Innovative Welding Processes for New Rail Infrastructures

Deliverable D2.3
Development of a prototype weld finishing tool (for aluminothermic welding)
Abstract
This document details the research, concept and development tasks of T2.4

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Keywords
Alumino-thermic welding, weld finishing, grinding, finishing

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Executive summary

1 Introduction

According to the task of WRIST WP2, the focus of the work package is to develop a device for the qualitative development of aluminothermic welding by using an automated rail alignment unit, a forging unit and a shear unit to create equipment for accelerated cooling of the weld and the conceptual development of a possibly automated weld joint processing unit (see D 2.2 Alignment, forging and shearing device). Particularly for the operation and parameterisation of the automated rail alignment unit, the forging unit and the shear unit, the development of comprehensive and efficient process control is necessary, which was developed as part of the work package T 2.1 Development of a process control system for aluminothermic welding (see D 2.1 Development of a process control system for aluminothermic welding).

The task within work package T2.4 The development of a prototype weld finishing tool (for aluminothermic welding) is the development of a machine which makes it possible to ensure that the contours and surfaces are restored following the aluminothermic welding process to comply with the standard, and the accelerated cooling of the welded joint. Moreover, the profile must be monitored during the process, and the surface must be monitored and evaluated afterwards. A different profile measuring instrument is used for the final finished profile measurement.

2 Methodology

The result of the work package T 2.2 Development of equipment able to apply controlled compressive forces to aluminothermic welds incorporating work package T 2.3 Development of an enhanced cooling system for aluminothermic welding is a so called Module 1.0.

Using the previously customary machining methods and tools as a benchmark, work began on the present work package. Module 1.0 from the previous work package provides the framework and space for the prototypes of the weld joint editing device which are to be developed, and a list of requirements has been derived from it, in which the detected requirements are clearly structured and have been defined as desires or demands. A black-box representation served as a first draft of the overall system. Through a functional analysis, required individual work steps were derived from operations and subsequently displayed as a graphical function chain. This has been expanded with the necessary auxiliary functions. Six different solution variations have been developed by means of a morphological box, in which technical solutions for individual and auxiliary functions are listed. These are recorded in the form of technical principles. Calculating the metal removal rate for all variations enables a concrete comparison to be made between them. All variants were then compared and evaluated in a number of weighted categories in a cost-benefit analysis. The final evaluation yielded the favourites module which must be described in more detail, and for which a prototype must be produced. Said prototype is shown in Figure 1.
The same procedure was used for measuring. A benchmark was implemented, based on the requirements. The aim was to either use - or to redevelop, if necessary - existing technology which was used for in-process measuring. See Figure 2 for the result.
3 Conclusions

The Prototype, developed within the package T 2.4 Development of a prototype for a weld finishing tool with the subtasks of in-process measurement tools and post-weld-quality check was closely connected to the results of two other work packages, namely:

T 2.2 Development of equipment able to apply controlled compressive forces to aluminothermic welds and work package

T 2.3 Development of an enhanced cooling system for aluminothermic welding.

Conditions such as construction space and the load bearing capacity of the construction have already been determined, which has led to challenges in its design.

The result of the construction is a belt grinding device which can be moved in several directions and which transfers the actual profile of the adjacent to the joint to the device using copying rollers, in order to create the desired profile across the welded joint. This type of machine was selected due to the good cutting performance coupled with, ongoing promising developments in the field of abrasive belts and compactness.

For the measurement process, a prototype of a profile measuring instrument was developed. The instrument can detect the cross profile of the rail head, and compare it with the desired profile via an app. This step is carried out uncoupled from the grinding module, but in future it could be incorporated into a closed loop system.

