Deliverable D1.1: Design and requirements of the elements of the cell.

Automated robotic system for laser deburring of complex 3D shape parts

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1 Introduction

This Deliverable is an intermediate result of Tasks 1 and 2. The final result of these tasks will be reported on Deliverables D1.2 and D1.3 at their completion.

The overall objective of the project is to design and set up an automated robotic station for laser deburring of metal casting 3D high quality complex parts. In particular, it is intended to develop a flexible, low-maintenance and environmentally friendly prototype, able to improve the quality, cost and cycle time of finishing operations (deburring, etc) of aluminum injected components. The system could potentially be applied to different light casting alloys (Mg, AlZn, etc.) and sectors (automotive, railway, electronics, furniture, electric appliances, etc.).

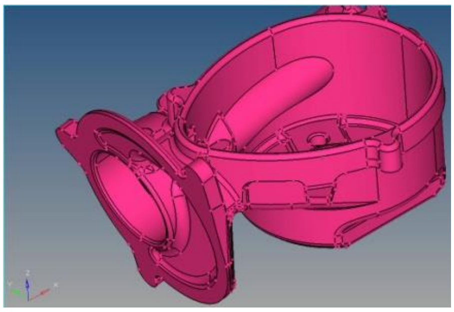
Automotive engine aluminum castings have been selected to demonstrate the technology. Regarding the laser system set-up, a flexible configuration has been considered, in order to evaluate both gas-assisted and remote laser cutting methods.

The design of the workstations, which forms the main demonstrator, is in progress, attending to the requirements generated by the parts selected by IDELT, the end user. For those parts a potential gripper has been analyzed. The 2D and 3D workstations are also under development. More specifically, for the 3D workstation three measuring systems have been tested with the selected parts to check which will fit better to the experiment.

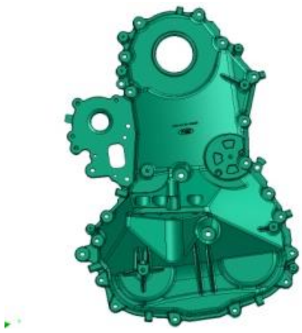
2 Design and development of the laser deburring station.

2.1 Industrial requirements of the process

During these two first months of activity, IDELT, which is the end user of the laser deburring robotic station, has defined the industrial requirements of the process. Two part geometries have been selected (see images below), which are aluminum castings for the automotive industry.



Reference 1

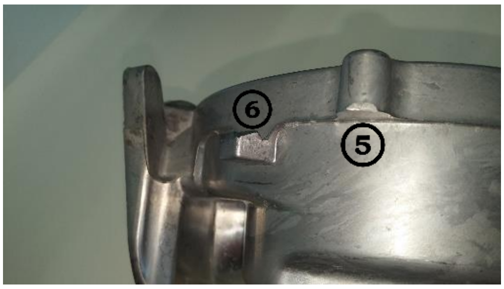


Reference 2

The areas where burrs are to be treated have been identified (mainly along the closure line of the mould). For Reference 1, nine different burr areas have been selected, and the thickness of each of these has been measured. The details of Reference 2 are still under discussion.

The roughness to be achieved has been obtained by evaluating the results using current finishing methods. The Ra parameter has been measured, according to standard ISO 4288, wherever possible, in a finished part provided by IDELT. As an example, some pictures with the burr zone number highlighted are shown in the following figures.

Reference 1 – Burr Zone 2



Reference 1 – Burr Zones 5 and 6

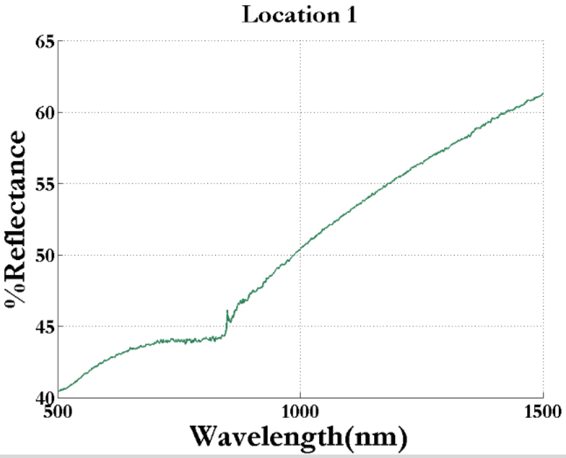
The thickness on each particular zone along with the required roughness, as expressed by the Ra parameter, are summarized in Table 1.

