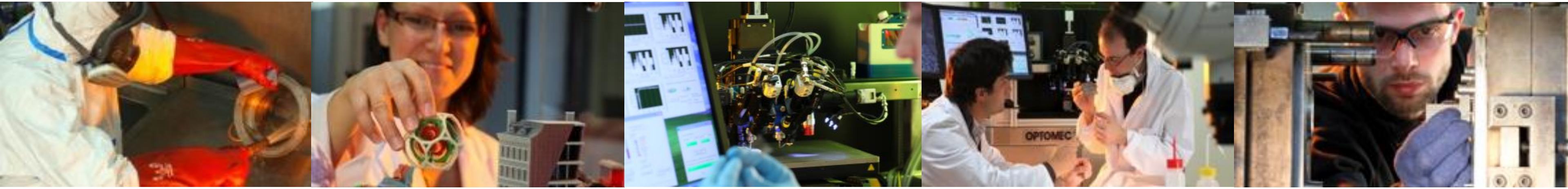


AM of aluminium extrusion moulds using H11 steel

A story on innovation

Introduction

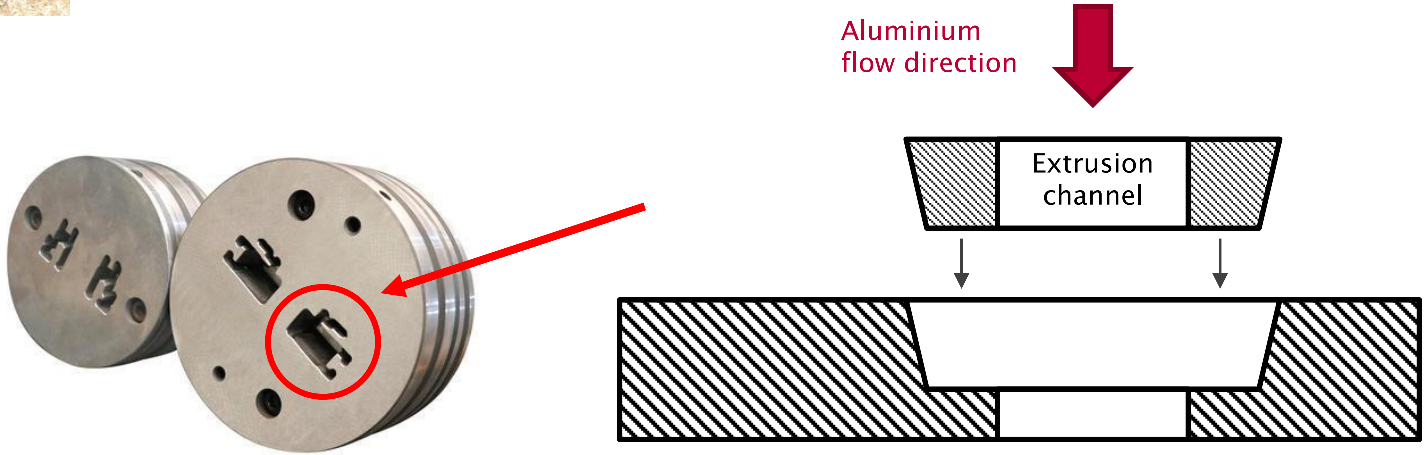
The INSIDE Metal AM project was started in 2018 in order to support the uptake of 3D printing with steel by the Belgian industry. Therefore, the aim was to be able to provide guidance along the entire process chain, starting from raw materials to finishing of the part. This was done through a combination of applied research and the realization of a number of industrial demonstrators. The project focused on three different AM technologies: Laser Powder Bed Fusion (L-PBF), Laser Metal Deposition (LMD) and Wire Arc Additive Manufacturing (WAAM). A number of different steels were used in the project: 316L, 17-4PH, H11, 2209 and S355. The topics covered by the project are materials selection and handling, the process-structure-property relationships and post-processing (including heat treatment and surface post-processing).

Here, one of the demonstrator parts realised within the INSIDE Metal AM project is presented. The use of 3D printing with H11 steel for aluminium extrusion moulds was investigated.

This project received support from the Strategic Initiative Materials (SIM Flandres) and het Vlaams Agentschap voor Innoveren & Ondernemen (Vlaio).