The quality control of the final end result is carried out with a longitudinal measuring device, which is already used by Goldschmidt Thermit GmbH, and which is suitable for this application. This result is transferred as a data set, and is processed in T2.5, Development of online weld quality control and data analysis.
4 In-Process measurement and post weld quality control

4.1 Idea description

The idea is to incorporate a measuring system into the overall construction. This should be easily interchangeable in this case, in order to ensure control and monitoring during the grinding process. Ideally, this is carried out by measuring the transverse profile with suitable sensors. A final quality statement should be created by measuring the longitudinal profile after the removal of all equipment. The measurement should make the data available via a communications interface, which can be used both for storage purposes and for process control.

4.2 Concept description

Various measuring principles must be considered when measuring the profile (See Figure 3). The main challenge is to guarantee accurate measurements in a construction site environment (dust, vibrations, and harsh environmental conditions). The measurement principle which is used for each measuring task is explained in the corresponding section.

![Figure 3: Measuring principles for in-line measurement](image)

4.2.1 In-Process measurement system

For this measurement task, a laser system is used, which not only provides accurate and reproducible results under the defined measurement conditions, but can also be adjusted to meet the challenges of construction operations. The following Figure 4 explains the operating principles for measuring with the laser system of the prototype.

1. Each laser individually measures the part of the rail head that lies in its light path.
2. A line is generated
3. The existing line is adjusted
4. Both lines are superimposed, aligned and connected
5. An actual profile contour is produced for the rail head
**Mechanical construction:**

The functional model shown in Figure 5 below contains all the relevant components. The two lasers are suspended from a rigid aluminium frame, at a defined angle of 10°. The same support structure also bears the weight of the electronics, which are installed in protective housing, and the batteries used to power the measuring system.
At the relevant measuring points, the prototype is fitted with master gauges. The measuring device has an aluminium housing in order to prevent measurements from being affected by external conditions and environmental influences (See Figure 6).

![Prototype](image)

**Figure 6: Prototype (A – Housing; B – Handle; C – Foot)**

**Data analysis**

The recorded profile is processed and evaluated by the data processing system. The result is an actual profile which is superimposed over a profile of the parent rail, and therefore provides a indication as to the quality of the result or any further profiling.

Figure 7 shows a representation of the evaluation app in action. The deviation (error line) can be seen below the profile curve, and the green line indicates the maximum deviation, and therefore an area for additionally profiling.
During the project, the individual profile steps are evaluated after a specific number of cycles in the grinding process. This means that the grinding module must be removed or switched to a neutral position for measuring. The evaluation should be carried out directly via the machine controls in the next stage, and therefore lead the process to a defined conclusion without any manual adjustments being required.

### 4.2.2 Post-weld measurement system

A magnetic-based measuring probe passes along the measuring beam and measures the distance between the examined surface and the beam. The equipment can be utilised to investigate the geometry of magnetic metal surfaces in a contactless non-destructive way.

This same measuring principle is part of a product in the Goldschmidt Thermit GmbH portfolio (See Figure 8). This should be used here. The evenness of the longitudinal profiles of the running surface and running edges should be measured with the RAILSTRAIGHT COMPACT before and after the grinding operation. After measuring on-site, the measurement data are transmitted via Bluetooth to the measuring computer, or transferred, displayed and documented using the RAILSTRAIGHT APP.

*Figure 7: In-App picture of profile measurement (A – Real curve; B – Ideal curve; C – Error beam; D – Maximum deviation)*
Using this system, it is possible to determine the straightness and evenness, and therefore make a quality statement, from a distance of 50cm to the left or right of the welded joint.

The outcome from these measurements dictates whether the grinding operation has been accepted or rejected (See Figure 9).

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4.3 Specification and drawings

The following chapter shows the technical data sheets and specifications for the two respective measurement modules prototypes.

4.3.1 In-Process measurement system

Figure 10: Dimensions of profile measurement system

Figure 10 shows the overall dimensions of the profile measurement system in a drawing of the whole system. The inclination angle of the two sensors is also shown in the picture.

