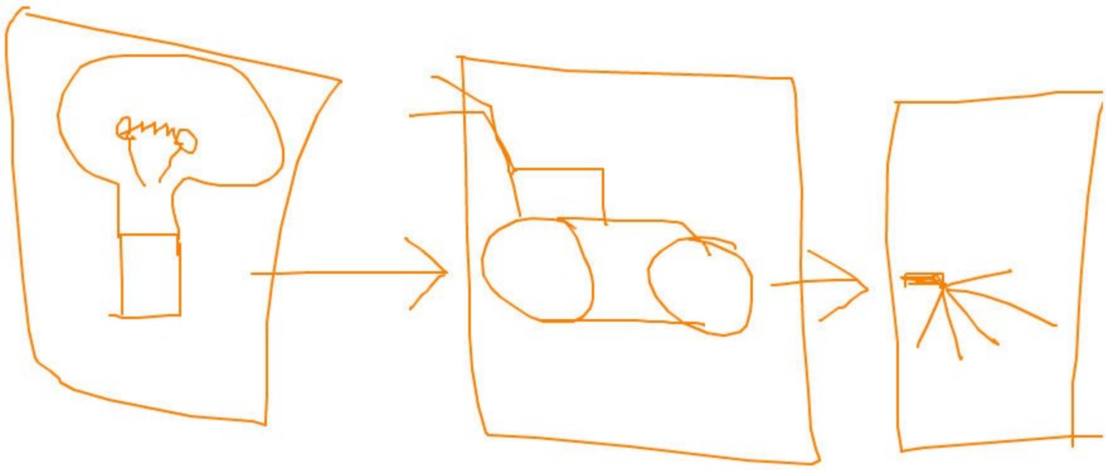
Appendix I Thesis in slides



- Group interviews with deminers
- Environment
- Local resources
- Breakable connection design
- Frame design
- Ground processing tool design

I.I. Group interviews with deminers

Group interviews to section leaders of NPA demining teams

Groups interviewed

Team n°	Gender	N° of section leaders	Date	Place
5	male	4 + 1 medic + 1 driver	5/2/2005	Along A9 (Kilinochi - Jaffna)

Team n°	Gender	N° of section leaders	Date	Place
8	female	4 + 1 medic	5/2/2005	Near to Talyady in their camp

Introduction – Task of the project

- Produce simple machines helping deminers
- Design them with deminers
- Teach elements of mechanic to a team of deminers
- Establish a workshop

Introduction - Advantages of machines:

- CONSTANT
- Good at simple tasks
- Good at repetitive tasks
- Work long hours
- Faster then humans

Introduction - Drawbacks of machines:

- STUPID
- Need of detailed and precise instructions
- Need human assistance
- Brake often
- Need of maintenance
- Need of power supply

Introduction - Phases of Design and Development of a machine:

- Identification of task: Area Reduction ?
- Idea: Many small cheap machines ?
- Design
- Analysis
- Prototype
- Test

Phase 1: IDENTIFICATION OF TASK - questions

- Area Reduction, steps:
- 1: (how is the minefield approached?)
- 2: (actions done by deminers in a sequence…)
- 3:
- 4:
- 5:
- 6:
- ….:

Phase 1: IDENTIFICATION OF TASK - *answers*

Team n°5

MAG technical survey team has cleared the base lane, a lane surrounding the minefield.

From the base lane they start clearing 1m wide lane (plus 20 cm for safety) every 10 m.

1. **visual checking through vegetation for tripwires**
2. **vegetation removal**
3. **light rake**
4. **water on ground (optional, only if ground is hard)**
5. **heavy rake**

Team n°8

1. **visual checking through vegetation for tripwires**
2. **vegetation removal**
3. **light rake**
4. **water on ground (optional, only if ground is hard)**
5. **heavy rake**

Phase 1: IDENTIFICATON OF TASK - question

- Where a group of machines could help you?

  (think about a group of animals going around doing something useful)

Bees, iguanas, dogs, snakes?

Phase 1: IDENTIFICATON OF TASK - *answers*

Team n°5

heavy rake + water

Visual checking for tripwire must be done by them, if you miss the wire the mine will detonate.
Vegetation removal is easy.

Team n°8

vegetation removal

The main problem in vegetation removal is cutting palm leafs and cutting roots of big trees.
Palm leafs are cut using the saw.

Phase 1: IDEA - questions

- What the group of machines could do?

Phase 1: IDEA - *answers*

Team n°5

machines should be no wider then the safety stick. They propose to develop a safety stick capable to roll on the ground alone and do the job of the heavy rake + water.

They suggest to create a machine mimicking tiger paws movement for removing the ground, as tiger nails are like heavy rake tines.

The machine should have a kangaroo pocket to collect the mines found.

They think that if it is cheap even if it detonates mines, is ok.

Team n°8

machines should cut vegetation only in front of the deminer. There's no use to cut vegetation in the areas where deminers will not work.

They suggest to use big trucks, such as the truck they use to go to work, or many small machines easy to handle.

Constraints - question

- Soil
- Vegetation
- Depth of mines
- Types of mines

Constraints - *answers*

Team n°5

SOIL:

There are 2 different types of soil: hard soil and light soil.

Hard soil must be wet before the heavy rake can work.

In summer time the soil is very dry.

In rainy season the soil is wet and raking is easy.

On the seaside there is sand and it's easy.

VEGETATION:

Removing vegetation is easy.

For the grass they use sickle. For small plants they use scissor. For palm leafs they use saw.

MINES:

Mines are found between 10 and 15 cm depth.

The types of mines found are: T72, P4Mark1

Team n°8

SOIL:

There are 2 different types of soil: hard soil and sandy soil.

Hard soil must be wet before the heavy rake can work.

VEGETATION:

They have to cut palm leafs at the hight of the person to access the area to demine.

MINES:

Mines are found between 5 and 15 cm depth.

The types of mines found are: T72, P4Mark1

Constraints - *answers*

Team n°5

FINAL COMMENTS:

The machine should weight enough otherwise after a detonation occurs, it will be thrown in the air.

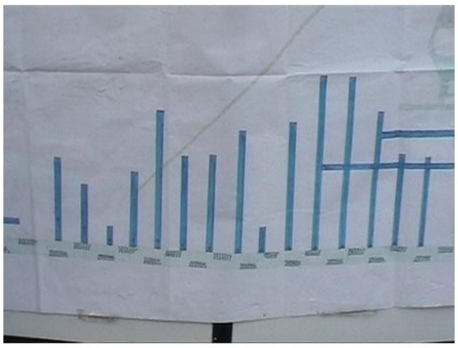
Conclusions

- 2 teams visited (1 men, 1 women):
  4 section leaders + driver and medic interviewed in each team
- Main results:
  - They would appreciate having a small machine (no wider then the base stick) helping them while they work
  - Possible applications: raking ground instead of heavy rake and vegetation cutting, specially palm leafs cutting
  - Ideas:
    - Bio-inspired by tiger paws – kangaroo pocket
    - Dimensions similar to base stick, anyhow small enough to fit in the vehicle
  - Problems:
    - Roots of big trees
    - tripwires

I.II. Environment

ENVIRONMENT

MINE BELTS

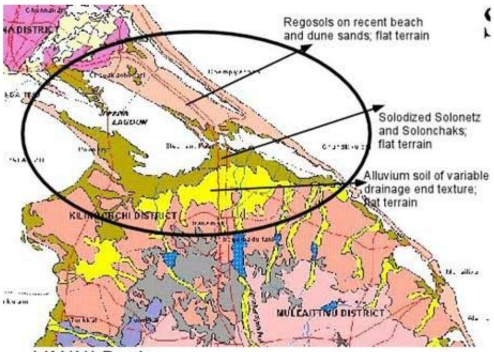


As usually mines have been laid in a pattern of four along defensive lines (called mine belts), clearance operations are primarily aimed at locating where the mine belt is, and later at clearing the belt.

MINE PATTERN


The pictures above show the typical mine pattern found in the Vanni; yellow poles indicate where mines have been found

SOIL 1



VANNI Region

The SOIL in the Vanni region is generally flat and soft, being of alluvium type.
Generally, soil in the Vanni region is highly contaminated with metal.

SOIL 2

These are different types of soil found in the Vanni

SOIL 3

-Parameters of interest for calculating drawbar pull, P:

Strength - Cone Index, CI [kPa]
Cohesion, c [kPa]
Angle of internal friction, phi [°]

Strength - Cone Index:

I. from Somapala, 1991, Alfisols soil in the dry zone of Sri Lanka (the most common soil), CI:
   0-150mm layer within forest belt: 360-400 kPa
   90-150mm layer within cultivated soil: 200-600 kPa

II. from Indraratna, 2005, analysis of coastal soil layers after Tsunami occurrence (once the wave receded fine sediments and debris settled), CI:
   500-1000mm layer loose sand plus organic sediments: 500kPa

Cohesion and Angle of Internal friction:

from Macmillan, 2007, typical values for sandy soil:
c = 7-15 kPa
phi = 30°

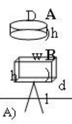
LANDMINES 1

LANDMINES found in the Vanni are mainly small, plastic AP mines.
The most common types are: Type 72, P4 Mark 1, and VS-50.

Rangan "Jony" 99, a locally manufactured mine based on the P4-Mark1 has also been widely used.

Other types of mines found in the region include the locally made wooden case small AP mine "Jony 95", the Claymore type directional fragmentation mine, few examples of improvised AP mines using mortar bombs and few AT mines, usually found at the end of each defensive belt.

LANDMINES 2 - LIST

device	type	fragmentation (Y/N)	can be activated by	dimensions 	explosive content	placement wrt ground surface (over, just below, below)	minefields with it
Type 72 A	AP mine	N	5 kg force on pressure plate, abrupt movement, fracture	A) h = 37 mm D = 78 mm	50 g of TNT	below	many
P4 Mark 1	AP mine	N	10 kg force on pressure plate, abrupt movement, fracture	A) h = 38 mm D = 70 mm	30 g of Tetryl	below	many
Jony-Rangan 99	AP mine	N	10 kg force on pressure plate, abrupt movement, fracture	A) h = 55 mm D = 88 mm	30 g of TNT	below	many
VS-50	AP mine	N		A) h = 45 mm D = 90 mm	45 g of RDX	below	many
Jony- 95	AP mine	N		box: 67x67 x105	120-150 g of plastic explosive	below	many

LANDMINES 3 – LIST cont.

device	type	fragmentation (Y/N)	can be activated by	dimensions	explosive content	placement wrt ground surface (over, just below, below)	minefields with it
Claymore AP mine Y	AP mine	Y	force on tripwire, abrupt movement, fracture	B) h = 81 mm w = 216 mm d = 43 mm l =	68 g of C4	over	many
improvised mortar mine	AP mine	Y	force on tripwire, abrupt movement, fracture	B) h = ?? w (D)= 81 mm l =		over	few
small rifle	UXO	Y	abrupt movement, fracture	A) h = 50-150mm D = 35-60mm	50 -100 g of	just below	many
hand grenade	UXO	Y	abrupt movement, fracture	A) h = 50-150mm D = 35-60mm	50 -100 g of	just below	many
AT mines	AT mine	N	force on pressure plate, abrupt movement, fracture			below	many, but only few in predictable positions

RAKES

Deminers working in the Vanni are simply equipped with RAKES: they proceed to full excavation of the area to be cleared at the depth of 10 cm, specified by the authorities. A detailed description of how the REDS system works is provided by Andy Smith in his website, http://www.nolandmines.com/RakeEDsystem.htm

Heavy rake

Light rake

VEGETATION

For reasons of convenience we have classified VEGETATION of the region in three different types:

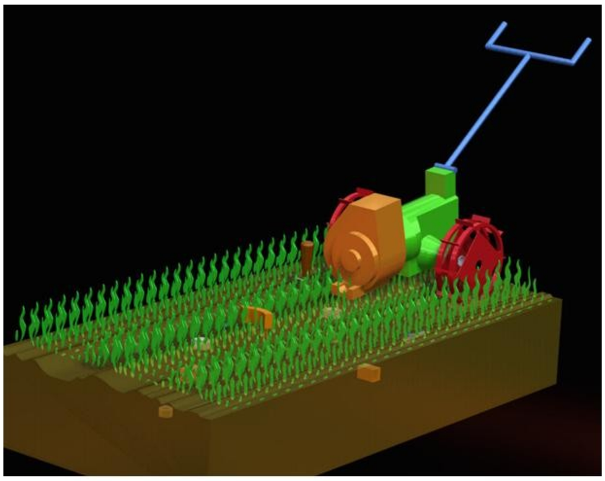
Light vegetation, where grass is prevalent:

Medium vegetation, where bush is prevalent:

Heavy vegetation, where bush is prevalent:

MODEL

A 3D model of the environment where the machine will work has been prepared to better visualize the problem



I.III. Local resources

TRACTOR UNIT
MODULE –
LOCAL RESOURCES

Smallest truck already available
to NPA

Isuzu ELF

Boot dimensions:
L: 5000mm
W: 1800mm

Load capacity:
2000kg

Biggest power tiller available in Sri Lanka

DONGFENG DF 12L

Dimensions:
L: 2680mm
W: 960mm
H: 1250mm

Weight:
350kg +
implement

ISUZU ELF
Boot dimensions:
L: 5000mm
W: 1800mm

Load capacity:
2000kg

Power tiller producers and supplier

Jinasena centres in Sri Lanka

Producer in China:
Chanzhou Dongfeng Agricultural Machinery Group
Model name:
Dongfeng DF-12L

Supplier in Sri Lanka:
Jinasena Agricultural Machinery

Model name:
AHT-12

Sri Lankan and Italian Power Tiller characteristics

Overall dimensions:
L: 1900mm W: 770mm H: 850mm
Weight: 243kg
Travelling speed (I gear): 1.1km/h
Engine: 10hp
Differential: yes
Gears: 3 forward, 3 reverse
Possibility to reverse handler: no
Cost: 100€ secondhand

Overall dimensions:
L: 2680mm W: 960mm H: 1250mm
Weight: 350kg
Travelling speed (I gear): 1.4km/h
Engine: 12hp
Differential: yes
Gears: 6 forward, 2 reverse
Possibility to reverse handler: no
Cost: 70€ secondhand, 250€ new

I.IV. Breakable connection design

TRACTOR UNIT MODULE
–
BREAKABLE
CONNECTION
DESIGN

Aim

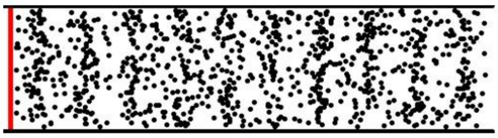
Drive over landmines safely, without damaging the power tiller body

(allow only minor adjustments in the field)

Explosion 1/2

The energy released during a detonation of an explosive charge, driven by the blast/shock wave within the ambient is transmitted to all what is found on the way.

Wave: disturbance which progresses from one point in a medium to other points without giving the medium as a whole any permanent displacement.

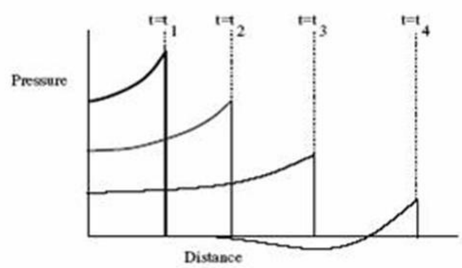


Like a mexican wave in a stadium

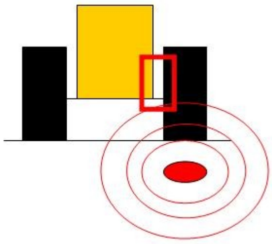
Explosion 2/2

Characteristics of blast waves:

- pressure riches very high values
(i.e. 13.6 bar at 1.71m from 3kg of TNT charge)
- speed of propagation is supersonic
- the wave compresses and heats the material that it flows through an irreversible process
- wave looses energy while traveling



Idea

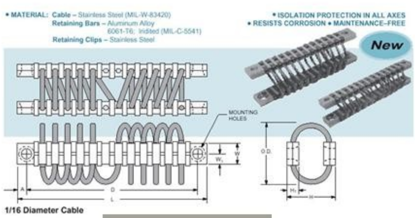


Absorb energy transported by shock wave before it enters the drive train through the axle

Some ideas from the state of the art

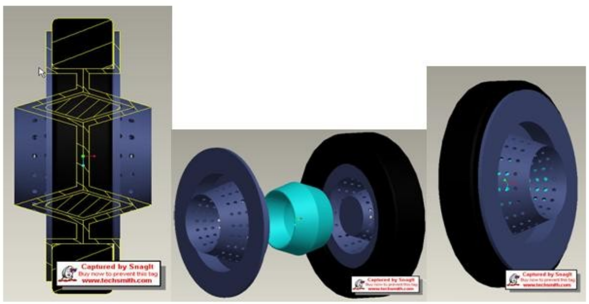
Wheel of Mars Rover

Cable isolators



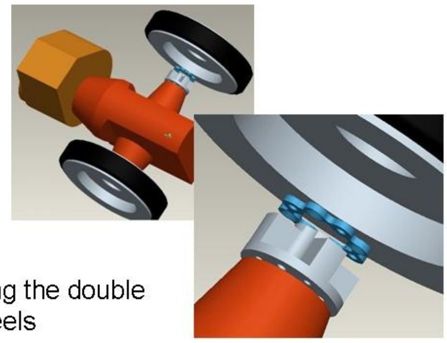
Possible wheel for power tiller

Wheel structure filled in with water



Idea investigated: breakable connection

IDEA: interrupt physical connection between axle and wheel, by letting the wheel to drop-off in case of explosion



→ design of a breakable joint solving the double function of protecting body and wheels

Characteristics:

- brittle material – cast iron
- able to withstand normal load conditions and break under explosion
- adaptable to the existing flange
- low cost

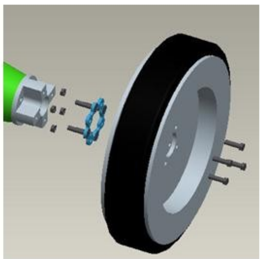
Design

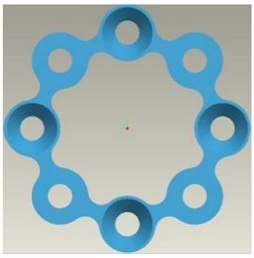
Features:

- fitting to existing flange
- 8 holes:
  4 cone shaped, hosting screws to fasten the connection to the flange
  4 simple, hosting bolts to fasten the connection to the wheel

-ring shape with reduced material between holes to weaken the structure and favour failure in case of explosion

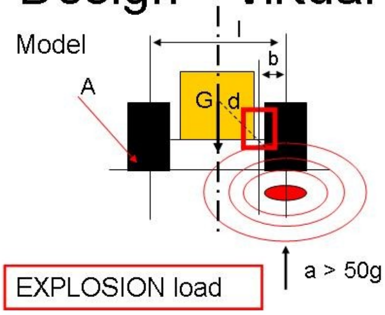
-material: cast iron ASTM 30 class





Design – virtual testing (FEM analysis)

Finite Element Method

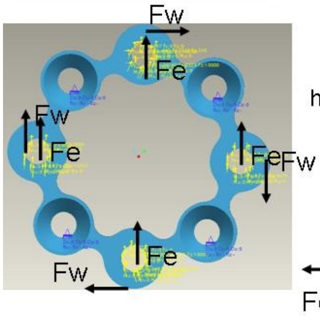


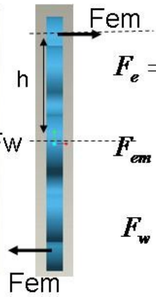
$$M_A = I_A \cdot \&\&$$

$$\&\& = \frac{a}{l} \qquad M_A = 26375 \cdot 10^3 [N \cdot mm]$$

$$I_A = I_G + m \cdot d^2$$

Cast iron 30ASTM grade:
S_{ut} = 213.59 MPa tensile strength
S_{uc} = 751.01 MPa compressive strength

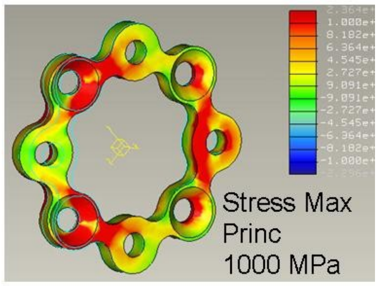




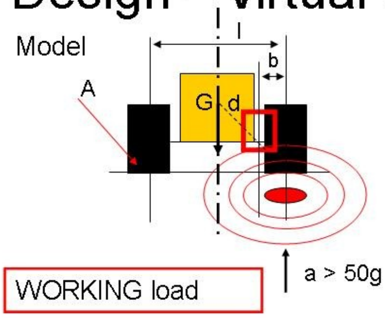
$$F_e = \frac{M_A}{l}$$

$$F_{em} = \frac{F_e \cdot b}{2 \cdot h}$$

$$F_w = \frac{T_w}{4 \cdot h}$$



Design – virtual testing (FEM analysis)



$$M_A = I_A \cdot \&\&$$

$$\&\& = \frac{a}{l} \qquad M_A = 26375 \cdot 10^3 [N \cdot mm]$$

$$I_A = I_G + m \cdot d^2$$

Cast iron 30ASTM grade:
S_{ut} = 213.59 MPa tensile strength
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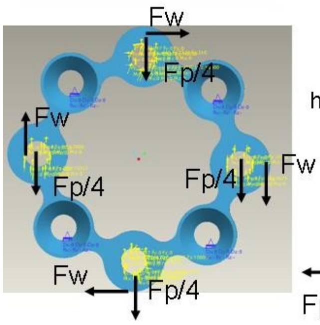
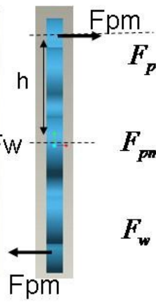
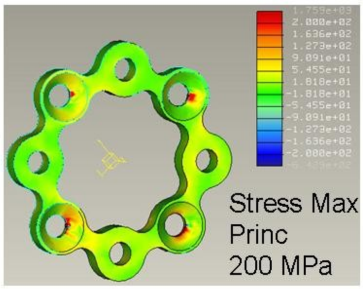




$$F_p = \frac{1}{2} mg$$

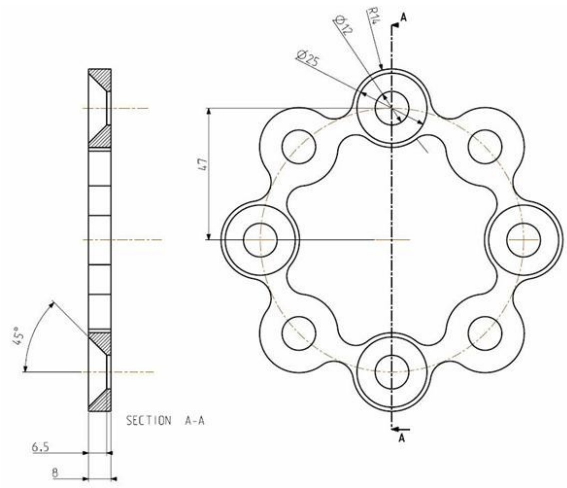
$$F_{pm} = \frac{F_p \cdot b}{2 \cdot h}$$

$$F_w = \frac{T_w}{4 \cdot h}$$



Design

Dimensions:



I.V, Frame design

TRACTOR UNIT MODULE
–
FRAME
DESIGN

Aim

Support front wheels and tracks
Support Ground Processing Tool
and vegetation cutting tool
Allow remote control

Tractor Unit will be a remotely controlled PLATFORM, where to attach different tools (even simple agricultural tools, allowing also weak people to do heavy agricultural works)

Power tiller existing structure

Dongfeng DF-12L
Sri Lanka

p.t.o

Possible places to attach frame or tools

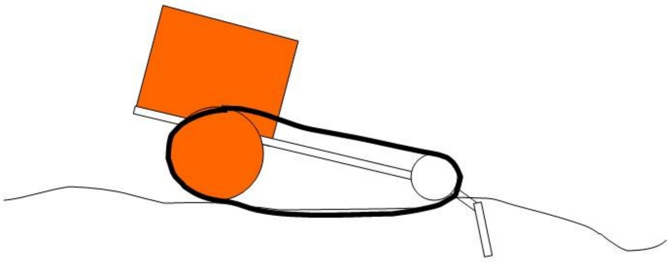
Brakes: NO

Power tiller modifications

Plus
tracks, brakes and attachement for tools

brakes mounted on
the semi axles allow
turning while braking
one of the two

Idea



Same frame supporting tools, front additional wheels and tensioning the track
Disk brakes secondhand from motorbikes

