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Mini-factories for customised products using local flexible production

ADvanced Digital technologies and virtual engineering for mini-Factories

D5.1
Flexible Insole Manufacturing system (v3)

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THE ADDFACTOR CONSORTIUM

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14	New Millennium Sports SL	KELME	SP	SME
15	Grey Mer Srl	GREYMER	IT	SME
16	KMWE Precisie Eindhoven BV	KMWE	NE	LE

LIST OF ABBREVIATIONS AND GLOSSARY

Acronym	Explanation
EVA	Ethyl vinyl acetate
BSUL	Bottom Surface of Upper Layer
USLL	Upper Surface of the Lower Layer

1 Document Reference

1.1 Document Identification

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1.2 Document Responsible

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1.3 Executive Summary

Aim of the report is to document the achievement of the final prototype of insole rapid-production machine.

The document contains sections with a brief description of the following items:

- Section 2: aim of the activity, for whom the machine is intended and what were the specifications that led to its realization.
- Section 3: prototype features. This section describes all the technical characteristics of the prototype including: dimensions, electric power, machining speed, etc.
- Section 4: main functionalities, which means how the machine works and what it can do.

2 Introduction on the Flexible Insole Manufacturing System

One of the main problems for the realization of high customized products, like accommodative insole, is the definition of strict specifics on highly complex-shaped products. These products become possible only through manual processing with continuous adjustment and this brings to high production time and cost. To make companies become competitive, new implementation strategies should be analyzed. For this purpose, AddFactor project aims to simplify the inherent complexity of the design and implementation of such products, reducing distances between retailer and customer. This allows to produce unique products in a short time.

In this overview, task 5.1 dealt with the realization of a novel modular machine for the rapid production of accommodative insole (Figure 1).

Figure 1 Multi layered and multidensity footbed.

Such machine is therefore intended for a local production center that allows to simplify the process and reduce the production times at retailer level.
The product specifications lead to having a fast system, easily configurable, in order to adapt with flexibly to ever-changing product.

3 PROTOTYPE FEATURES

As mentioned above, machine is designed according to rapid production criteria. In order to meet these needs it was decided to divide the realization of the insole in more independent machining, moving forward in parallel. For this reason the final system is composed of two independent machines. In one we will have 5 axes, able to do the finishing of the product with the required level of detail. In the other, we will have the movement on 3 axes which allows to work semi-finished layers and with these, assemble the final product (refer to previous documents for the analysis of the realization phases).

3.1 Architectural features

The architecture of the entire manufacturing system is composed as shown in Figure 2Figure 2.

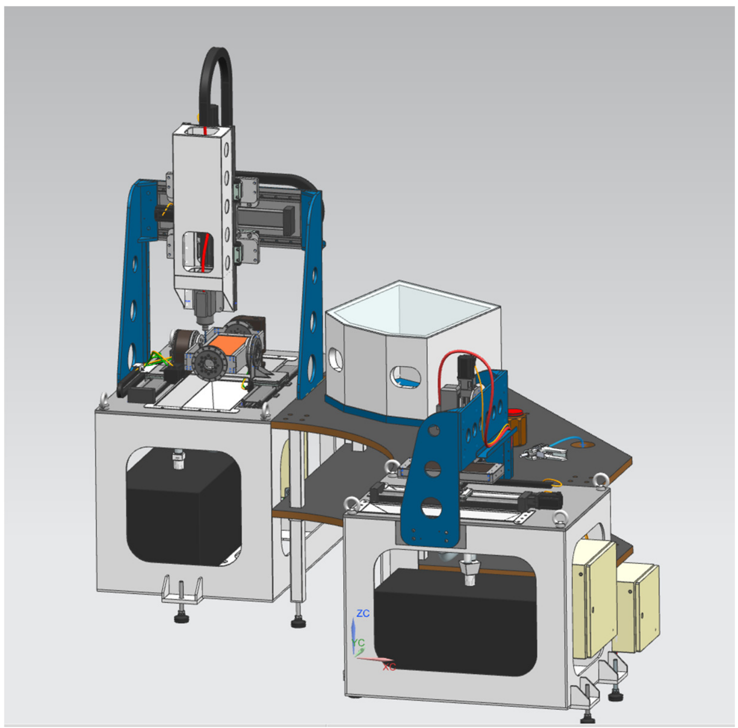


Figure 2 Insole Manufacturing system.