Specifications for prototype

W x H x L: 200 mm x 350 mm x 300 mm

Weight: approx. 10 kg

Reference resolution of the laser (manufacturer): 12 µm

Repeatability: +/- 50 µm

Profile: 60E1, 60E2, + others

Protection class: IP65

Actual capacity: 95 Wh
The overall structure of the module is shown in Figure 11, and explanations of the component parts can be found in the Table 1 below.

**Table 1: Technical description**

<p>| | | |</p>
<table>
<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Sensor 1</td>
<td>Right profile spline measurement</td>
</tr>
<tr>
<td>B</td>
<td>Sensor 2</td>
<td>Left profile spline measurement</td>
</tr>
<tr>
<td>C</td>
<td>Controller</td>
<td>Data acquisition and interface management as well as controlling power supply</td>
</tr>
<tr>
<td>D</td>
<td>Battery</td>
<td>Power supply for the whole system (10hrs)</td>
</tr>
<tr>
<td>E</td>
<td>Supporting frame</td>
<td>Rigid and stiff skeleton to ensure high precision</td>
</tr>
<tr>
<td>F</td>
<td>Foot</td>
<td>Template for rail profile with foot to stand on</td>
</tr>
</tbody>
</table>

**Sensors**

LLT 2600-100/SI triangulation sensors, made by MicroEpsilon, are used (See Figure 12). After rigorous testing and comparisons with sensors made by other manufacturers, it was found that the present sensors fulfilled all expectations in terms of accuracy and durability.
Battery

The battery is a preconfigured overall system, with its own battery management system (BMS). It is mechanically attached to the device by means of a v-mount. The design guarantees easy access for battery replacement. The battery is inserted into the device from below (See Figure 13).

Figure 12: Laser sensor

![Laser sensor](image)

Figure 13: Battery for profile measuring prototype

![Battery](image)
Supporting frame

This is a self-supporting frame construction made from individual aluminium sections, produced by ITEM, having edge lengths of 40 mm and 20 mm. The device can be very easily assembled, adjusted and calibrated, and is stable without its housing. It can therefore be operated without its cover. The housing is therefore only "imposed" onto the device, and has no influence on the measuring function. To keep the housing as light as possible, but also to maintain a certain level of rigidity, a wall thickness of 2 mm has been adopted.

Foot

Gauges which are attached to the lower cross profiles aid the adaptation to the rails (Z and Y). These gauges simultaneously serve as feet (See Figure 14), and are simple laser-cut parts which are attached to the corners of the frame. Suitable adjustments allow the accommodation of different rail profiles.

4.3.2 Post-weld measurement system

Advantages of using the recommended measuring devices (See Figure 15) to carry out the quality control are outlined below:

- Both running surface and running edges are easily measured
- The measured data is of high precision
- There is full electronic documentation of rectilinearity after welding, and a record of the acceptance results
- Remote control by PDA or smartphone is possible
Figure 15: RAILSTRAIGHT COMPACT in measuring position on track

The following Table 1 gives a brief overview of the technical specifications for the RAILSTRAIGHT COMPACT. Further data can be found in the manual.