Table 1. Thickness and target roughness specification

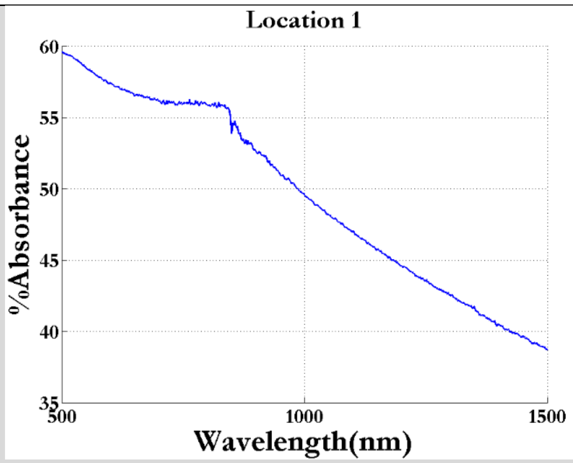
ZONE	*Burr thickness (mm)	Target roughness Ra(µm)
1	3	7.5
2	3	7.5
3	1.5	7.5
4	1.4	7.5
5	1.7	7.5
6	0.25	7.5
7	1.6	7.5
8	1.6	7.5
9	1.2	7.5
10	0.9	7.5

**Might vary slightly from part to part*

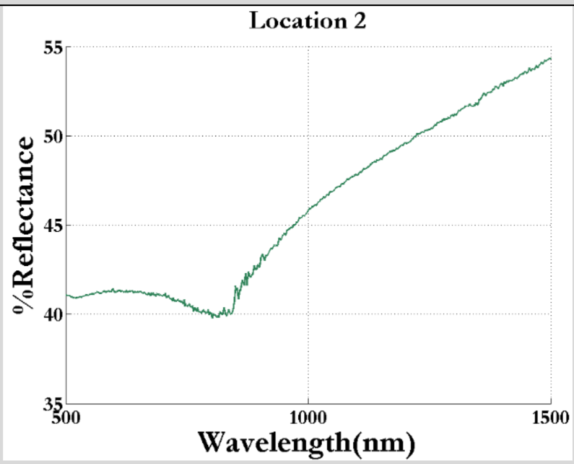
Regarding the material optical properties, the reflectance and absorbance of the alloy have been characterized at room temperature by optical methods. This is a key magnitude, since it governs the efficiency of the laser material coupling. The reflectance has been measured directly, using an integrating sphere and a spectrometer. It is defined as the ratio of the intensity absorbed by the target to the incident intensity. The absorbance is inferred by assuming zero transmittance. The reflectance has been measured at two different locations, and the corresponding results are shown in the following figures, as a function of the incoming wavelength.



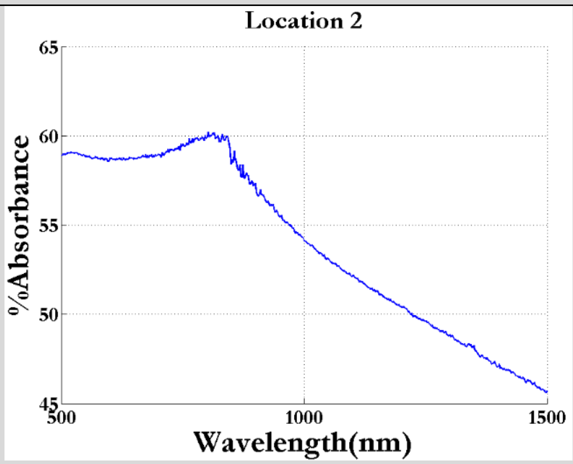
Reflectance at position 1



Absorbance at position 1



Reflectance at position 2



Absorbance at position 2

The values corresponding to the typical laser wavelengths have been evaluated and compared. The main results are gathered in Table 2. The first column introduces the most typical laser wavelengths used for the industrial processing of metallic materials, alongside the active medium used to provide such radiation. Those entries that are highlighted correspond to the systems available to the current consortium.

Table 2. Optical properties of the selected material at room temperature

Active medium/λ(nm)	Absorbance at point 1 (%)	Absorbance at point 2 (%)	Absorbance Average (%)
Diode / 808	55.9	60	57.95
Diode / 900	52.6	57.4	55
Diode / 940	51.5	55.7	53.6
Diode / 980	50.2	54.7	52.45
Diode / 1018	48.8	53.5	51.15

Diode / 1030	49.1	53.9	51.5
YAG / 1064	47.9	52.8	50.35
Active Fiber / 1070	47.7	52.7	50.2

It must be noted that the parts show a much higher absorbance than that usually attributed to aluminum, which is probable due to the high surface roughness. The presence of an irregular surface enhances higher order reflections, and therefore increases the probability of absorption. In any case this is a positive feature for the laser processing of the material and the energy efficiency of the overall process.