Project partners: Sirris, CRM, BIL

In a four-cavity die (which can extrude 4 profiles simultaneously), one of the cavities typically fails. When this happens, the entire die needs to be replaced. If however 3D-printed, replaceable inserts would be used, this could potentially reduce the down-time and save the die.



It was decided to first test the performance of the 3D-printed material, in this case H11 steel, with a simple test sample. This H11 steel requires specific equipment that can preheat the powder bed to 500 °C and thanks to VAC Machines in Bruges, Trumpf was willing to print a ring that could be built into the E-max extrusion die used for the extrusion of aluminium tubes. The ring has an outer diameter of 78 mm and a height of 10 mm.

Ring in as-built state.

TRUMPF

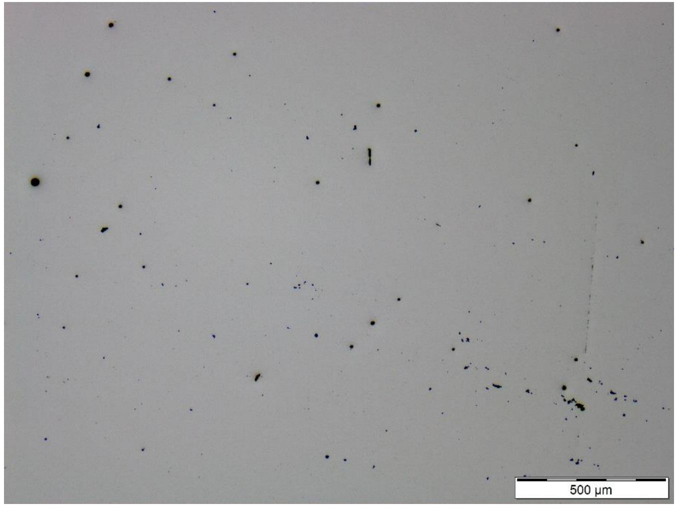
V.A.C MACHINES

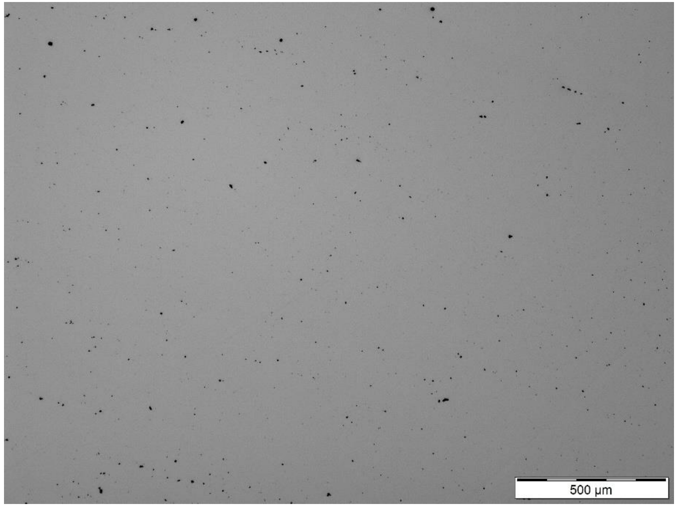
The ring was built into a die on which a 250kg test production batch was run.
In addition, another ring was cut in small section to analyse the hardness, density and microstructure of the material.

Ring after finishing by turning.

Technical info:

- The ring was used an investigated in it’s as-built condition (i.e. no heat treatment was applied)
- Reference hardness of the conventional H11 material: 52-53HRC, 60HRC after nitriding
- Expected hardness H11 “as-built”: 51 HRC





Observations (AB, no heat treatment)