On the left of the figure can be observed the 5 axes machine with the rotary table. In detail we will have:

- Three linear axes: X, Y, Z which move the spindle
- Two rotary axes: A,B which move the workpiece

On the right side there is the 3 axes machine, used to machining the layers that will assemble the final product. In this case there will only:

- Three linear axes: X, Y, Z which move the spindle

Between the two machines a support bench has been realized to allow the assembly of the various layers. The final product can be done without interfering with the operation of the two lateral systems.

All the structures are made of steel to ensure a rigid and strong system to maximize the working hours number without external actions (components replacement, repairs, ect.)
The machine axes are also interpolated within the software control to allow great flexibility in the implementation of each piece.

3.2 Geometrical features

In the section below, it will be presented the geometrical features of the system.

3.2.1 Stroke

The individual axes strokes of each system's machine are shown in the following table.

Five Axes machine				
X axis	Y axis	Z axis	A axis	B axis
230mm	450mm	450mm	+-60°	360°

Three Axes machine		
X axis	Y axis	Z axis
230mm	450mm	100mm

3.2.2 System dimensions

Below the geometrical maximum dimensions of the entire system.

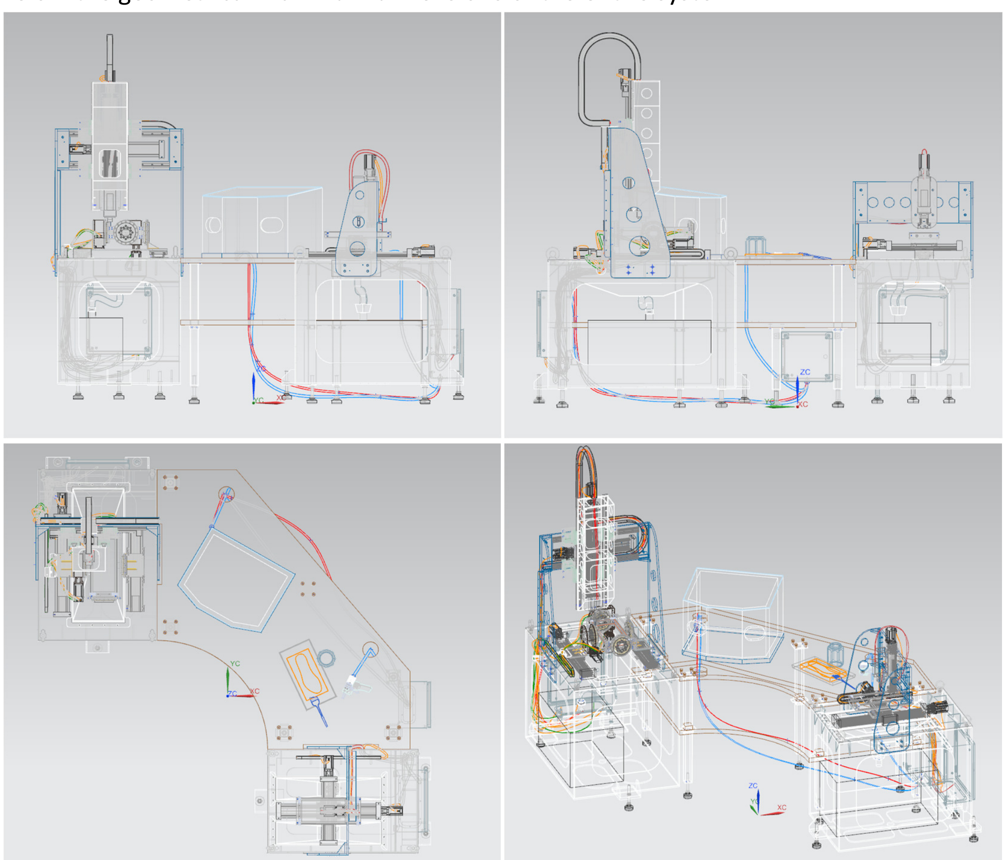


Figure 3 Insole Manufacturing System draft.