Brake design

Disk brakes secondhand from motorbike

Disk

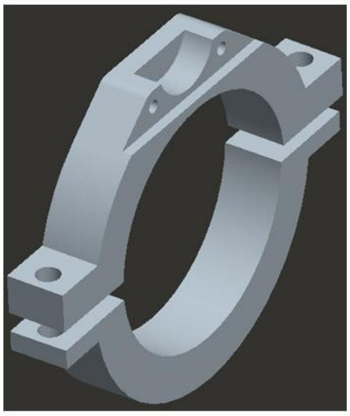
Floating caliper with double piston

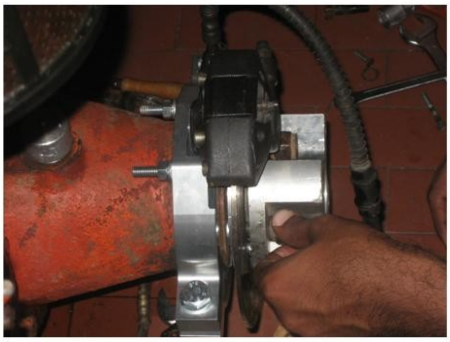
Lever and fluid reservoir

Characteristics:
-low cost
-easily available
-can be fit to existing structure with little adjustments

Brake fixtures design

-fitting to existing structure, only small additional flange required
-aluminium

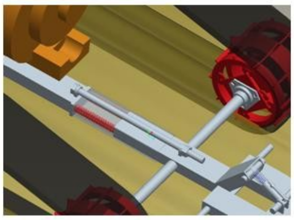


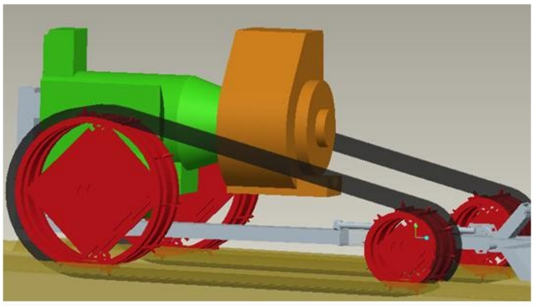


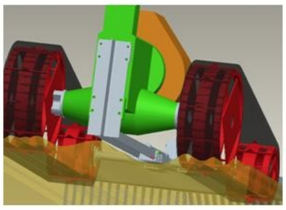
Frame design

Features

- made of steel standard profiles
- cheap and easy to weld (assembly or manitenance) near to the field
- need of specially designed open cage sproket wheels
- embedding tensioning system







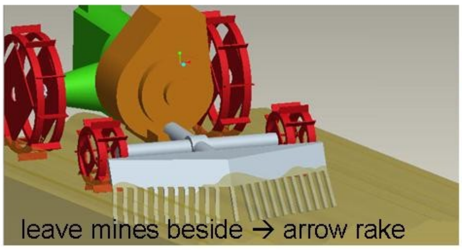
I.VI. Ground processing tool design

GROUND
PROCESSING TOOL
MODULE - DESIGN

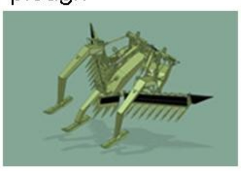
Ground Processing Tool

AIM: remove landmines from the lane where the machine is working and to process soil at constant depth (100mm)

Mine disposal problems:
- tracks do not have to pass over mines already lift up
→ 2 possibilities: collect mines, leave mines beside



Analysis of similar tools:
agriculture: potato digger
military: mine plough

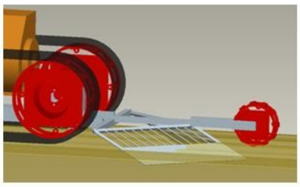


Ground Processing Tool - shape

Implications:

1. weight transfer →soil tool interaction force contributes transferring weight from rear to front (undesirable)

2. depth control → depends on hitch system



using semi mounted, plus depth control wheel → helps reducing weight transfer from rear to front

3. soil processing → cutting and sieving:
   cutting soil at required depth
   and pass it through a sieve allowing
   any object bigger then a mine to be lifted up

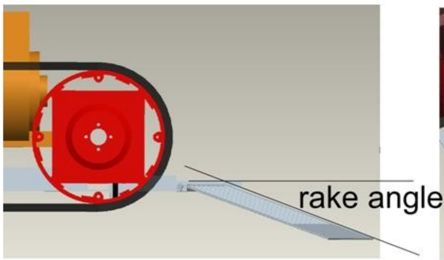
space between tines: 40mm

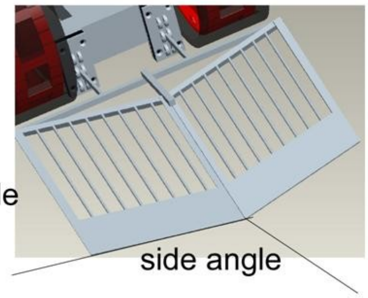
Ground Processing Tool - shape

To simplify manufacturing: plane shapes

→ the arrow rake is defined by two angles:

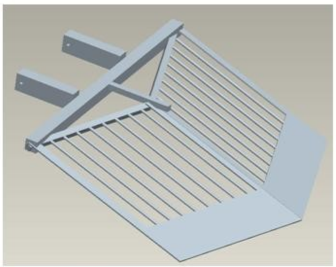
Rake angle = between the tool and the horizontal (ground), in the longitudinal vertical plane
Side angle = between the tool and the vertical plane, on the horizontal plane





Ground Processing Tool - shape

I design:



Rake angle = 20°
Side angle = 30°

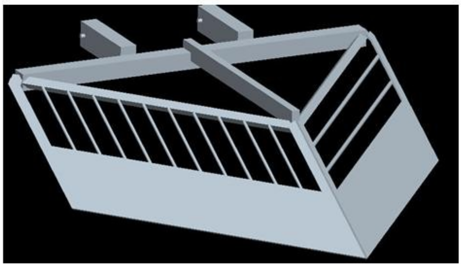
Crap-up prototype: cardboard model and test in sand

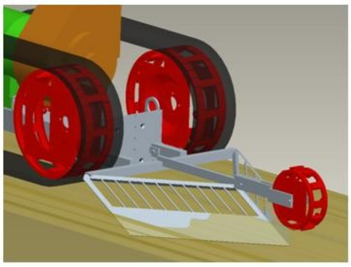
Ground Processing Tool - shape

II design:

Side angle = 50°, as small side angle causes the soil to move to the side

→ Rake angle = 30°, increased to keep the distance of tool tip from the frame relatively small





- 2 different tine positions for testing which one works better
- open cage depth wheel, mounted on friction arm for reducing damages from possible blast
- possibility to add vibratory motion: cylinder or bumpy wheel

Soil-tool interaction force, S

-Estimation of force required to push/pull ground processing tool, S:

I. Agricultural Machinery Management Data, ASAE D497.5 FEB2006, published by ASABE:

$$S = F_i \cdot [A + B(V) + C(V)^2] \cdot W \cdot T$$

Where, F is a dimensionless soil texture adjustment parameter whose value is given in ASABE tables, A, B and C are machine specific parameters, given in ASABE tables, V is field speed, W is machine width, T is tillage depth. For pushing a tool 1200mm wide, at 100mm depth, at 1.1km/h, in fine textured soil

S = 2500N

II. Extrapolating data regarding a 19 tines scarifier fitted with 150mm wide dart points, Kruger&Palmer, 1982:

S = 2000N

III. The Australian Tillage and Trafficability Data Bank – regression eq.'s:

For scarifiers in medium soil, optimal moisture, speed range of 0.53-3.27m/s, depth range of 29-150mm, with Variance Accounted for 47.6%,

$$D = 0.949 + 0.69 \cdot V + 0.01846 \cdot D$$

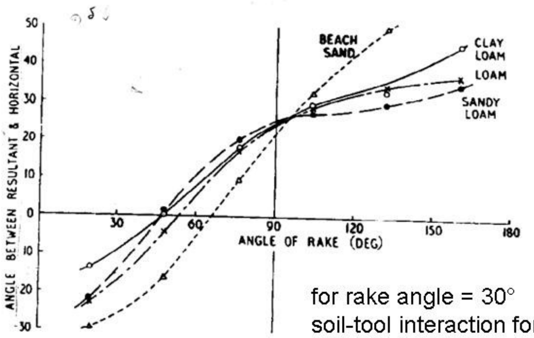
Where, V is ground speed [m/s], D is working depth [mm]

S = 3000N

Soil-tool interaction force, S

-Estimation of direction of soil-tool interaction force, S:

From Payne 1959:



for rake angle = 30°
soil-tool interaction force angle = 17°

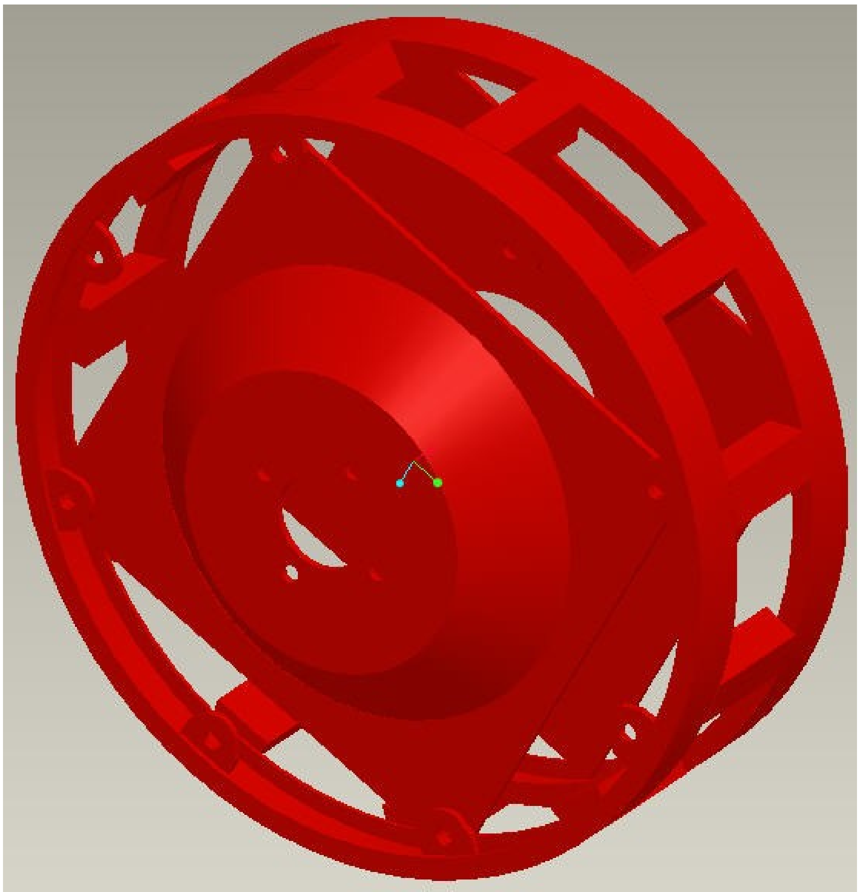
FIG. 7

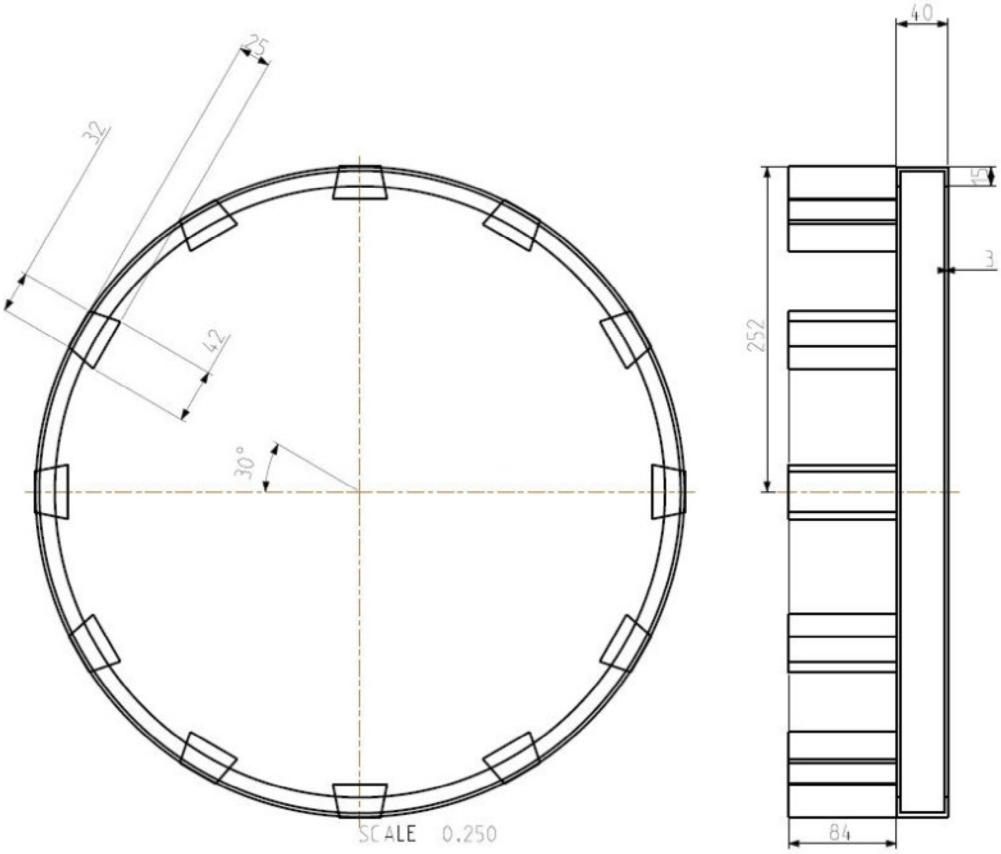
DRAUGHT – ANGLE OF RAKE

Appendix II Technical drawings

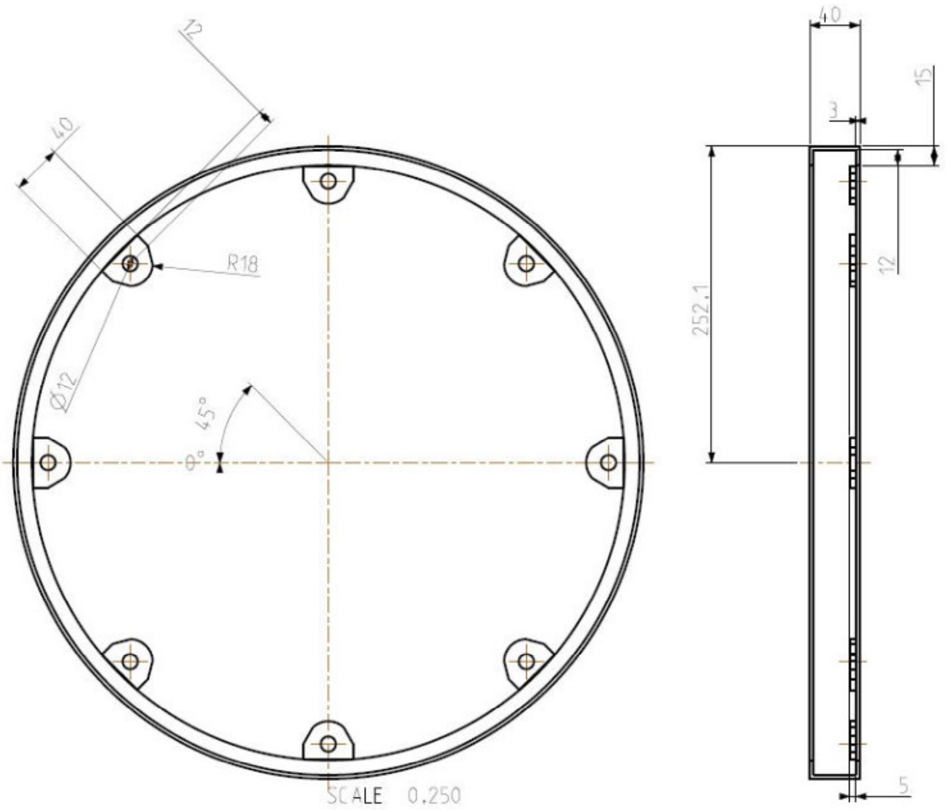
- Wheel
- Frame
- Brake fixtures
- Ground processing tool

II.I. Wheel

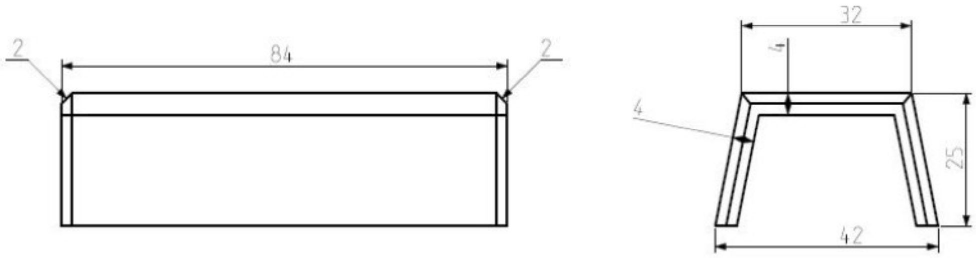




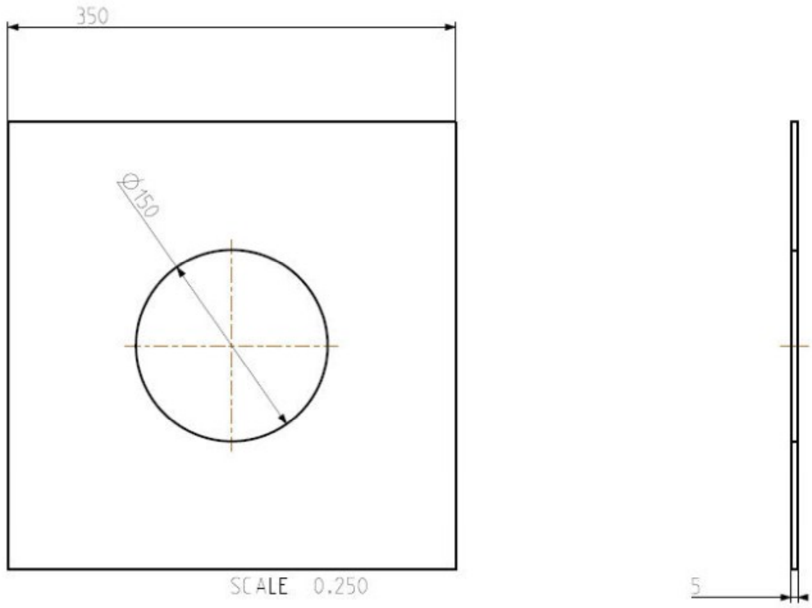
Università degli Studi di Genova DIMEC			
Progetto: POWER TILLER		Disegno n°: WHEELSPROCKETTRACKMODRIM1	
Scala: 0,250	N° pezzi:	Disegnato: Emanuela Cepolina	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: STEEL	Peso:



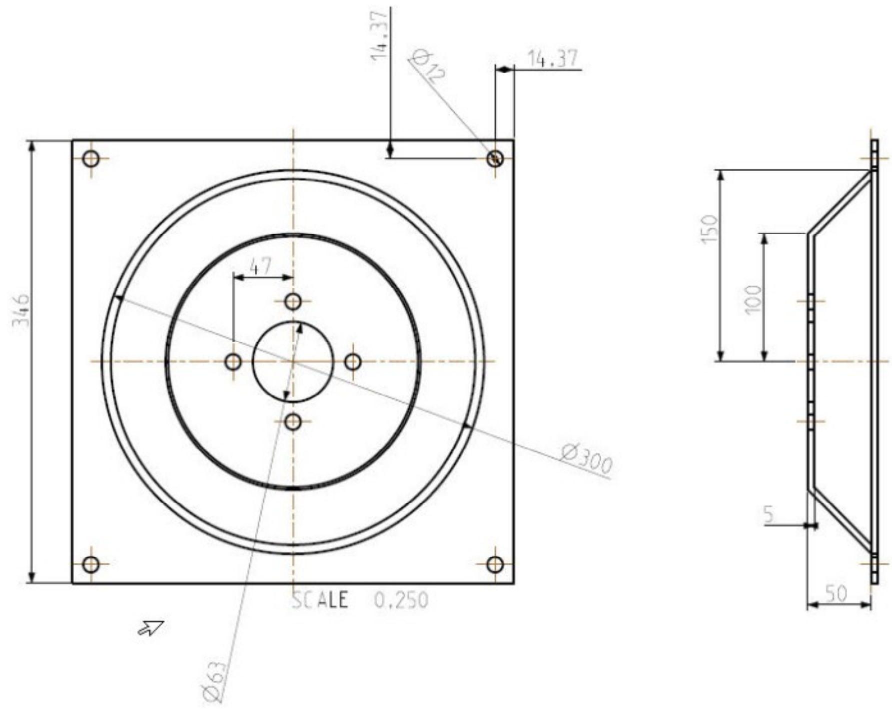
Università degli Studi di Genova DIMEC			
Progetto: POWER TILLER		Disegno n°: WHEELSPROCKETTRACKRING2	
Scala: 0,250	N° pezzi:	Disegnato: Emanuela Cepolina	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: acciaio	Peso:



Università degli Studi di Genova *DIMEC*			
Progetto: POWERTILLER FRAME		Disegno n°: WHEELSPROCKETLUG	
Scala: 1,000	N° pezzi: 44	Disegnato: Emanuela Cepolina	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: Acciaio	Peso:



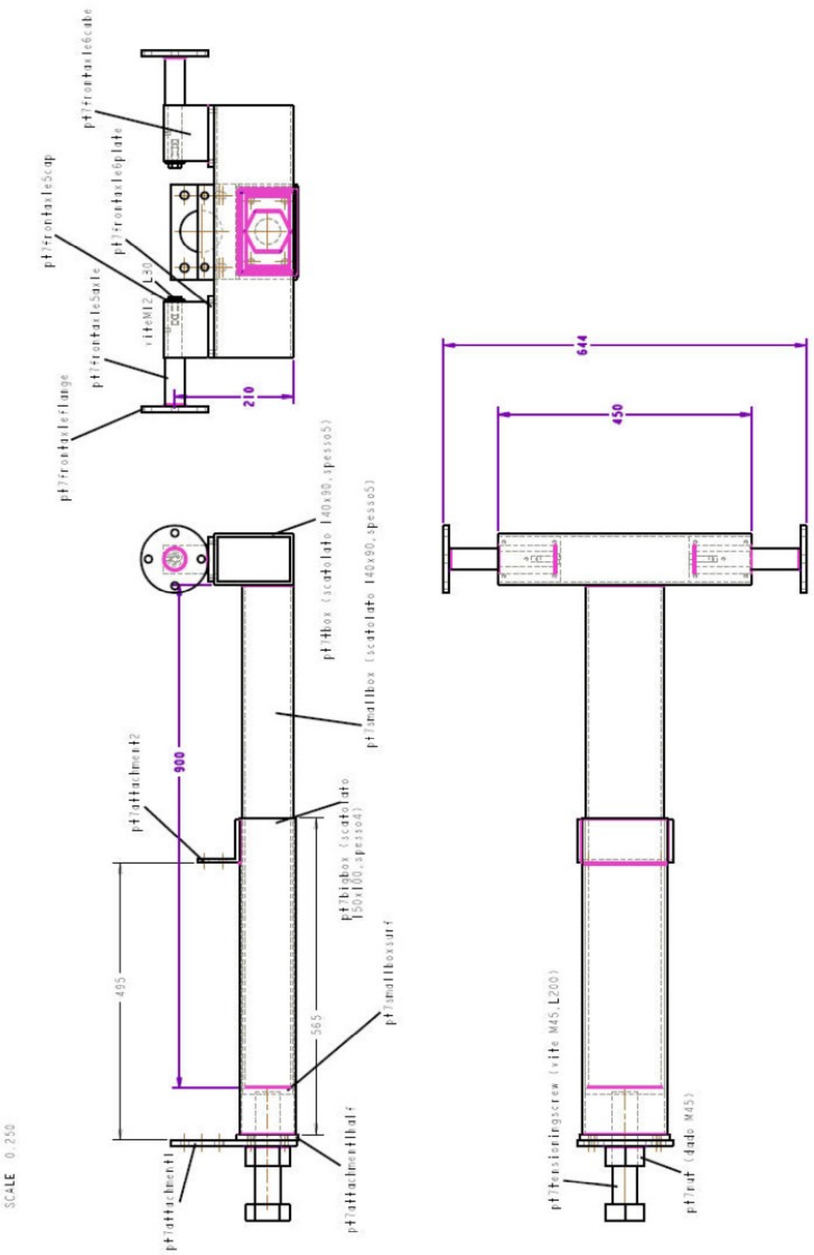
Università degli Studi di Genova DIMEC			
Progetto: POWER TILLER		Disegno n°: WHEELSPROCKETTRACKSQAUREPLANE	
Scala: 0,250	N° pezzi:	Disegnato: Emanuela Cepolina	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: acciaio	Peso:

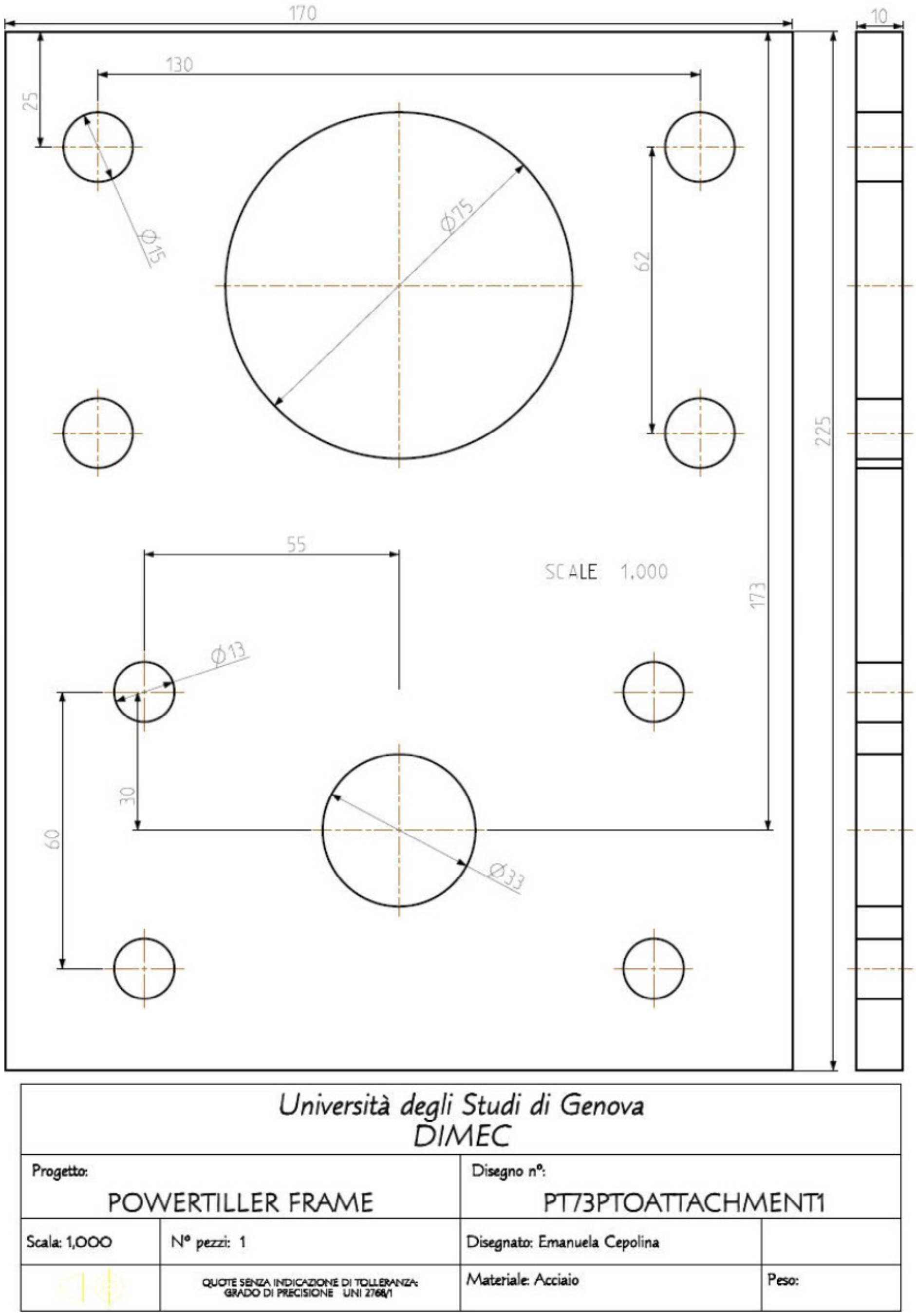


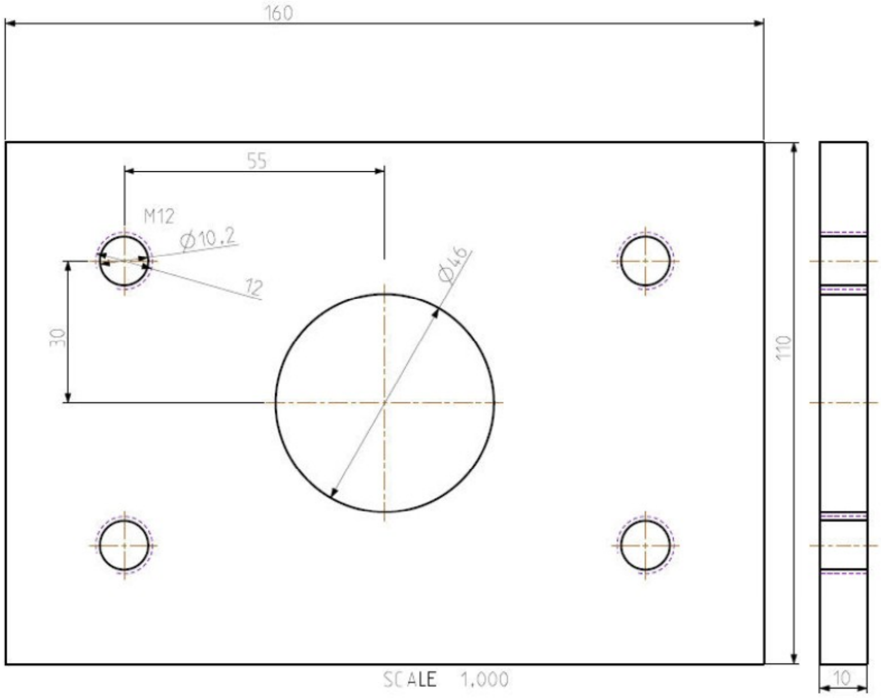
Università degli Studi di Genova DIMEC			
Progetto: POWER TILLER		Disegno n°: WHEELSPROCKETTRACKSQUARE	
Scala: 0,250	N° pezzi:	Disegnato: Emanuela Cepolina	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: acciaio	Peso:

Part name (tot n°)	**N°**	**Modifications**	**Verifications**
WheelSprocketLug	48	Change of shape from parallelepiped to tubular	
WheelSprocketTrackSquarePlane (4)	3	Hole: to be done D200	
	1 right front	To be welded 5mm inside to avoid touching between tbox and square	
	4	Corners: to be cut to fit into rings	

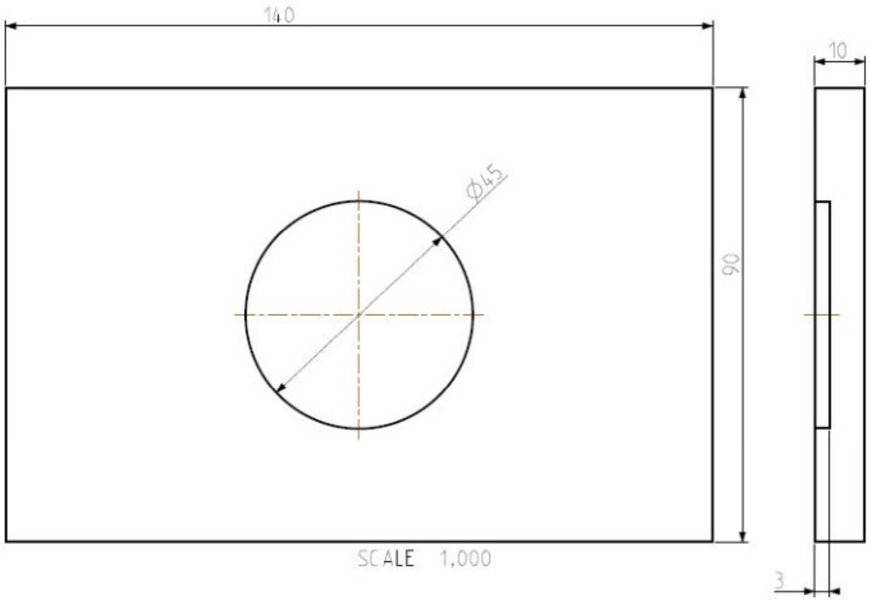
II.II. Frame



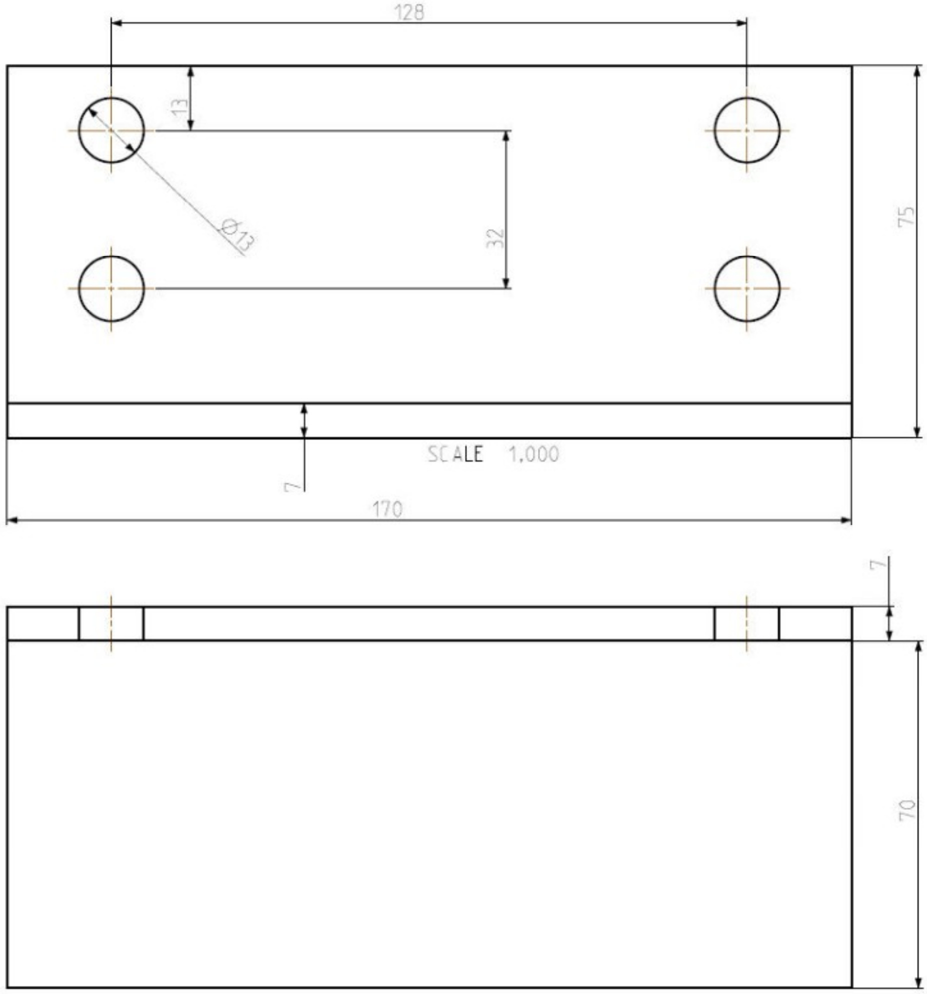

170
10
130
25
Ø15
Ø75
62
225
55
SCALE 1,000
173
Ø13
30
60
Ø33
Università degli Studi di Genova
DIMEC
Progetto:
POWERTILLER FRAME
Disegno n°:
PT73PTOATTACHMENT1
Scala: 1,000
N° pezzi: 1
Disegnato: Emanuela Cepolina
QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1
Materiale: Acciaio
Peso:



Università degli Studi di Genova *DIMEC*			
Progetto: POWERILLER FRAME		Disegno n°: PT7PTOATTACHMENT1HALF	
Scala: 1,000	N° pezzi: 1	Disegnato: Emanuela Cepolina	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: Acciaio	Peso:



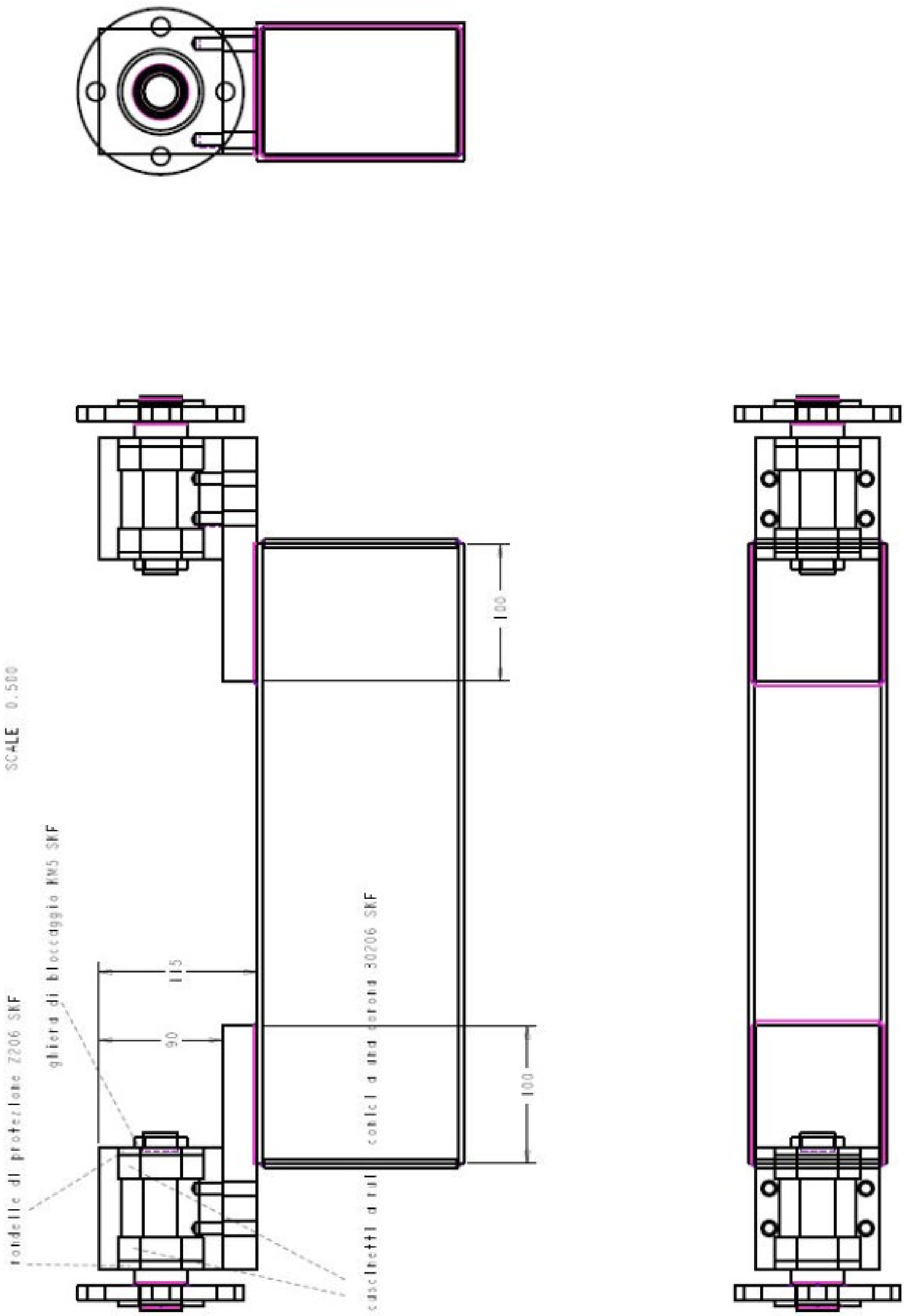
Università degli Studi di Genova DIMEC			
Progetto: POWERTILLER FRAME		Disegno n°: PTSMALLBOXSURF	
Scala: 1,000	N° pezzi: 1	Disegnato: Emanuela Cepolina	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: Acciaio	Peso:

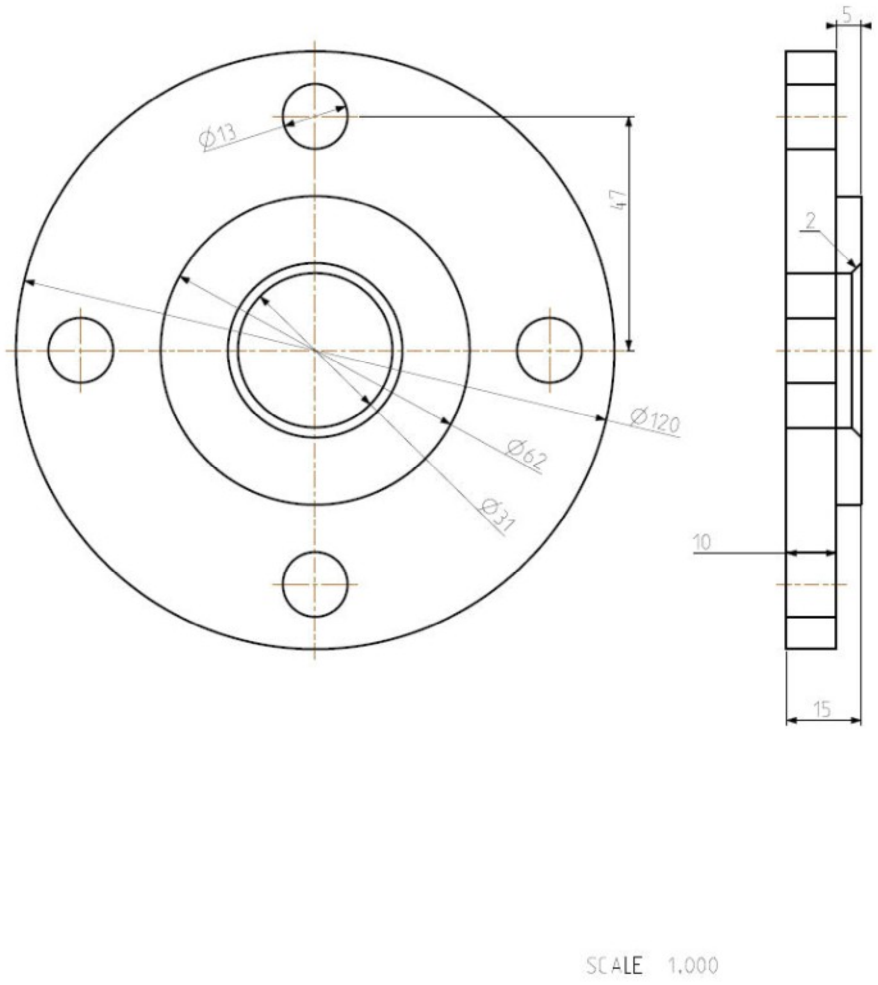


Università degli Studi di Genova *DIMEC*			
Progetto: POWERTILLER FRAME		Disegno n°: ATTACHMENT2	
Scala: 1,000	N° pezzi: 1	Disegnato: Emanuela Cepolina	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: Acciaio	Peso:

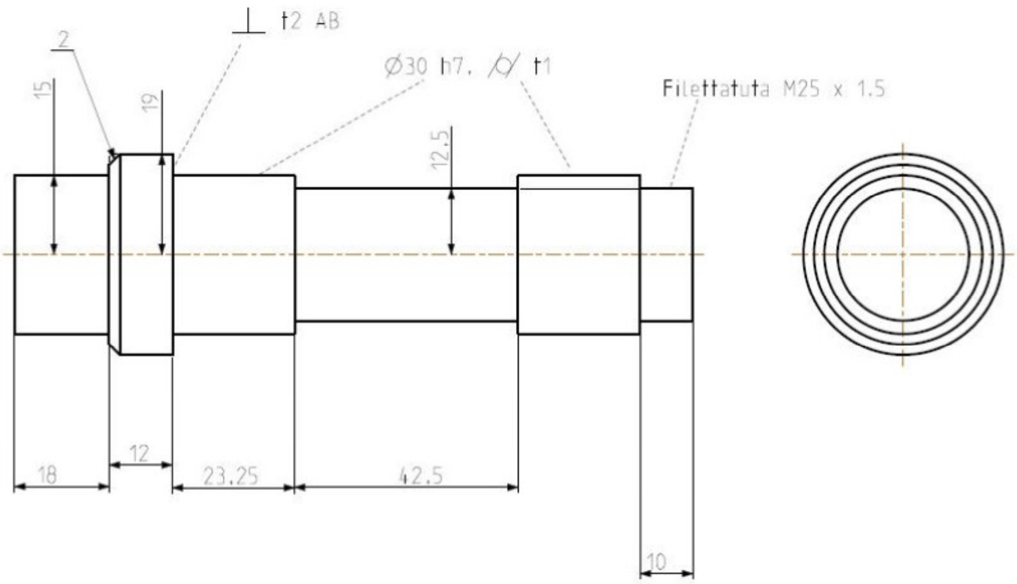
Part name (tot n°)	**N°**	**Modifications**	**Verifications**
Pt7tensioningscrew	1	M30 instead of M45	Max normal force the screw can stand before yelding (Sigmay=100N/mm^2): F = Sigma*A Cross section area A = pi*D^2/4= 710mm^2 F = 7100 N >>>> Sh=2500N OK
		280 long instead of 200	L
Pt7nut	1	M30 instead of M45 double height: h30	L
Pt7attachment1	1	Bottom hole D33	Robustness improved because now the hole is smaller
		Distance of four D13 holes from center of 33hole: H: 45 V: 20	A bit less stability as screws are placed more internally than before
Pt7attachment1half	1	Hole D33	Robustness improved because now the hole is smaller
		Thickness from 10 to 15	L
		Distance of four D13 holes from center of 33hole: H: 45 V: 20	A bit less stability as screws are placed more internally than before
Pt7 smalboxsurf	1	NO groove	L
		Dimensions changed to fit inside SmallBox: W: 130 H: 80	Maybe dimensions have to be reduced to actually fit into small box (140x90, s = 5)
		Welded half inside smallbox	L
Pt7 smallbox	1	Length could be shorten **820**	L
Pt7 attachment2	1	A L shaped standard profile used: dimensions: 80x80, s= 8	Hole distance from base unchanged, I have 5mm more in height, if it is necessary it can be cut. Angle might not be 90°.
Pt7Tbox3	1	Profile 100x150 can be used instead	To achieve the same axle for front axle as for rear axle, ground clearance reduced by: 87.1-10 = 77.1 Hitch for GPT: GPT height over soil: 140 when working at 100 depth, 90 when working at 150 depth Both >> than ground clearance Both << than (77.1+150) max height of box Or (by also reducing thickness of 6plate from 10 to 5) 87.1-5 = 82.1 Hitch for GPT: GPT height over soil: 140 when working at 100 depth, 90 when working at 150 depth Both >> than ground clearance Both << than (82.1.1+150) max height of box
			Holes for frontaxle6plate move internally (more space for screwing), by enlarging 6plate
			L