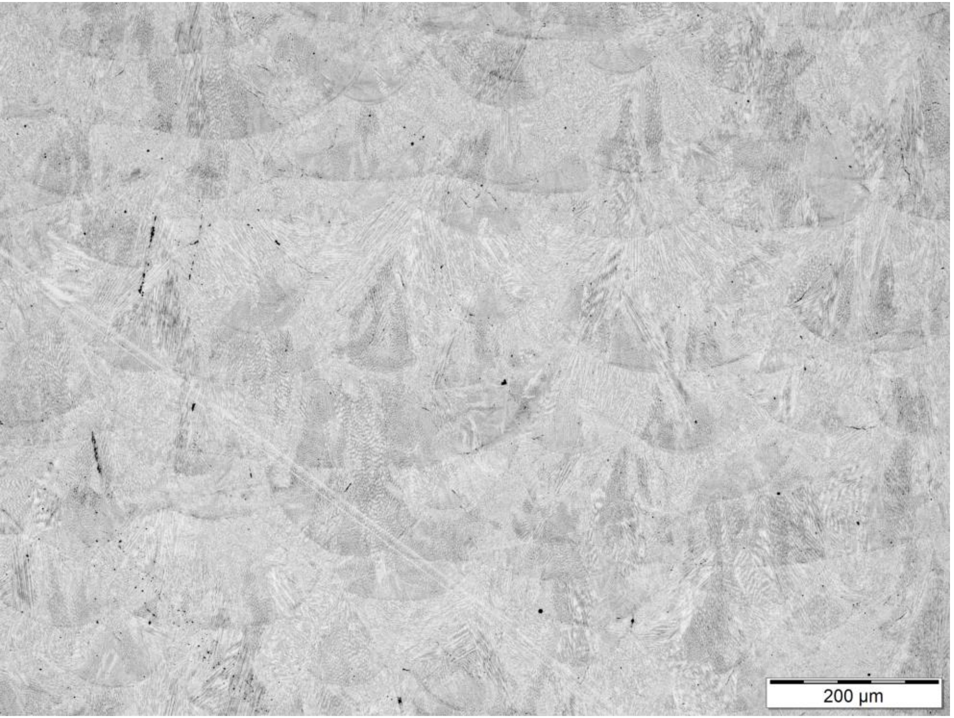
No cracks

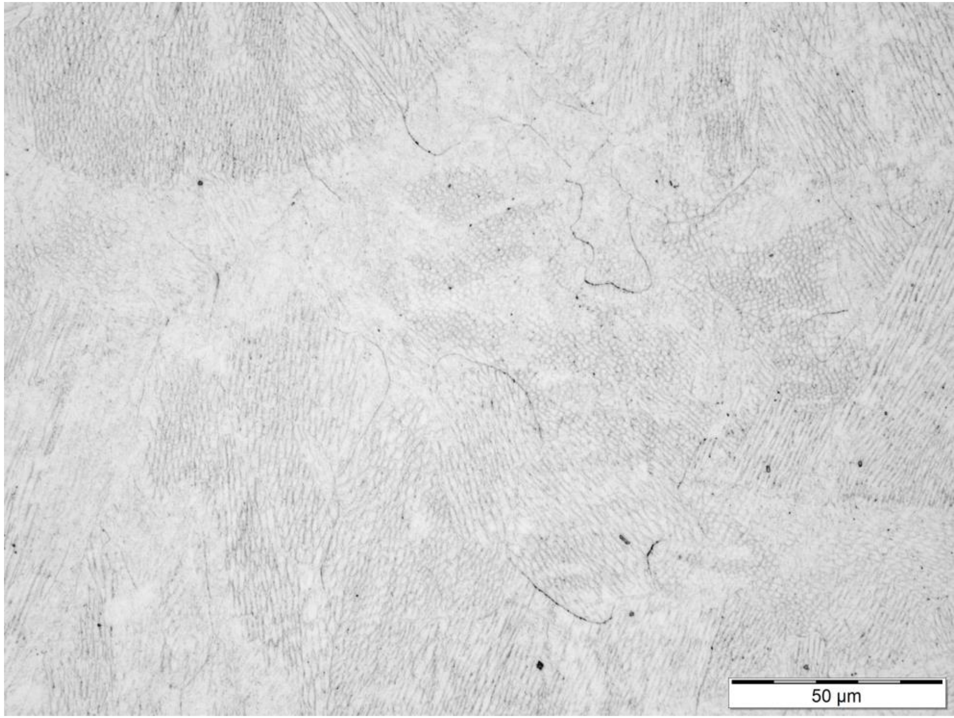
Some porosity (density: 99.1%)

Remark: this is a demonstrator part, with further optimization, densities of 99.9% have been achieved for this material on Trumpf machines