Five Axes		
X axis	Y axis	Z axis
800mm	1100mm	2250mm

Three Axes		
X axis	Y axis	Z axis
700mm	950mm	1600mm

3.3 Dynamic features

The dynamic features have been defined to reach a good compromise between performance – in terms of processing time and rigidity - and global dimensioning of the structures. Here under the chosen values of speed and acceleration are reported:

Linear Feedrate[m/min]	Linear Acceleration[m/s^2]	Rotary Federate[rad/s]	Rotary Acceleration[rad/s^2]
1.8	1.5	0.42	0.167

3.4 Working area and volume dimensions

Machine is designed for accommodative insole. The raw material size resulting to better adapt to these needs (refers to previous documents) is:

360mmx160mmx30mm

The volume dimensions of the entire area reachable from the axes however is larger and results from the strokes of those minus the physical dimensions of the supports.

Five Axes machine		
X axis	Y axis	Z axis
215mm	435mm	435mm

Three Axes machine		
X axis	Y axis	Z axis
230mm	450mm	100mm

4 Main prototype characteristics and functionalities

Present section documents the achievement of the rapid production machine through a briefly description of its major features. We will see then the mechanical design, the servos and the electrical equipment on board.

Figure 4 Flexible Insole Manufacturing system.

Main features documented by Figure 4 are:

- Five axes machine on the left (main body and structure).
- A table for mounting insole and for the arrangement of the control computers.
- Three axes machine on the left (main body and structure).

More specifically:

Figure 5 Five axes machine.

Main features documented by Figure 5 are:

- Five axes machine
- XYZ movement system + spindle
- Rotary table with A and B axes

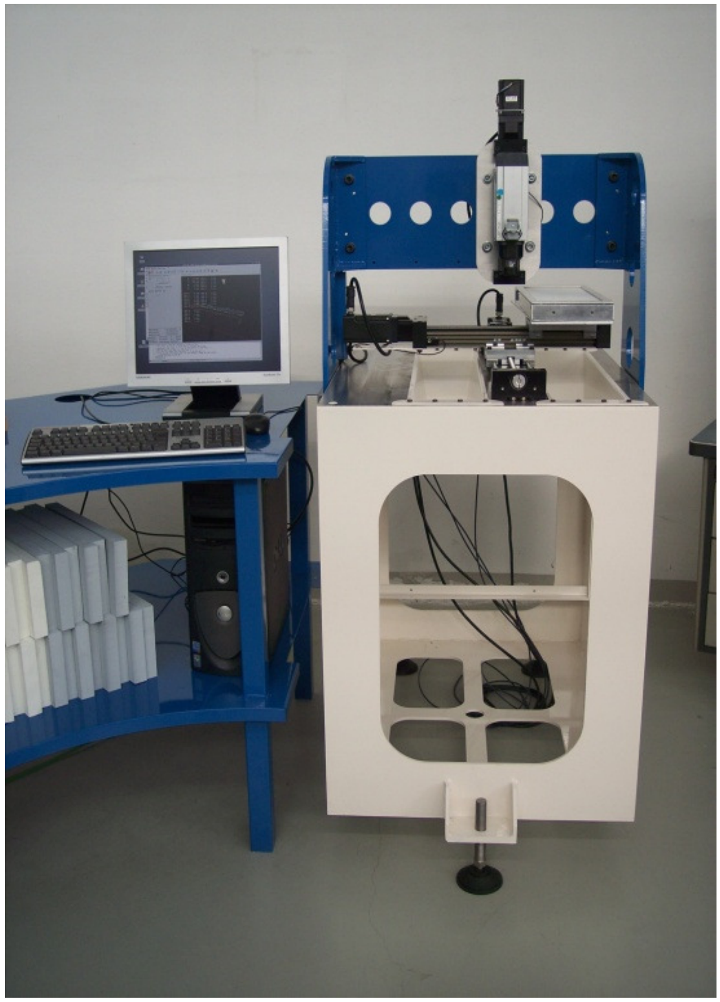


Figure 6 Three axes machine.