Table 2: Technical data RAILSTRAIGHT COMPACT

<table>
<thead>
<tr>
<th>Parameter</th>
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<tbody>
<tr>
<td>Measuring length</td>
<td>1 m</td>
</tr>
<tr>
<td>Horizontal resolution</td>
<td>200 measuring points</td>
</tr>
<tr>
<td>Vertical resolution</td>
<td>0.01 mm</td>
</tr>
<tr>
<td>Linearity error</td>
<td>± 0.5%</td>
</tr>
<tr>
<td>Measuring range</td>
<td>• max: +1.5 mm</td>
</tr>
<tr>
<td></td>
<td>• min: -2.5 mm</td>
</tr>
<tr>
<td>Measuring time</td>
<td>6 s</td>
</tr>
<tr>
<td>Weight</td>
<td>5 kg</td>
</tr>
<tr>
<td>Dimensions (WxDxH)</td>
<td>1230 × 165 × 110 mm</td>
</tr>
<tr>
<td>Internal rechargeable battery</td>
<td>• 3 x 3.7V Li-Ion</td>
</tr>
<tr>
<td></td>
<td>• Operating time: approx. 400 measurements</td>
</tr>
<tr>
<td></td>
<td>• Charging time: approx. 7 hrs</td>
</tr>
<tr>
<td>Protection class</td>
<td>IP54 (protection against dust, complete protection against contact, protection against water splashes)</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>• min: -10</td>
</tr>
<tr>
<td></td>
<td>• max: +50 °C</td>
</tr>
<tr>
<td>Rail temperature</td>
<td>• min: -20</td>
</tr>
<tr>
<td></td>
<td>• max: +60 °C</td>
</tr>
<tr>
<td>Air humidity</td>
<td>• max: 90% relative humidity</td>
</tr>
<tr>
<td>Connection interfaces</td>
<td>• Bluetooth</td>
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<td></td>
<td>• USB</td>
</tr>
<tr>
<td>Standard requirements</td>
<td>• EN 61000-4-2</td>
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<td></td>
<td>• EN 55022</td>
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5 Realization of a prototype weld finishing tool (for aluminothermic welding)

The following chapters will contain the ideation, conceptual design and technical implementation of the automated weld finishing tool. First of all, and as a benchmark, should give a short overview as to of state of the art and mark provides a starting point for the ensuing development.

5.1 Review of current finishing practices

Review of available methods including advantages, limitations, cost, production, and environmental impact is a task of GTG and ID2. The current section focuses on manual grinding or small hand held grinding machines that are usually operated in a half-crouched position. Current manual grinding work includes rough grinding and finish grinding.

Abrasive rail grinding methods are classified into three major types. These are listed below with some advantages and disadvantages.

Grinding
- Bespoke grinding to suit specific worksite
- Low efficiency
- Short replacement cycle

Milling
- High-efficiency
- Milling possible at high temperature

Linishing
- Highly accurate
- High efficiency
- Linishing process difficult to predetermine

5.1.1 Portable rail grinding modules

5.1.1.1 Hand-held rail grinding modules

The most common tools for final finishing of welded joints are hand held grinders such as the profile grinder GP 4000 by Goldschmidt Thermit Group. (See Figure 16)
Figure 16: Profile grinder GP 4000²

The grinder uses a circular rotating grindstone which is applied by manual adjustment by the operator to the welded joint. An suitable adjustment enables the inclination of the grindstone and the functional components of the machine against the rail head to facilitate the grinding of the rail running surface and both sides of the rail head.

On the market there are many companies who have hand-held equipment in their portfolio, e.g. PortaCo, Geismar, Cemafer, Robel, Railtech Matweld and GeaTech.

Hand-held grinders are very flexible in their use and less expensive to purchase and maintain compared to automatic grinding machines. In terms of their operation the user does not require specific knowledge, but the resulting performance is very dependent on the operator competency and tool maintenance.

The machines do not have any measurement technology and the finished profile is usually determined by application of a steel straightedge to the finished ground surface to determine the final ground levels. The grinding result depends primarily on operator skills. A common grinding cycle takes 5 minutes for coarse grinding and approximately 10 minutes for fine grinding.

A special Rail Head Profile Grinding Machine by Robel (See Figure 17) is used for true-to-form grinding of the rail head after welding work to restore the ideal profile. It allows for a perfect copy of the rail profile by virtue of a special copying device (See patent for further information e.g. DE202010007264U1)

² GTG
Rail Shape Eco by Goldschmidt Thermit Group is designed to deburr and re-profile the running edges of grooved and flat bottom rails. The machine is not yet suitable for processing the running surface of the rails. (See Figure 18)
5.1.1.2 Automatic and semi-automatic rail grinding modules

More interesting for the current project are automatic and semi-automatic rail grinding modules.