Observed microstructures

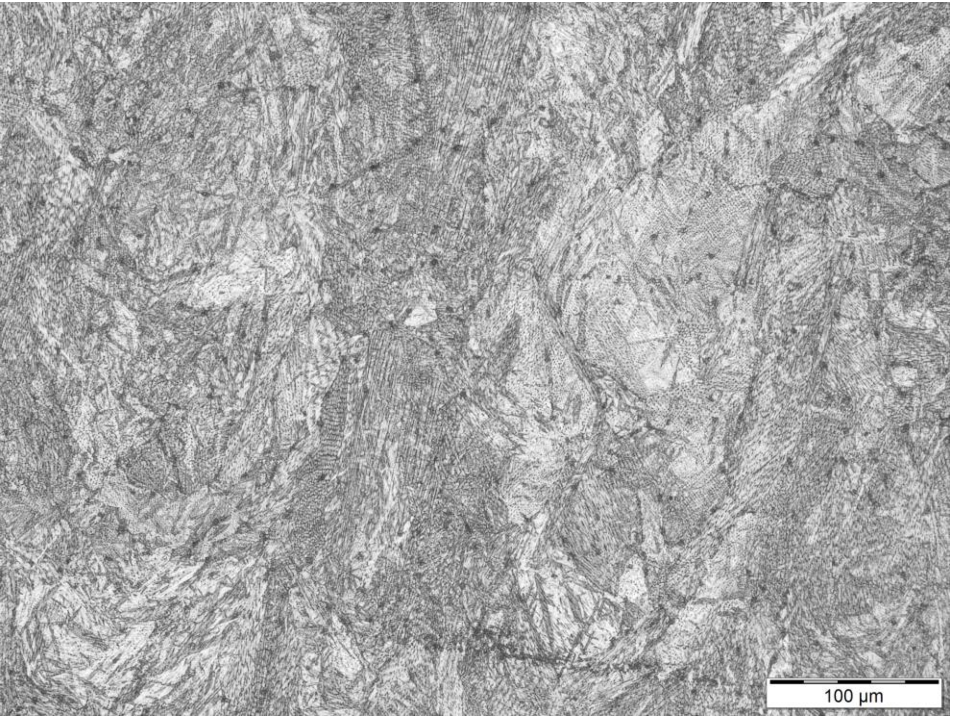
2% Nital, Light optical microscope

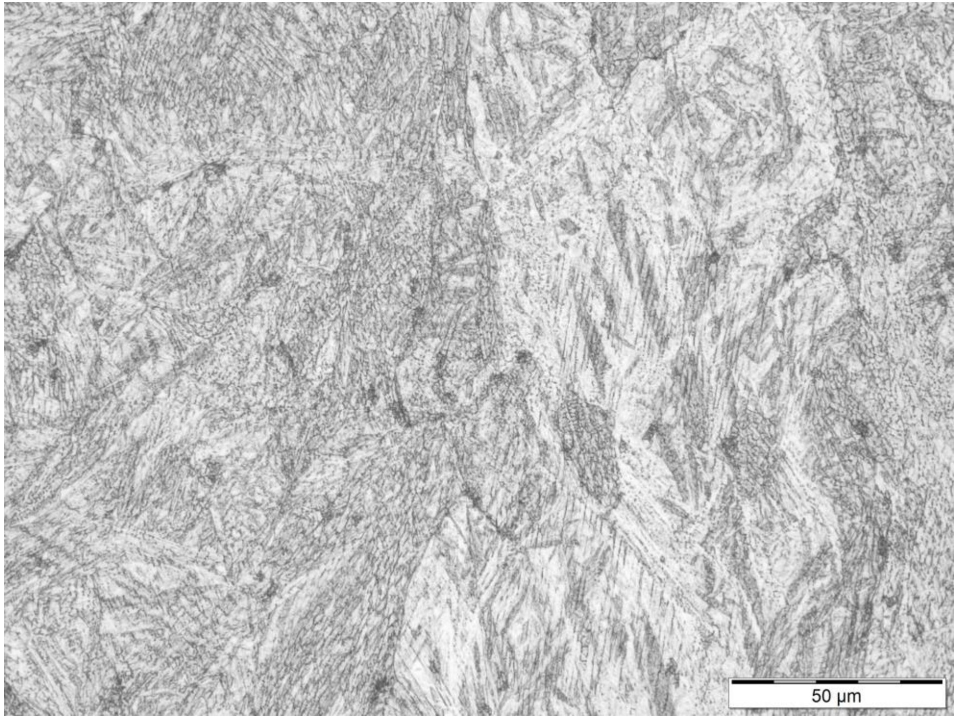