Main features documented by Figure 6 are:

- Three axes machine
- XYZ movement system + spindle

The system is designed in order to have:

- A unique basemen for each machine (i.e. the bottom part of the machine), providing facilities related with:
  - Auxiliaries;
  - vacuum system;
  - cabinet with servo and drives
  - possibility to PC hosting the Linux RTAI control system
- On the top, a single common workpost that links the machines while keeping them indipendent

Here under some details.

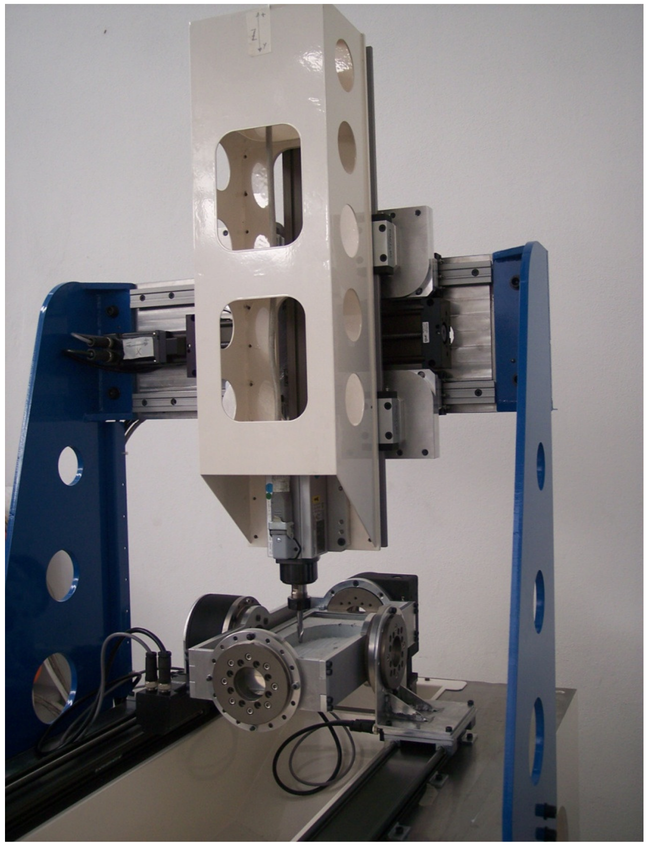


Figure 7 Ram-type milling machine detail.

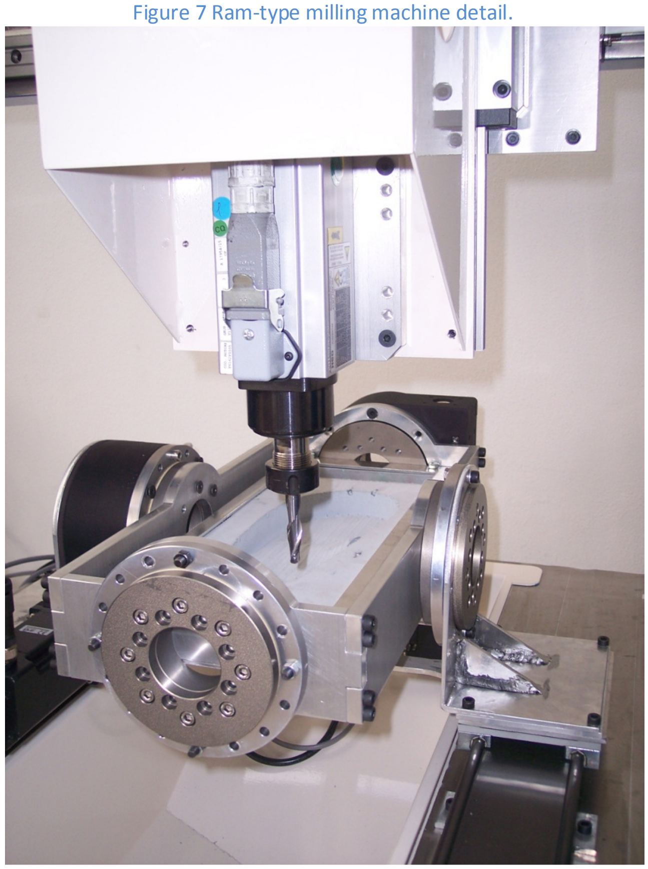


Figure 8 Tilting rotary table detail.

Figure 9 Working table.

Here under some technical pictures of the elements used.