The portable rail grinding module Cemafer "MSV 150" is a semi-automatic rail grinding machine offering a complete grinding cycle in less than 5 minutes. The machine is very heavy (weight ~2t) and not flexible in its use (See Figure 19).

![Figure 19: Cemafer “MSV 150”](http://www.cemafer.de/fileadmin/cemafer.de/user_upload/Maschinen_Prospekte/Geismar_MSV_150.pdf)

The module can automatically locate the rail surface position by means of sensors. The vertical and longitudinal stroke of the grinding cup operates automatically through precision guide elements, which can be programmed by the controller.

Another example for a semi-automatic rail grinding modules is the “Compact Rail Grinding Equipment” from Kintetsu Railcar Engineering Co.,Ltd.

In cooperation with East Japan Railway Culture Foundation they developed portable, compact rail grinding device that is shown in Figure 20.

![Figure 20: Compact rail grinding equipment](http://www.kre-net.co.jp/en/planning/index.html#compact)

5 [http://www.cemafer.de/fileadmin/cemafer.de/user_upload/Maschinen_Prospekte/Geismar_MSV_150.pdf](http://www.cemafer.de/fileadmin/cemafer.de/user_upload/Maschinen_Prospekte/Geismar_MSV_150.pdf)

The machine grinds only the running surface of the rail head. Rough grinding of the surface of the running edge has to be done manually or with a hand-held grinder. But the time required for manual finishing using a stone grinder after automatic rough grinding could be reduced. Instead of a grinding stone a milling cutter tip is used.

A grinding method (See Figure 21) having a simple automatic control mechanism to measure and control the height of the excess weld metal, therefore resulting in automatic rough grinding with better accuracy.

The LRGM 1-2/ AM16 from L & S Luddeneit und Scherf GmbH is a turnout grinding machine for profiling the rail head which composes of a grinding unit and a generator.

The turnout grinder can be used for removal of the rolling skin, elimination of rail corrugations (long and short waves) on the rail head as well as for the re-profiling of the rail head. (See Figure 22)

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The grinding process is computer monitored. Fixed and adjustable grinding programs are available. Modification of grinding angles and horizontal grinding stone adjusting is realized by electro mechanical control. It is believed that there is no integrated measurement system incorporated into the device.

A comparable system was introduced by Autech AG (See Figure 23). The self-propelled grinding system type AT-3389-4 can be used for grinding corrugations, removing imperfections, restoring the profile of worn rails and grinding new rails and switches on grooved and vignole rails. As with the LGRM machine, it is presumed that no integrated measurement system is integrated in this system.

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**Figure 23 : Grinding system type AT-3389-4**

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9  [http://www.l-und-s.de/lrgm-1-2-kopie.html](http://www.l-und-s.de/lrgm-1-2-kopie.html)

5.1.2 Grinding trains

The advantage of grinding trains (See Figure 24) is that the track does not have to be taken out of service, i.e. scheduled services can continue without impediments due to grinding and milling work on the track. The resulting metal shavings are sucked directly away as the dimension of such grinding trains can easily accommodate all the technical fixtures.

*Figure 24: HSG grinding train*

For high speed grinding a number of grinding cup wheels are operated in parallel in a row (See Figure 25) and positioned with the aid of hydraulic systems. This enables the continuous machining of track sections of 40 km in length at a speed at least 80 km/h. A number of repeated runs are required, however, in order to remove 0.1 mm of material.

*Figure 25: Arrangement of the grinding wheels*

High speed milling is characterized by the removal of high quantities of material (per run) from the running surface of between 1.5 to 3 mm and to 10 mm from the running edge. However, with typical speeds of between 1 to 3 km/h, it is considerably slower than the grinding process. A milling wheel is used for the cutting process (See Figure 26) with a high number of indexable cutting inserts. These are then coordinated by a tool measurement system.