Observed microstructures

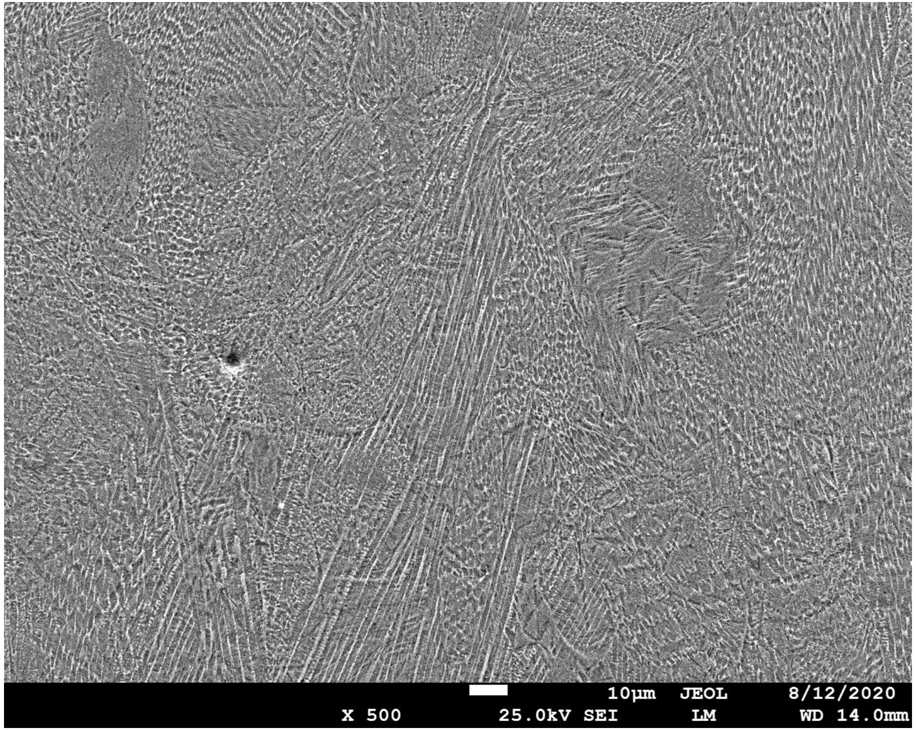
Villella's reagent, Light optical microscope