Figure 10 Igus linear axis (mod. SAW).

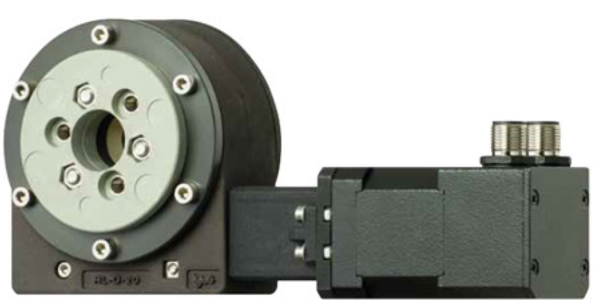


Figure 11 Igus Rotary axis (mod. PRT).

Figure 12 Igus NEMA23XL stepper motor.

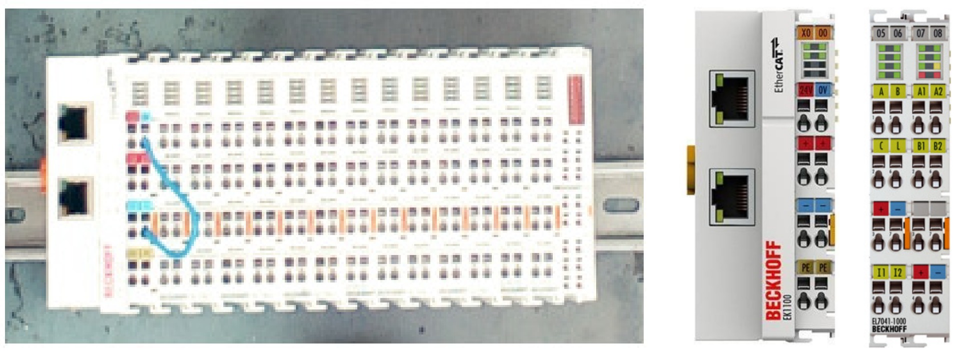


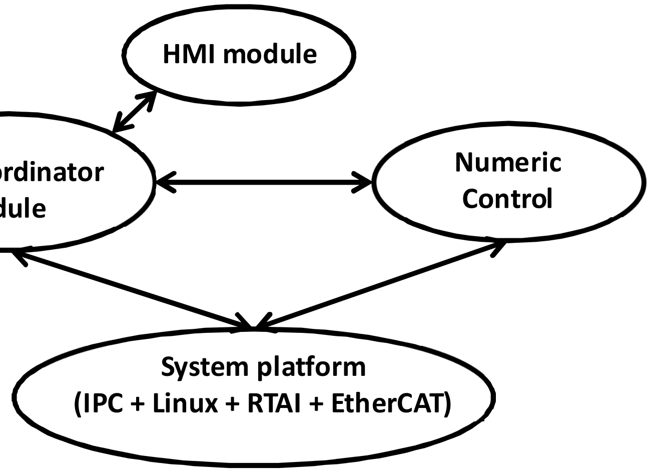
Figure 13 Beckhoff with EtherCAT terminals as drive system (EK1100, EL7041).

Figure 14 HSD Electrospindle (1Kw – 24.000rpm).