2.2 Laser system analysis and selection

The laser system has been set-up in a way that allows for flexibility in the deburring processes, meaning that both a conventional gas-assisted laser cutting and remote cutting are possible. Both variants will be evaluated in the next stage of the experiment.

Regarding the laser source, although the assessment of the optical properties has shown that the diode laser provides a slightly better absorbance, the low quality of the laser beam makes it not appropriate for the laser deburring system. Therefore, only the active fiber and the YAG system are considered as candidates for the final demonstrator.

3 Design and development of the different modules of the cell: grasping, trajectory tracking and laser adaptive control

3.1 Description of the cell

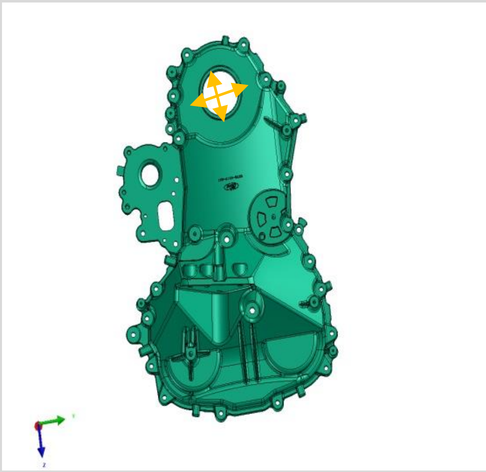
The demonstrator cell is subdivided in three stations:

- The parts feeder
- The 3D measurement system
- The Laser Deburring system

3.1.1 The Parts Feeder

The components of this station are a feeder line that transports the parts one by one. Also there is a zenital 2D camera for 3D position estimation. The incoming part is analyzed through a 2D vision system, that as a result, sends to the robot the pose of the part, (including its x,y,z position and alfa, beta, gamma angles of the piece referred to the robot coordinate system). With this information the robot grasps the part so it may be precisely positioned in the next stations.

On this task it is also required to integrate grasping capacity to the robot flange. For that, a parallel three finger gripper is being analyzed.

 Gripper	
 Grasping position of Part 1	 Grasping position of Part 2

The two selected part geometries can be grasped by such a gripper. The part 1 has three possible positions on the belt, where the robot can reach the grasping position. In the case of part 2, there are two possible positions where the robot can reach it.

3.1.2 The 3D Measuring station

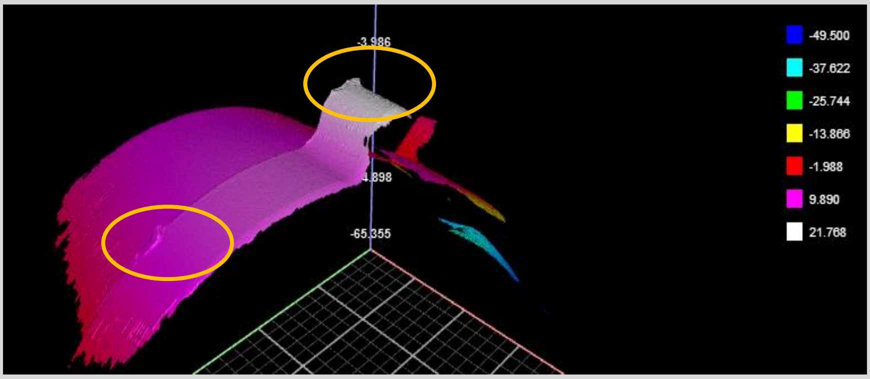
The second station uses a 3D Measuring system to detect the position and size of the burrs on each part. It comprises the following operations:

- The 2D camera positioning for grasping may have some inaccuracies and therefore a second analysis with the 3D station could be necessary. The 3D station could improve the pose estimation to the required precision of the deburring process.
- To locate on the part the height, length and position of the burrs to be eliminated in the deburring workstation.

For the second operation, different 3D systems have been tested. Two technologies have been analyzed: a 3D active stereo vision system and a sheet of light device. Each technology will offer different solutions to the burs positioning task.

The first tested technology has been the 3D active stereo vision.

In this case, a Gocator 3110 system has been used. Burrs can be clearly seen as it is shown on figure below.