*Figure 26: Milling device*
5.2 Weld finishing tool

5.2.1 Idea description

In 5.1 the current available techniques have been described, however, for the prototype weld finishing tool a different principle has been developed. Linear movements, spring deflection and a mechanical guide roller move a rotating grinding belt along the rail profile (profile-independent). A spring-loaded slide is guided along the rail profile, whereas the guide roller copies the current actual profile. Due to the suspension, the positioning of the grinding belt is simplified, in that the number of required controlled axes is reduced. (See Figure 27)

Figure 27: Working principle (A – Starting point; B – Intermediate state; C – End point)

5.2.2 Concept description

Figure 28: Workflow for weld finishing device

Figure 28 shows the workflow plan for the machine, and implemented as the actual workflow. This is explained, step-by-step, below.
1. The grinding device is attached and fixed to the receiving and fastening device on the basic frame of Module 1.0.
2. The next step is to connect the machine to the network. This can be done either separately or in the next step, or directly to the overall supply of Module 1.0.
3. The module awaits input from the touch panel. The automated procedure can be started.
4. So that the positions can be compared, the linear slides move to the two end positions.
5. After the calibration of the two end positions, the motor of the belt grinder is started.
6. From here on, the two linear axes operate continuously and position the head of the grinding belt in accordance with the inputs of the programme or the sensor.
7. When the system receives an end signal, processing with this signal is complete, and both linear slides return to their starting positions. The grinding belt is also stopped.
8. For safety reasons, the rest position is checked in order to guarantee safe removal.

With the automated device, the excess weld metal of a rail weld is virtually removed completely. Following “rough grinding” circa 0.5 mm of excess material is left over the welded joint to account for any expected dipping of the joint due to thermal and residual stress effects. However, this ensures that the joint is fit for the passage of traffic until any final fine grinding is undertaken.

After installation onto the base frame, switching on the power supply, and making the appropriate programme selection, the work process begins with the initialisation of the linear slide positions and the movement of these into the relevant starting position. Firstly, the two lower synchronised linear drives are moved to their starting positions, after which the belt grinding machine is switched on, and the upper sliders move uniformly across the rail profile.

In a digital machining process, it is important to move the tool to the exact position on the workpiece to be processed, as well as setting the direction of movement. If one considers the complex contours of a rail profile, the not inconsiderable technical expense that this entails soon becomes clear. The wide range of rail profiles with differences - some of which are minimal - substantiate this fact.

In contrast, the copying process employed requires just a single smooth movement over the rail profile which is to be ground. The copying rollers are applied mounted directly onto the surface profile of the unaffected parent rail adjacent to the weld, and rolled in the transverse direction on the rail profile. The conditional height which is determined by the radii is offset by the height-adjustable sliders, while the weight of the belt grinder provides sufficient pressure for machining.

Once the profile has been looped one time, the belt grinder returns to its starting position, and is brought to the next processing position, where the process step is repeated. This process step, as well as the use of the synchronous linear drive, is necessary due to the 100 mm bandwidth of the grinding belt, as the welding bead which is to be ground should be at least 100 mm in length, and this cannot be ground in a single work step.
5.2.3 Specification and drawings

The Figure 29 shows the overall structure in which the processing module (2.0) is placed within the aligning, trimming and forging module (1.0). The specification for this overall structure is (module 1.0 plus 2.0):

**W x H x L:** 947mm x 920mm x 2433mm

**Weight:** 985 kg

The overall structure of the module is shown in Figure 29, and explanations of the parts can be found in Table 3.

