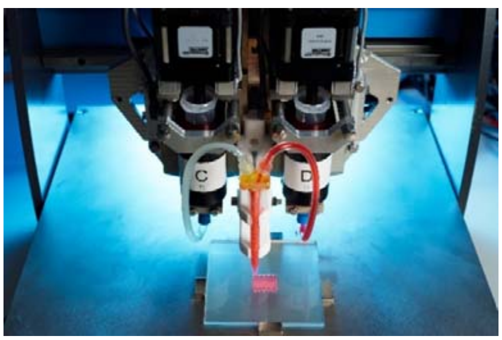
M.Sc. graduation assignment

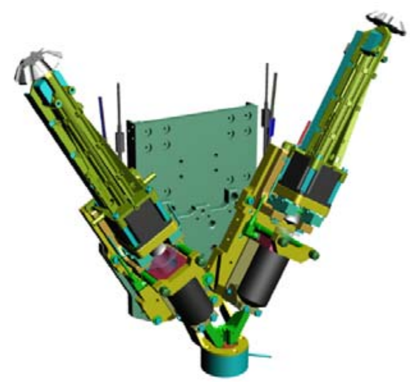
Software development for 3D-printing of energetic materials

Background

The performance of gun and rocket propellants is determined largely by their geometry and composition. Conventional production methods put constraints on both, thereby also limiting the maximum performance that can be achieved. For example, the production method of extrusion allows you to create features only in the direction of extrusion. With additive manufacturing (AM) or 3D-printing there are less geometry constraints because you can build in three dimensions. This creates new opportunities for optimizing performance when producing gun and rocket propellants.

AM provides a higher degree of geometric freedom and enables the use of new materials, when compared to conventional production techniques. However, the big game changer is the ability to combine multiple materials (or variants of a composition) in a single product, creating a (functional) gradient. This allows optimization of performance far beyond what is possible now. Over the past few years, TNO has become one of the world leaders in the field of additive manufacturing of energetic materials.





For more information on TNO's work on 3D-printing of energetic materials, see for example: https://time.tno.nl/nl/artikelen/munitie-uit-de-printer/

Research

At TNO we are currently developing a 3D-printer which is capable of combining two materials. Because the two material feeds can be mixed in virtually any ratio, this printer will be capable of producing both discrete and continuous material changes throughout the geometry. We expect the printer to be operational in June 2018. In terms of software, there are a number of challenges that we still have to tackle, such as how to model a multi-material structure and how to translate this model to paths for the printer to follow. Ideally, the 3D-model of the multi-material structure could also be also be used as input for internal ballistics calculations.

This assignment focuses on these software challenges. The proposed research can be split up in the following tasks:

1. Develop a process for modeling and printing multi-material objects. Questions that could arise are:
   a. At what point in the process do I implement the material changes? (In the initial CAD model? In the software that calculates the printer path?)
   b. How do I design and implement the material changes? (Analytically? Numerically, for example as part of the discretization step?)
   c. How to optimize the printer paths to achieve the best quality gradient?

2. Design a general software architecture that can be used to execute every step of the process developed under Task 1. Where possible, use should be made of existing, open-source software packages. Important aspects of this task are:
   a. Design robust interfaces between the various steps.
   b. Minimize the level of expertise required by the end user.

3. Build and implement the software architecture developed under Task 2. At the end of this task it should be possible to print a multi-material gradient product using TNO's 3D-printer hardware.

Start date and security screening

The graduation assignment is part of an on-going study and can start at any time (but the sooner the better). Please be aware that due to the Defense nature of the work, you will require a NATO security screening before you can work at our location in Rijswijk. For Dutch applicants this usually takes about 10 weeks. Although in principle anyone can apply for the screening, we know from experience that it can take many more months for a non-Dutch applicant to get approved. Unfortunately, we therefore have to limit this application to <u>Dutch students only</u>. You will not be charged for the screening.

If you would like to start in less than 10 weeks this can be arranged, but you would have to work from your university campus until the screening is finished.

Contact information

Would you like to be part of this unique line of research? Then please contact:

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