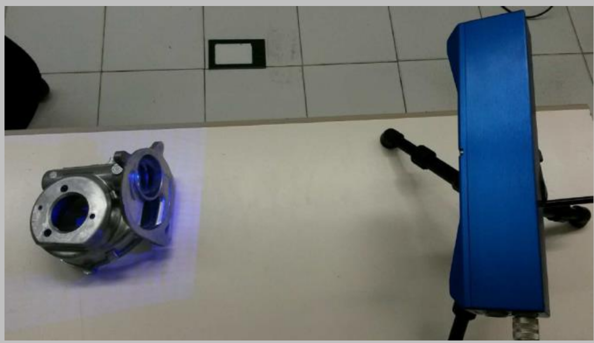
Results with a stero system

Position of burs

Different view

It is important to remark that this technology requires a precise matching of the obtained points cloud with the CAD. Burrs information come from the comparison of the 3D obtained against the ideal part CAD.

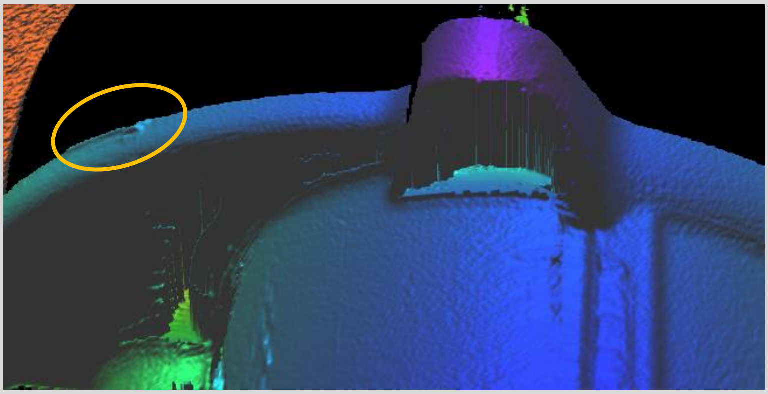
In addition, the HDI-120 system has also been evaluated. This device is more precise than the previous one, however it requires a big amount of time for capture. Besides, it requires a rotation of the part, which means adding an extra rotary axis to the system. Due to these two reasons, this particular solution has been discarded.



Acquisition process

Matching of different views

The second technology tested has been the laser sheet of light, in this case a Ranger E50 camera. By using this device, burrs also are clearly detected. With this technology, it is easier to produce undesired inaccuracies when the obtained profiles are added to generate the point cloud. In this case the approach would be to compare every obtained profile against the one generated when a good part is captured. From this comparison, the position and size of the burrs can be obtained.

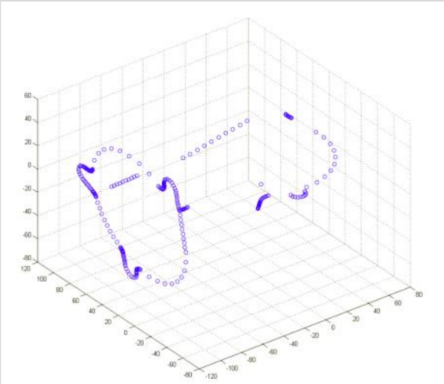


Burr measurement through sheet of light

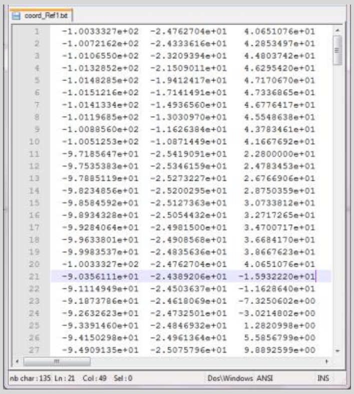
3.1.3 Manipulation of the part on the laser deburring station

As a result from the 3D station, the burrs present on the part are characterized by its position and size. In this last station, the actual laser deburring process will take place.

On the CAD, the areas of the part where burrs should appear will be defined. Then, the deburring trajectory of the robot will be defined on the CAD. This trajectory also will be used by the 3D station.



Deburring path definition



Path points for robot trajectory

This trajectory will be completed with the information coming as a result of the 3D analysis of burrs. This information will be aggregated to the robot program, in the form of start/stop instructions and trajectory optimization, such as a faster movement on those areas where no burs are present.

In parallel, several laser deburring tests are being undertaken, so as to obtain a velocity based close-loop feedback to optimize process time. In order to implement this system, the intensity of the reflected signal is being evaluated as the sensing magnitude for the velocity loop.

4 Conclusions

- The major part of the industrial requirements has been defined.
- The parts feeder station is designed and under construction.
- Further analysis must be done to definitively select the 3D system. This will allow designing the station and constructing it.
- For the deburring station:
  - First tests of the laser deburring process have taken place.
  - Debur trajectories for the robot are being defined at CAD level.