*Table 3: Parts and their description of the whole unit*

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>A</td>
<td>Module 1.0</td>
<td>Aligning forging and shearing device</td>
</tr>
<tr>
<td>B</td>
<td>Module 2.0</td>
<td>Weld finishing device (finishing)</td>
</tr>
</tbody>
</table>
Specifications of the complete unit

W x H x L: 838 mm x 695 mm x 796 mm

Weight: 115 kg

The overall structure of the edit module is shown in Figure 30, while explanations of the components can be found in Table 4

Table 4: Parts and their description Module 2.0

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Fixation H-shaped feet with fast clamping mechanism for fixing the GRIMLI (Module 2.0) on the connecting rods of ALFONS (Module 1.0)</td>
</tr>
<tr>
<td>B</td>
<td>Frame Aluminium-cast profiled frames and associated linear carriages</td>
</tr>
<tr>
<td>C</td>
<td>Cross table Linear carriage drives connected synchronously</td>
</tr>
<tr>
<td>D</td>
<td>Spring carrier Carries the linishing device and ensures optimal pressure on the linishing band tip</td>
</tr>
<tr>
<td>E</td>
<td>Linishing device Working device of the machine</td>
</tr>
</tbody>
</table>
Figure 31: Frame of weld finishing device (A – Fixation; B – Profiles; C – Linear carrier)

Specifications of the frame

W x H x L: 838 mm x 695 mm x 796 mm

Weight: 70 kg

The frame of the unit is made up of individual aluminium profiles, each having an edge length of 80 mm. The linear drives are part of this supporting structure, as these are provided by the same manufacturer, and therefore have the correct fastenings (notches). A high degree of rigidity and flexibility is required for mounting the device onto the basic frame. A socket specifically designed with a clearance fit is fitted with a highly rigid retaining plate, and connected to the framework of the device. Once everything has been successfully set up, the socket can be secured using a clamping lever.
The table below refers to these components. The purpose of this design was to provide a broad stable frame, having functional integration.

Table 5 shows the names and description of the frame shown in Figure 31.

**Table 5: Parts and their description frame**

<table>
<thead>
<tr>
<th></th>
<th>Fixation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>H-shaped feet with fast clamping mechanism for fixing the GRIMLI (Module 2.0) on the connecting rods of ALFONS (Module 1.0)</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Profiles</td>
<td>Aluminium-cast profiles (80 mm edge length) with connecting grooves</td>
</tr>
<tr>
<td>C</td>
<td>Linear carriage</td>
<td>Linear carriage drives synchronously connected to each other to guarantee perfect movement in both axis</td>
</tr>
</tbody>
</table>

![Figure 32: Cross table for moving the linishing device](image)

**Specifications of the cross table**

W x H x L: 838 mm x 196 mm x 796 mm

Weight: 33 kg
With its toothed belt drive, the KLE 8 linear unit is distinguished by its flat design, its positioning accuracy, and its tolerance of relatively high bending torque, and is therefore defined as a popular linear drive. A servomotor-gearbox combination has been selected for the required driving power, in cooperation with ESR Pollmeier. A requirement for this choice was the capability to move 50 kg load by at a linear velocity of at least 1 mm/s, and a positioning accuracy of ± 1 mm. Three drives are combined to a cross table. (See Figure 32)

**Figure 33:** Linishing device with copy rollers

**Specifications of the linishing device**

W x H x L: 375 mm x 500 mm x 329 mm

Weight: 30 kg
The belt grinder which is employed is a Grit GI 100, manufactured by Fein (See Figure 33). The holes which are already present in the belt grinder must be used when constructing the copying rollers, as they are aligned with the axes of the drive roller. The actual copying components, which follow the rail profile at a later stage, are fitted with a radial deep-groove ball bearing, and can be dismantled once the retaining rings have been removed. Various copying components can easily be changed and implemented.

![Figure 34: Spring carriage](image)

**Specifications of the spring carriage**

W x H x L: 150 mm x 545 mm x 180 mm

Weight: 15 kg

Figure 34 shows the spring carriage, that with the help of springs having spring rate of 0.1 do force the linishing device towards the rail head to ensure optimum process results and guidance.
Control unit

For the control unit a Starter Kit of Siemens, the S7-1200 (See Figure 35) and a touch panel with the necessary software have been chosen. With this setup, a connection to a profinet bus system is also possible. In this way an effective communication with the servo controller of the drives for the cross table is ensured.

