CaMPUS Non-Technical Report
Linde AG, Unterschleißheim

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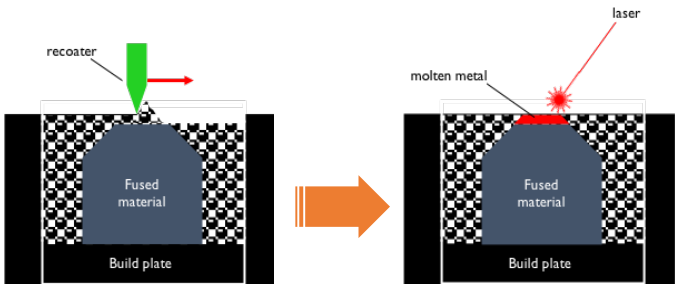
Having completed three years of my Natural Sciences degree, I felt that I had a good amount of experience in the style of research conducted in a university setting, bolstered by my previous CaMPUS placement at the University of Cambridge. I knew I wanted to carry on to do the masters degree and then a PhD, but there was something I'd never done before – industrial research. The CaMPUS programme gave me an unrivalled opportunity try such research, and with the confidence that only a GCSE in German can inspire, I put together an application to the Munich-based company, Linde AG. Despite the fact that a GCSE does not prepare you for actual German conversations, the trip has been one of the best experiences of my life, both academically and personally.

I arrived in Munich the afternoon before I was due to start work, so I barely had time to say "Servos" – the traditional Bavarian greeting - to my landlady before I was thrown into life at Linde AG. The first week was a whirlwind of faces, names and safety meetings, and I managed to commit four safety violations before I'd even been shown my desk, but I quickly learned how the lab worked, both by itself and with the rest of the organisation. The group itself was wonderful and made me feel instantly at home. It helped that the common language was English among such an international group, three of whom were French, one Danish and one Ecuadorian, as well as several Germans. By the end of the week I was up to speed with their work, and ready to get stuck in…

Me being introduced to the main printer. The safety gear protects your lungs from breathing in the small metal particles.

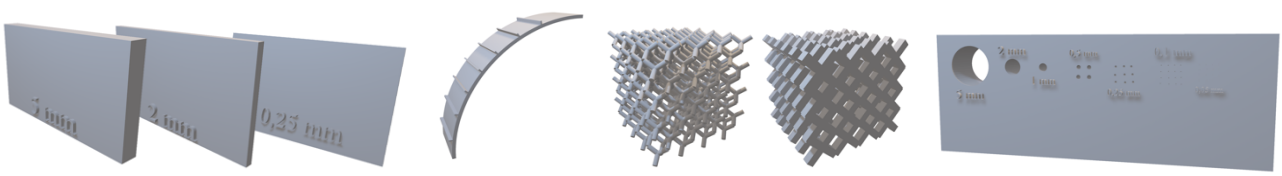
The group researches Laser Powder Bed Fusion (LPBF), which is a type of additive manufacturing, colloquially known as "3D printing". In this process, the part being produced is built up layer by layer. The machine melts metal powder with a laser (see below), fusing the grains of the powder together into a physical version of a 3D computer model.



Powder deposition (left) and laser melting (right). These two steps are repeated until the part is complete.

This process must occur in an inert atmosphere to avoid adverse reactions with various contaminants, especially oxygen. This was the topic of my first project. My work used a constant flow of inert gas into the printing chamber, rather than modulating the flow according to contaminant level, which was Linde AG's current method. I printed small cubes in a titanium alloy, using atmospheres that ranged from pure argon to a 50-50 mix of argon and helium, to examine the effect of the gas type on the printed part. I found that the more expensive helium-containing atmospheres improved the quality of the part, although malfunctioning equipment made some of the data inconclusive. In the future, the group will combine my work with theirs, using a modulated flow, to quantify the benefits of the extra machine required for such precise control.

I also undertook two non-experimental projects. The first was to design a series of computer models that could test geometries that were difficult for the printer to produce, such as thin walls, overhangs, lattices and lateral holes (see below). The group will use these in the future to optimise the composition of the atmosphere to successfully print these structures.



From left to right: vertical walls with thickness labels, a curved overhang with bars every 10°, a diamond type lattice, a lattice with only 45° overhangs, and a wall with lateral holes (labels give the radius of the hole).

My second – and largest – project was to produce a cost-analysis tool. This is an Excel spreadsheet that takes a few inputs to give a comprehensive cost breakdown of a print job, as well as a gas usage summary (the primary focus of the group's research). It has data on common machines, metals and gases, as well as options for adding custom parameters, factoring in the cost of every detail, from powder recycling to batch processing. It is enormously complex, and I had to teach myself a huge number of new Excel skills, but the project was a great success. Initially, the group were only expecting to do a few calculations with it, but it turned out to be such a powerful tool that I'm proud to say that they are now going to incorporate it into their future work.

The evenings and weekends gave me plenty of time to explore the vast city of Munich. I had bought a bike to commute to work, which gave me the freedom to explore all day for free, and I cycled everywhere, from the 1972 Olympic park, to the colossal English Gardens and the beautiful, baroque old town. To the west of the centre is the Nymphemburg Palace, the summer residence of Bavarian kings built in the mid-1600s. Having wandered through the grounds and the main buildings all day, I visited the largest traditional Biergarten (beer garden) in the world – "Hirschgarten", with seats for over 8000 people!

Right: Inside a mid-sized "tent" (6000 seats here!). There are 14 tents in total – one for each brewery in Munich. Left: Me enjoying my first beer of Oktoberfest. No, I don't know who that hat belonged to…

My internship finished in early September, but I wanted to explore more of Germany while I had the chance. I went north, to the medieval city of Hannover, and south to the Alps on the Austrian border. The last thing I did, back home in Munich, was also the best – Oktoberfest! One of the largest festivals in the world, the atmosphere was like nothing I'd experienced before. Sharing a table with complete strangers, I made friends with people from the USA, Italy and France, all in a single afternoon. The previous three months of living in Germany meant I was then able to help translate for those who were at my table. The main focus, though, was the beer, served in the classic Bavarian litre glasses and brewed specially for the occasion. Despite the higher-than-normal alcohol content, it was certainly a time I will never forget.

This experience has given me invaluable insight, both into the world of industrial research and into the unique and wonderful culture of Bavaria, so I would like to thank everyone who made this trip possible. In particular, Dr Pierre Forêt and Ms Camille Pauzon at Linde AG for their help and support in running my internship; the Materials Science Department of Cambridge for organising and creating the CaMPUS programme that made it possible; and, of course, the Worshipful Company of Armourers & Brasiers, without whom I could never have made it to Munich.