering (ICME) helps to tackle these issues on the application case of an armrest that was redesigned to be lighter and more cost efficient while still fulfilling structural requirements.

Challenge

The printing strategy in FDM offers flexibility and a broad range of approaches. However, it is difficult to determine the exact impacts of infill, contours, shell thicknesses and printing direction. A good example is shown in Figure 1 where the tensile test data significantly differ in stiffness but also in failure depending on the printing and testing directions. Whereas in traditional simulation approaches the weakest material properties had to be considered for validation, it has become apparent that this conservative approach is leading to excessive material use. With the ICME approach, it is possible to evaluate the influence of the infill and printing direction in a quick and easy way, leading to a faster adaptation of AM parts in commercial environments.

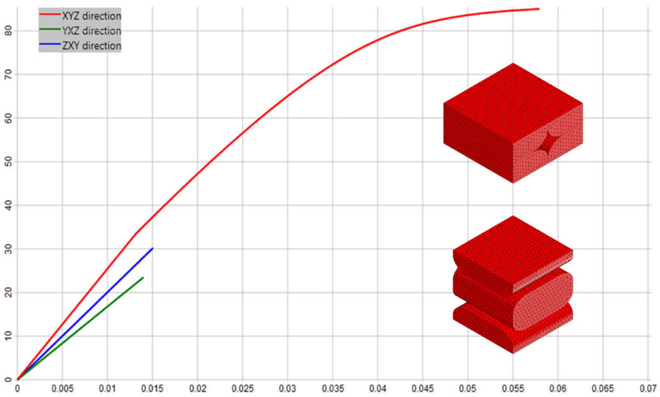

Figure 1: Tensile test data depending on the printing direction XYZ (red), YXZ (green), ZXY (blue)

Solution

Stratasys performed tests in the respective different directions in order to reverse engineer material cards based on tensile test data, microstructure and micro-mechanical modelling. Using Stratasys' Insight software, it is possible to export the toolpath data that is needed for the simulation. The toolpath data is automatically mapped onto the finite element mesh as is shown in Figure 2. This enables to consider the local FDM microstructure and printing directions for each load case. In addition, the calibrated material card allows to easily evaluate different printing strategies with only a few clicks.

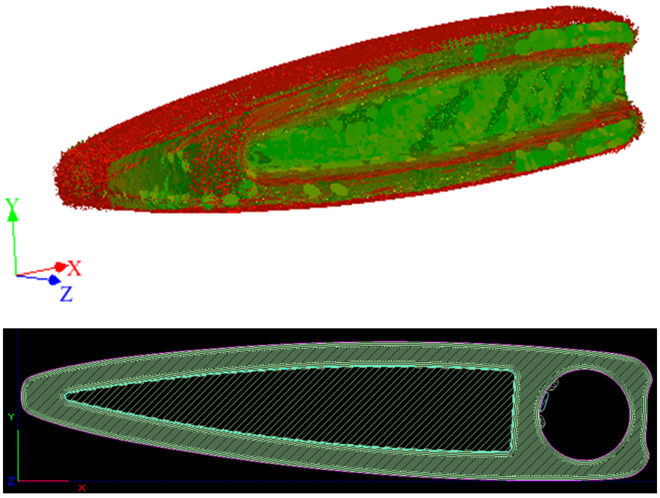

Figure 2: Local orientations of the mapped toolpath

Hexagon's Digimat has validated the optimized design of the armrest, which consists of an outer shell and a hollow inside. The two validated load cases are bending tests with 1 kN and 0.75 kN respectively in the two different directions. Destructive physical testing was used to verify the results. As infill, default sparse and sparse double-dense were evaluated.

Hexagon's Digimat has validated the optimized design of the printed armrest.

Figure 3 shows one of the RVE studies that were performed for the different infills. The resulting material properties were considered as an element set in the finite element analysis. By means of more recent developments however, it is also possible to draw this information right out of the toolpath.

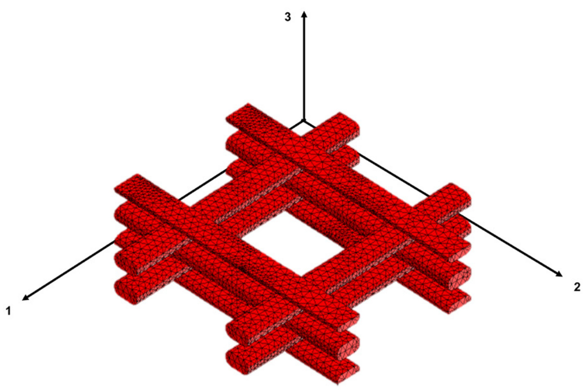

Figure 3: In-depth studies at RVE level

Results & Benefits

With a convincing experimental comparison in Figure 4, the consortium was able to validate the simulation workflow with physical results. The average experimental failure load identified was 3400 N while the simulations expected a failure between 2800 N and 3800 N depending on the load case, indicating a perfect failure prediction. The estimated strength is therefore much more accurate than the original conservative approach that indicated failure already between 750 N to 2300 N, which largely underestimates the reality and cannot validate the necessary strength.

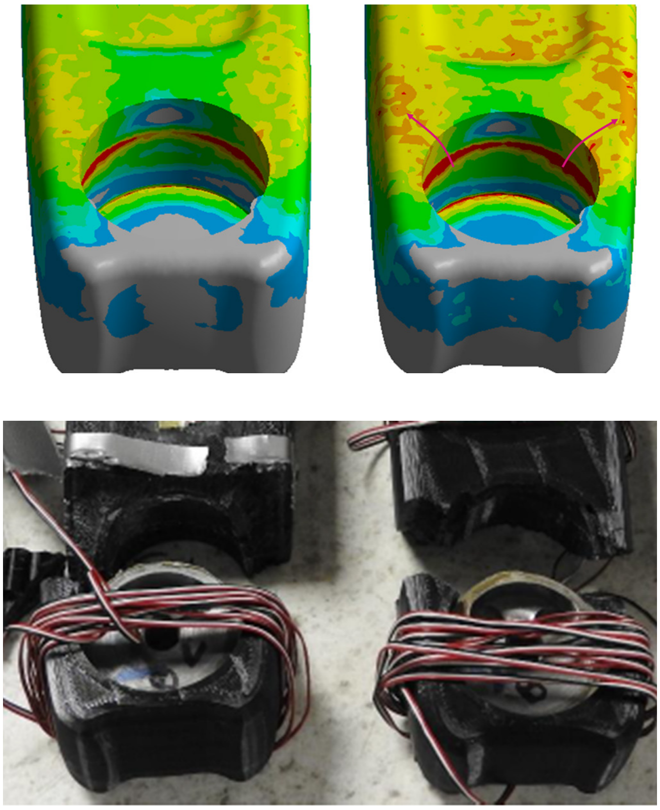

Figure 4: Comparison of the simulation and physical results

Moreover, the workflow shows how significantly the material usage and therefore the costs can be decreased to establish FDM printed parts as standard replacement parts for the rail industry.

Within Angel Trains, additive manufacturing has already significant lead time benefits for many of our spare parts, however the difficulty in validating 3D printed, structurally loaded parts using traditional FEA has led to overly conservative designs that are heavier and more expensive to produce, which has limited the savings we can achieve. This project has shown how with Hexagon's Digimat software we can more accurately model the behaviour of 3D printed parts allowing us to significantly reduce design margins. For our sample armrest part we were able to achieve 50 % weight and cost savings and we are now looking at further parts to roll this approach out to."

James Brown,
Data and Performance Engineer,
Angel Trains

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