Figure 35: Siemens S7-1200 SPS CPU Starter Kit

The use of a frequency converter is required (See Figure 36) to create a frequency change in the power feed of the linishing device. This however allows the controller to adjust the speed of the device variably thereby perfectly facilitating the optimization of the weld finishing process.

Figure 36: Frequency converter ATV312HU15N4

In the following Table 6 the technical specifications of the frequency converter can be found. For further information refer to the data sheet.

**Table 6: Technical specification of frequency converter**

<table>
<thead>
<tr>
<th>Main</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Range of product</td>
<td>Altivar 312</td>
</tr>
<tr>
<td>Product or component type</td>
<td>Variable speed drive</td>
</tr>
<tr>
<td>Product destination</td>
<td>Asynchronous motors</td>
</tr>
<tr>
<td>Product specific application</td>
<td>Simple machine</td>
</tr>
<tr>
<td>Assembly style</td>
<td>With heat sink</td>
</tr>
<tr>
<td>Component name</td>
<td>ATV312</td>
</tr>
<tr>
<td>Motor power kW</td>
<td>1.5 kW</td>
</tr>
<tr>
<td>Motor power hp</td>
<td>2 hp</td>
</tr>
<tr>
<td>[Us] rated supply voltage</td>
<td>380…500 V (-15…10 %)</td>
</tr>
<tr>
<td>Supply frequency</td>
<td>50…60 Hz (-5…5 %)</td>
</tr>
<tr>
<td>Network number of phases</td>
<td>3 phases</td>
</tr>
<tr>
<td>Line current</td>
<td>6.4 A for 380 V, 1 kA</td>
</tr>
<tr>
<td></td>
<td>4.8 A for 500 V</td>
</tr>
<tr>
<td>EMC filter</td>
<td>Integrated</td>
</tr>
<tr>
<td>Apparent power</td>
<td>4.2 kVA</td>
</tr>
<tr>
<td>Maximum transient current</td>
<td>6.2 A for 60 s</td>
</tr>
<tr>
<td>Power dissipation in W</td>
<td>61 W at nominal load</td>
</tr>
<tr>
<td>Speed range</td>
<td>1…50</td>
</tr>
</tbody>
</table>

The following Figure 37 shows the whole wiring diagram of the weld finishing tool. It includes all the above mentioned parts and pieces.
In Table 7 the weld finishing tools automation components are named and explained.

**Table 7: Description of the parts in the wiring diagram**

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Servo motor</td>
<td>Drives the linear carrier</td>
</tr>
<tr>
<td>B</td>
<td>Servo controller</td>
<td>Controls the servo motors and therefore allows precise positioning of the linishing device</td>
</tr>
<tr>
<td>C</td>
<td>Frequency controller</td>
<td>Adjusts the frequency of the voltage that is supplied to the asynchronous motor</td>
</tr>
<tr>
<td>D</td>
<td>Asynchronous motor</td>
<td>Drives the linishing band</td>
</tr>
<tr>
<td>E</td>
<td>SPS S7-1200</td>
<td>Stores and executes the process parameter in the program that controls the whole weld finishing</td>
</tr>
<tr>
<td>F</td>
<td>Transformer</td>
<td>Transforms the voltage</td>
</tr>
<tr>
<td>G</td>
<td>Main switch</td>
<td>Turns whole automation unit on and off and is combined with an emergency stop button</td>
</tr>
<tr>
<td>H</td>
<td>Limit switches</td>
<td>Held the controller to get the feedback of the servo controlled linear carrier</td>
</tr>
<tr>
<td>I</td>
<td>Fuse</td>
<td>Main fuse for the whole automation unit</td>
</tr>
</tbody>
</table>