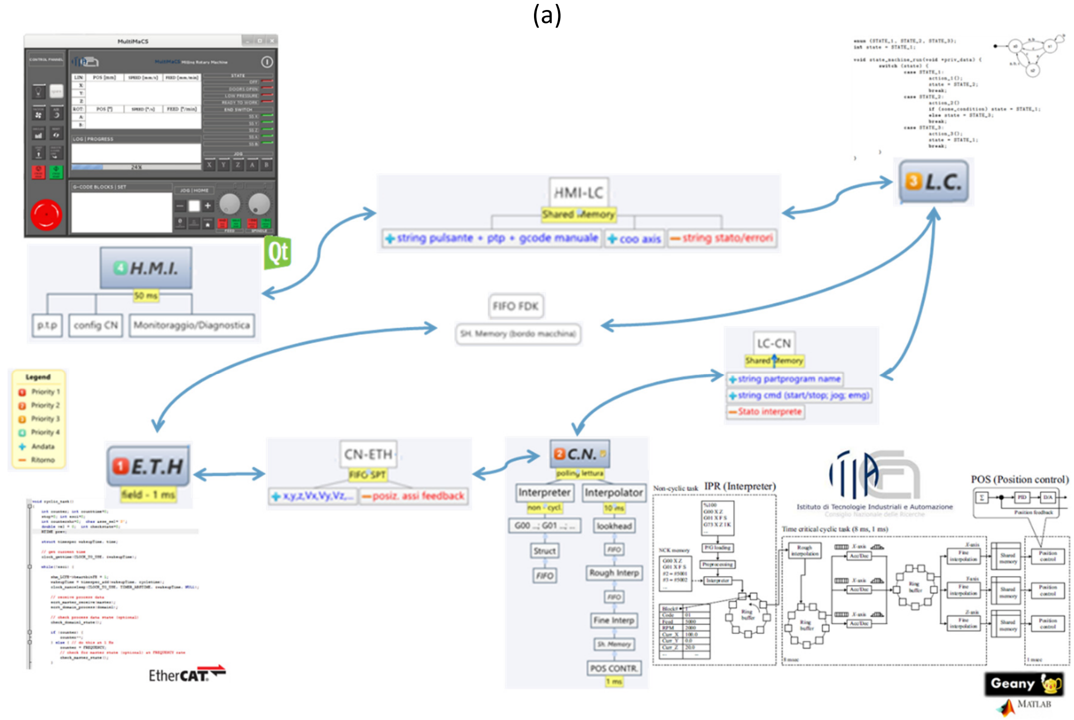
Figure 15 TDEMACNO DSA spindle motion controller.

4.1 Manufacturing Control System

A PC based solution has been realized for the system control. This means that the human interface, the numeric control and the fieldbus master run on a PC. Every part of this software system has been written internally. In the figure below the control system structure.



(a)



(b)

Figure 16 Structure of the control system software (a) logical view (b)deployment view.

To simplify the processing operations a simple interface has been designed using linux Qt graphics libraries (Figure 17).

Figure 17 HMI manufacturing control system.

To check the correct operation of the system, tests are made also with the linuxcnc software (Figure 18).

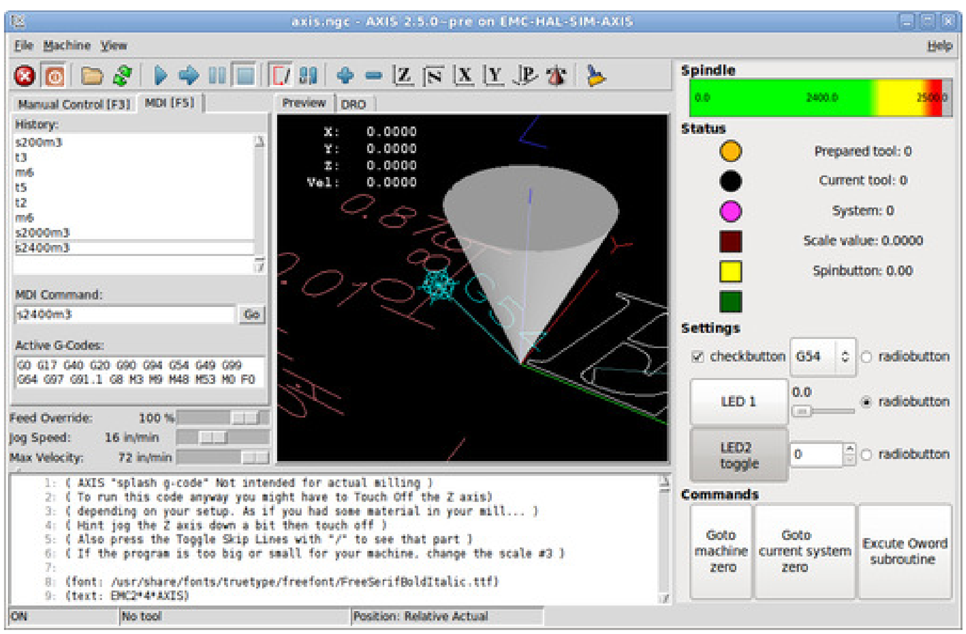


Figure 18 Linuxcnc – open source CNC machine controller.