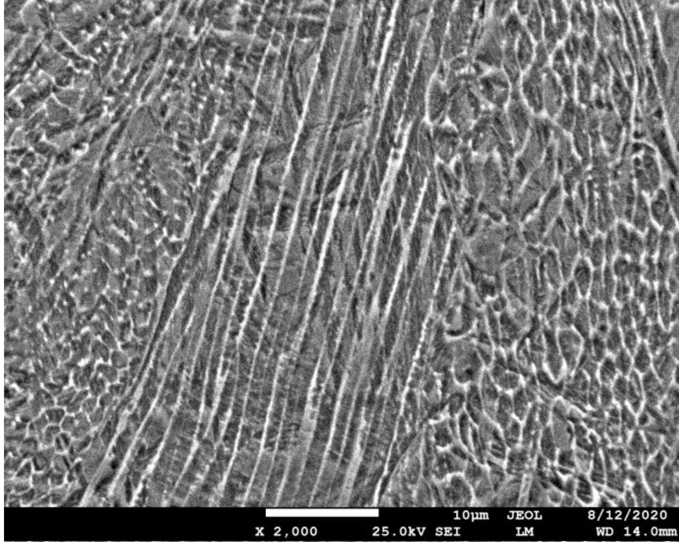


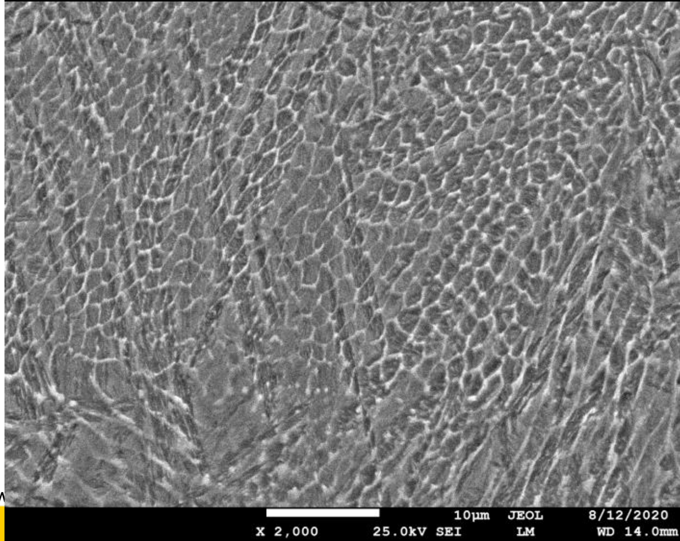


Observed microstructures

Villella’s reagent, SEM







Observations

The meltpool boundaries and cellular dendrites within the cells can be seen

Very fine cellular microstructure (prior austenite)

Martensite formations crossing cell boundaries

Hardness as expected (51-52), and very homogeneous across the ring

Sample nr.	**[HRC]**	**Conversion HV**	**[HV10]**			**[HV0.5]**		
			no. 1	**no. 2**	**Av.**	**no. 1**	**no. 2**	**Av.**
3	51	531	537	555	546	572	629	601
6	50.5	518	584	575	580	596	605	601
11	50.5	518	551	543	547	586	590	588
14	51	531	549	541	545	539	515	527

Samples 3, 11 and 14 were cut parallel to the building direction, sample 6 was cut perpendicular to the building direction.

EMAX

SUSTAINABLE ALUMINIUM

Result after 250 kg of aluminium extrusion

The 3D printed ring performed exceptionally well in the first production run of 250 kg and is still being used in production at the time of this writing.
Because of the good material performance, further investigations were undertaken to evaluate the economic and technological feasibility of printing inserts for the extrusion channels.

Unfortunately the tight tolerances on the extrusion channel turned out to be an insurmountable obstacle (for now). The channels have a width of approximately 1mm and require tolerances of 0.03 mm. In order to achieve this, post machining is required. For this, additional material in the range of 0.3-0.5mm needs to be added on each side, effectively meaning that almost the entire channel is closed and needs to be machined afterward. This makes that it is much cheaper to manufacture these inserts in a conventional way. Therefore, further study of 3D printing of the cavity was abandoned.

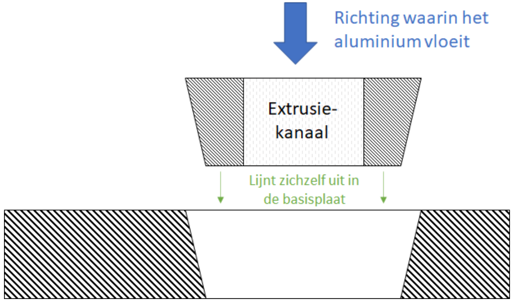
However, the excellent performance of the test ring opened up a new opportunity: printing of conformal cooling channels around the die could help improve the process stability for extrusion with recycled aluminium, something which has not yet been considered in this industry. This route is currently being investigated further.

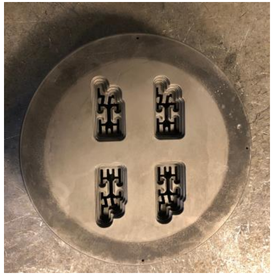
In conclusion, this shows that innovation does not always need to follow a predefined trajectory, and that creativity is key. This specific demonstration example, although not leading up to what we had initially expected, led to three important outcomes: (1) know-how on printing and performance of H11 steel, (2) the idea for cost reduction by using interchangeable inserts was discovered and remains valid, albeit with conventionally manufactured inserts, and (3) use of conformal cooling as a new innovation idea for aluminium extrusion (with a sustainable touch).

Aluminium Extrusion Mould

L-PBF of H11 steel

Starting small can lead to new insights





Internal cooling for improved extrusion of recycled aluminium.

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