		Thickness:4	Verified FEM Max Von Mises Stress: 40N/mm^2 Max displacement: 0.185mm
		Thickness 5	Verified FEM Max Von Mises Stress: 32N/mm^2 Max displacement: 0.1mm
Pt/ stub axle	1 (assem bly)	New frontaxle 9	

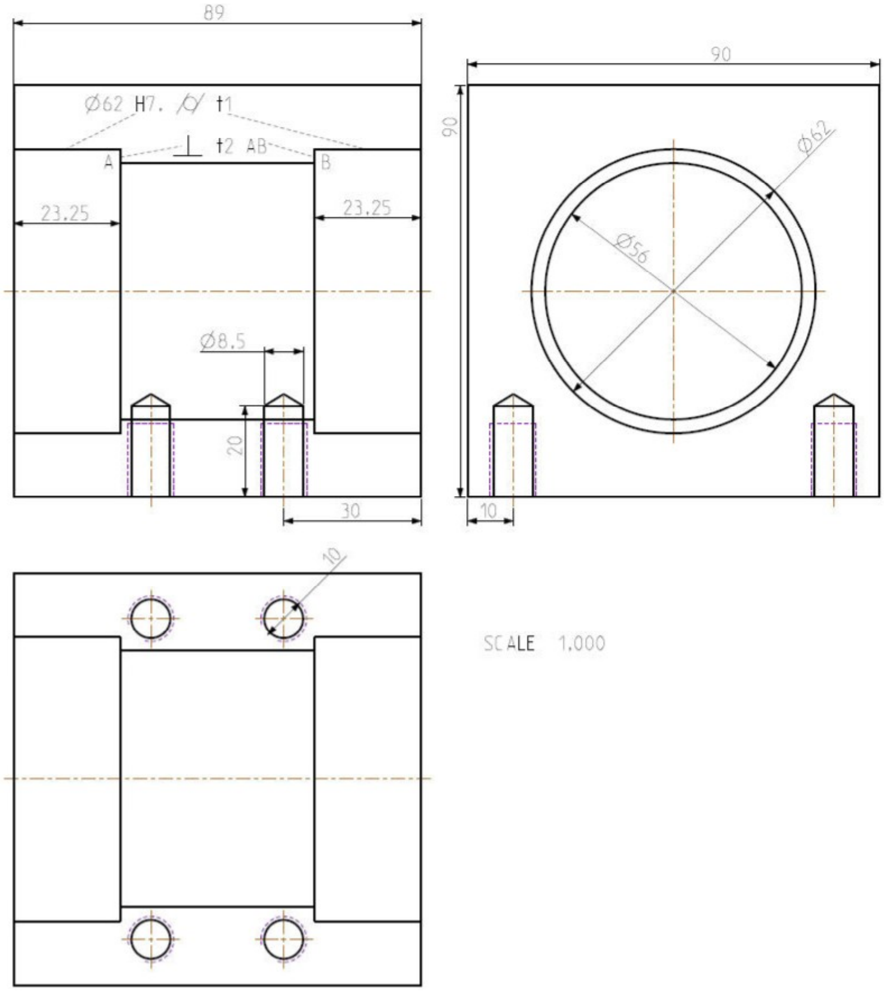

100
SCALE 0.500
ghiera di bloccaggio KM5 SKF
rondelle di protezione 7206 SKF
115
90
cuscinetti a rulli conici a una corona 30206 SKF
100



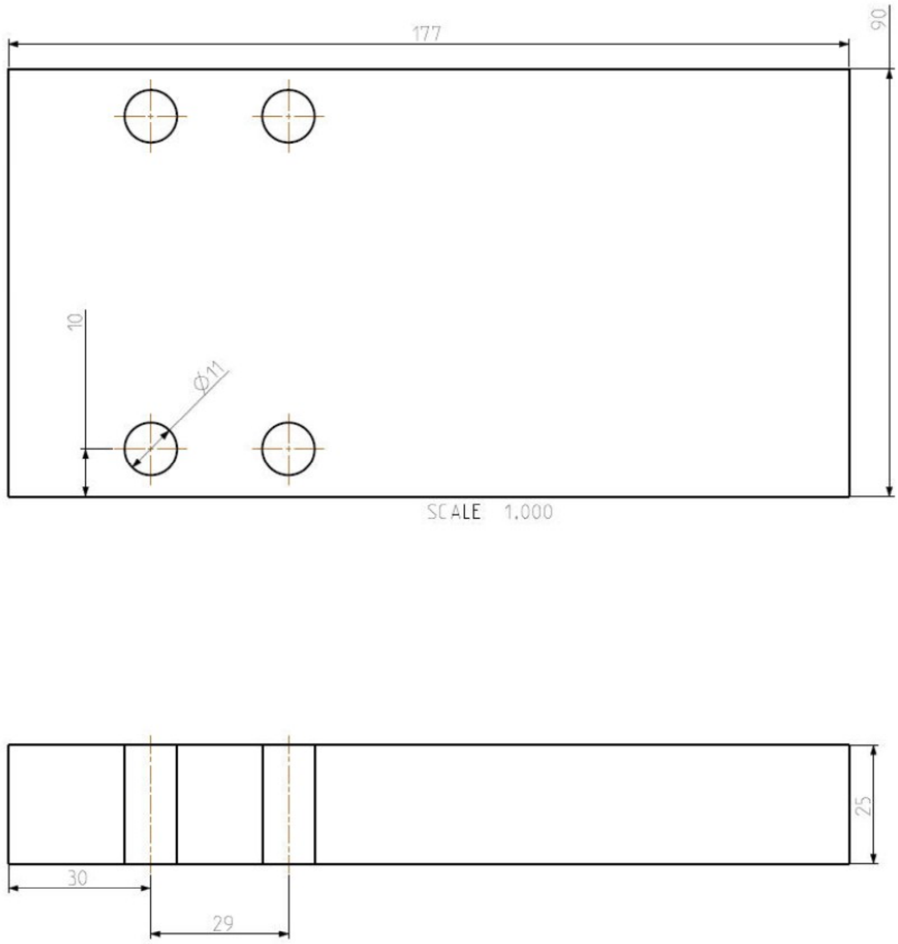
Università degli Studi di Genova DIMEC			
Progetto: POWERTILLER FRAME		Disegno n°: PT7FRONTAXLE9FLANGE	
Scala: 1,000	N° pezzi: 2	Disegnato: Emanuela Cepolina	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: Acciaio	Peso:



Università degli Studi di Genova DIMEC SCALE 1.000			
Progetto: POWERTILLER FRAME		Disegno n°: PT7FRONTAXLE9AXLE	
Scala: 1,000	N° pezzi: 2	Disegnato: Emanuela Cepolina	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: Acciaio	Peso:

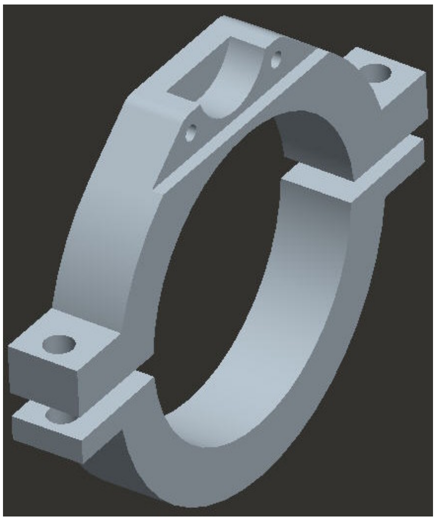


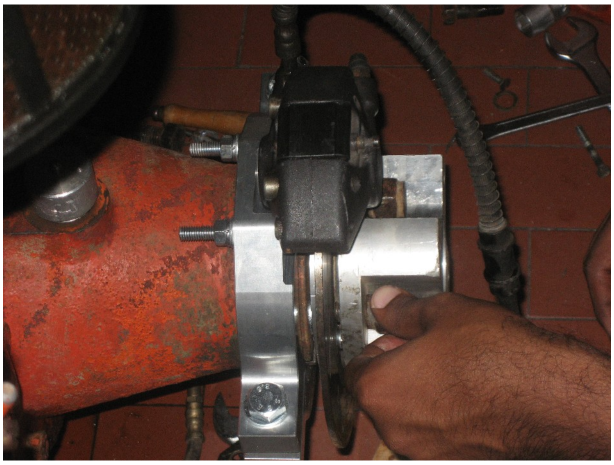
Università degli Studi di Genova DIMEC			
Progetto: POWERTILLER FRAME		Disegno n°: PT7FRONTAXLE9CUBE	
Scala: 1,000	N° pezzi: 2	Disegnato: Emanuela Cepolina	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: Acciaio	Peso:

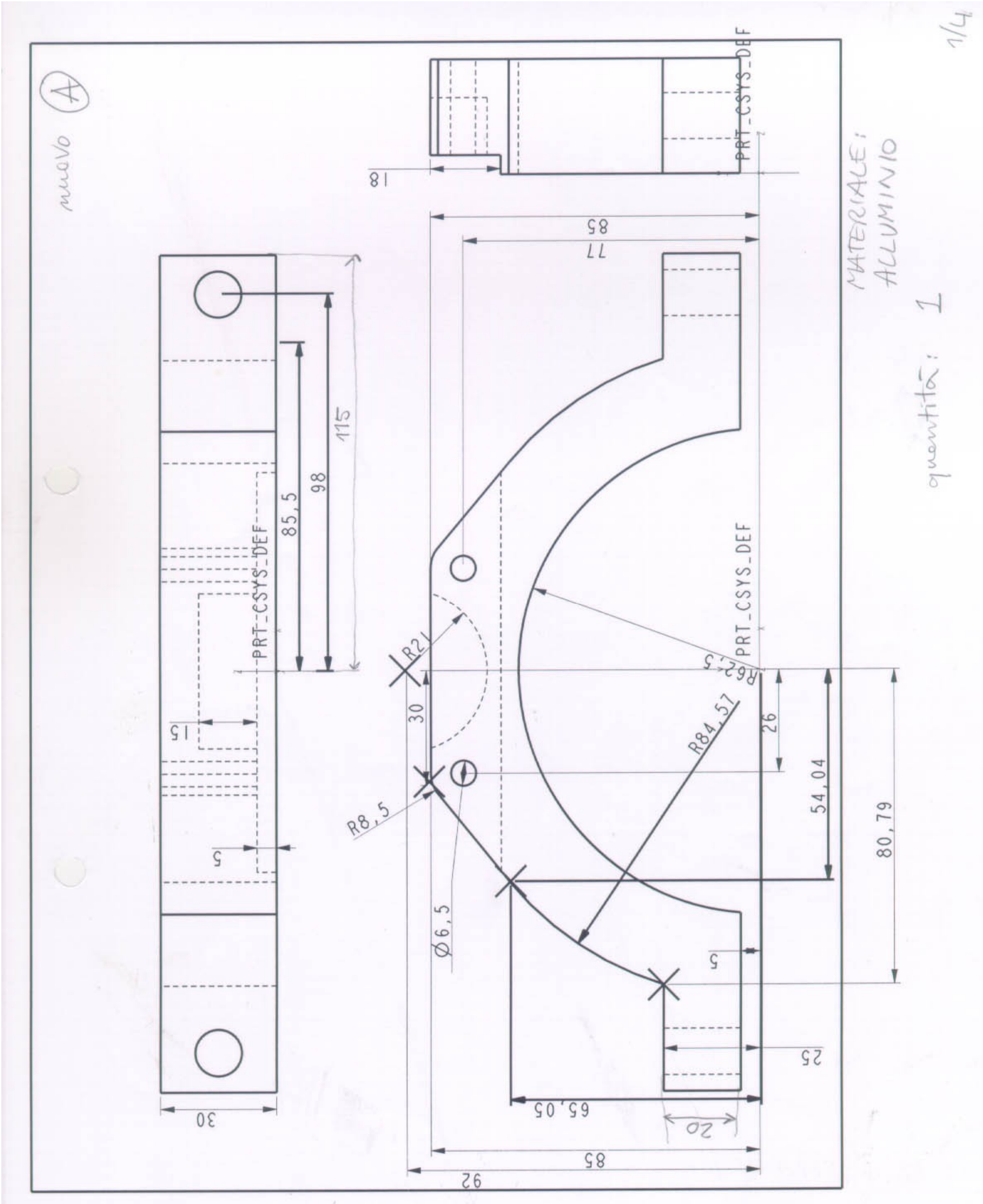


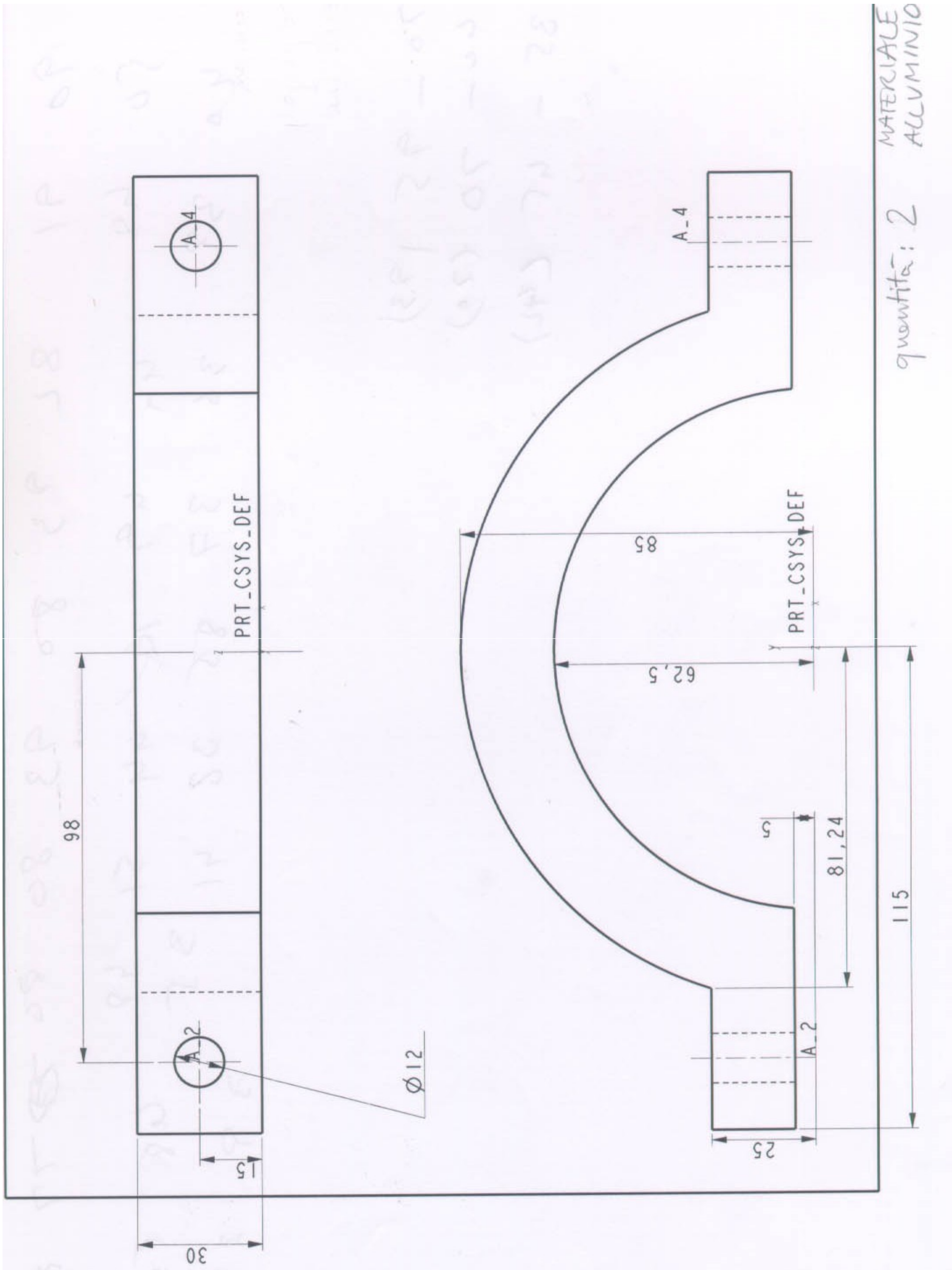
Università degli Studi di Genova DIMEC			
Progetto: POWERTILLER FRAME		Disegno n°: PT7FRONTAXLE9PLATE	
Scala: 1,000	N° pezzi: 2	Disegnato: Emanuela Cepolina	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: Acciaio	Peso:

II.III. Brake fixtures

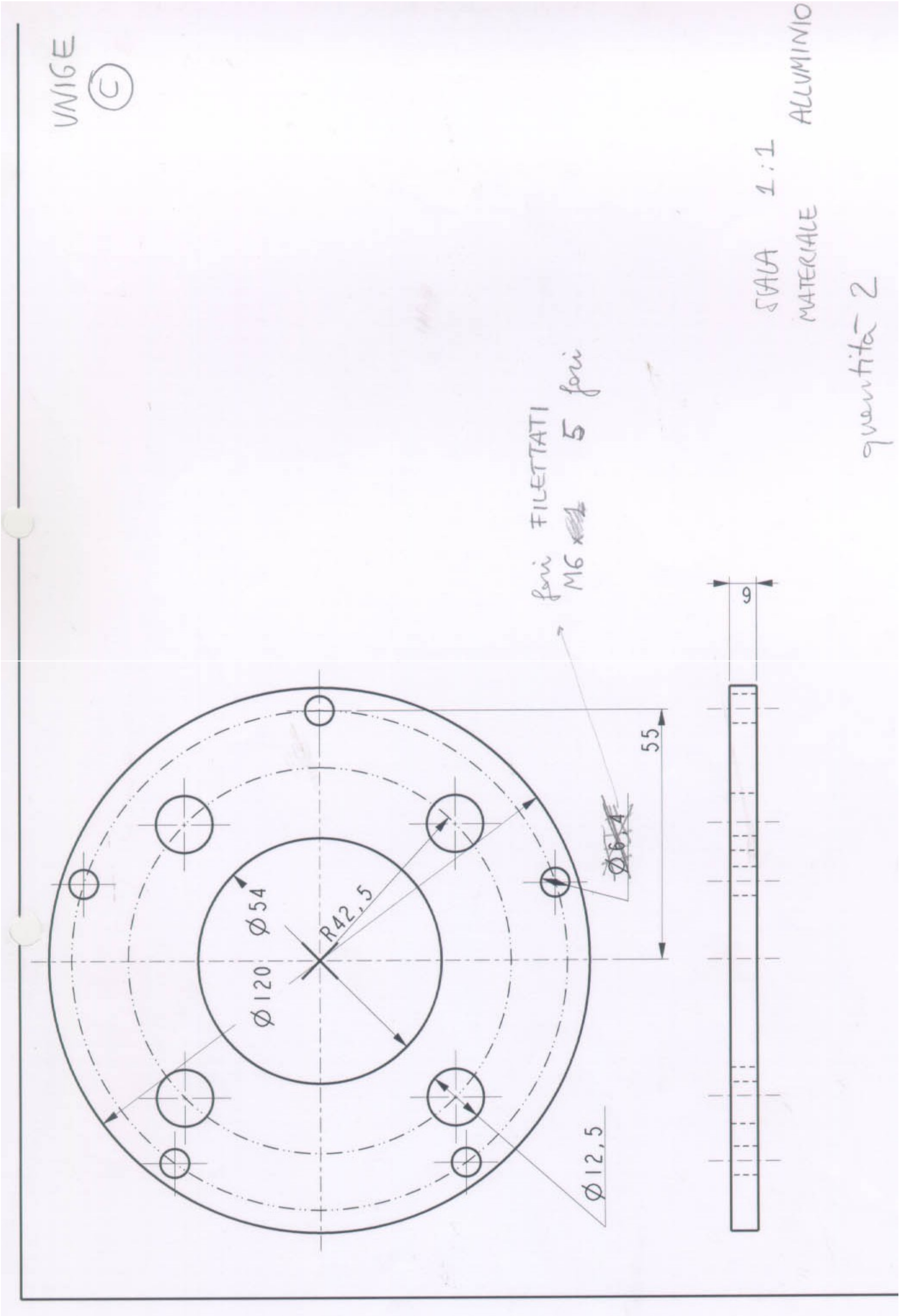


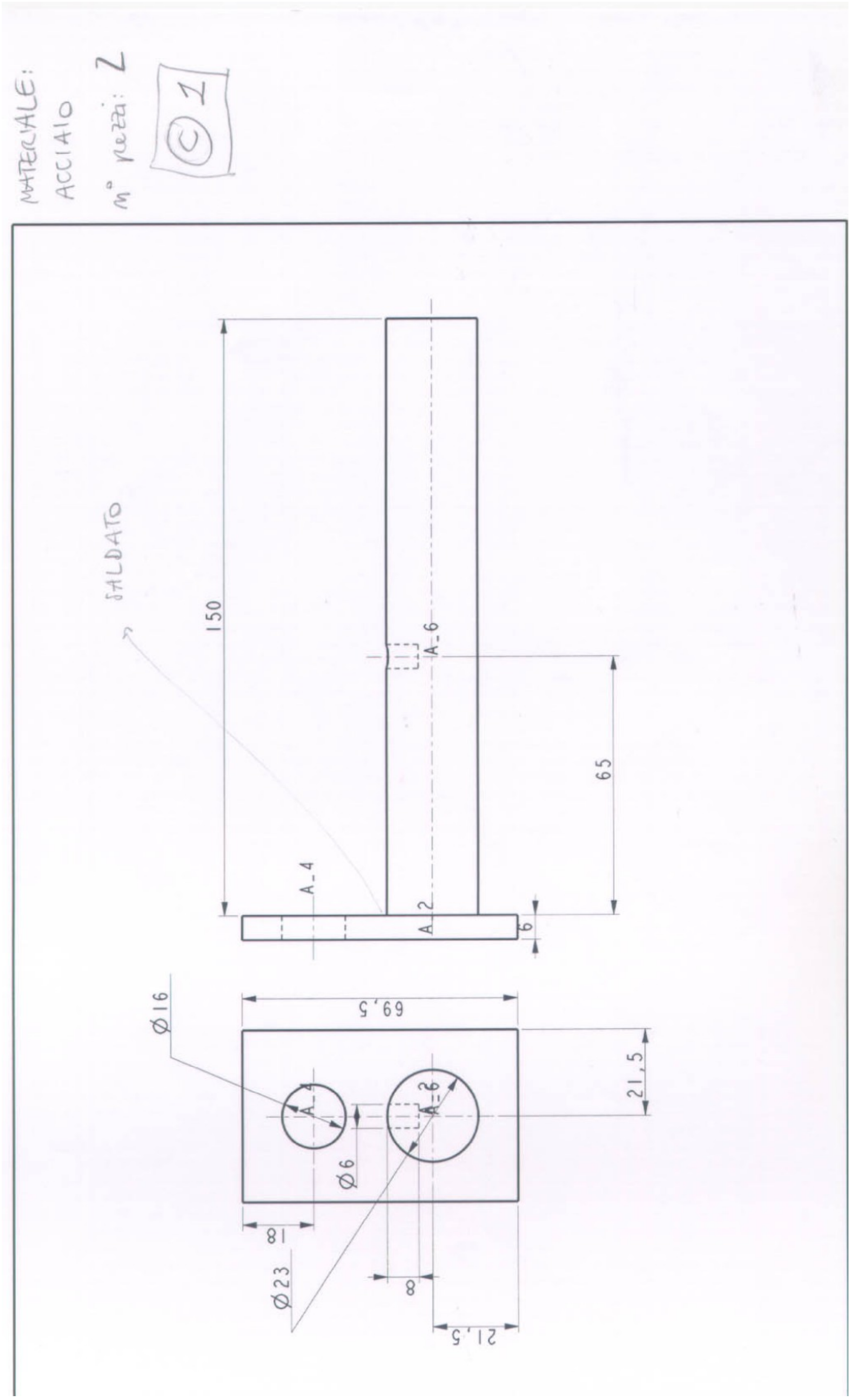



nuovo
A
1/4
MATERIALE: ALLUMINIO
quantità: 1
PRT_CSYS_DEF
18
85
77
115
98
85,5
R21
30
R62,5
R84,57
26
54,04
80,79
R8,5
Ø6,5
15
5
30
65,05
20
25
92

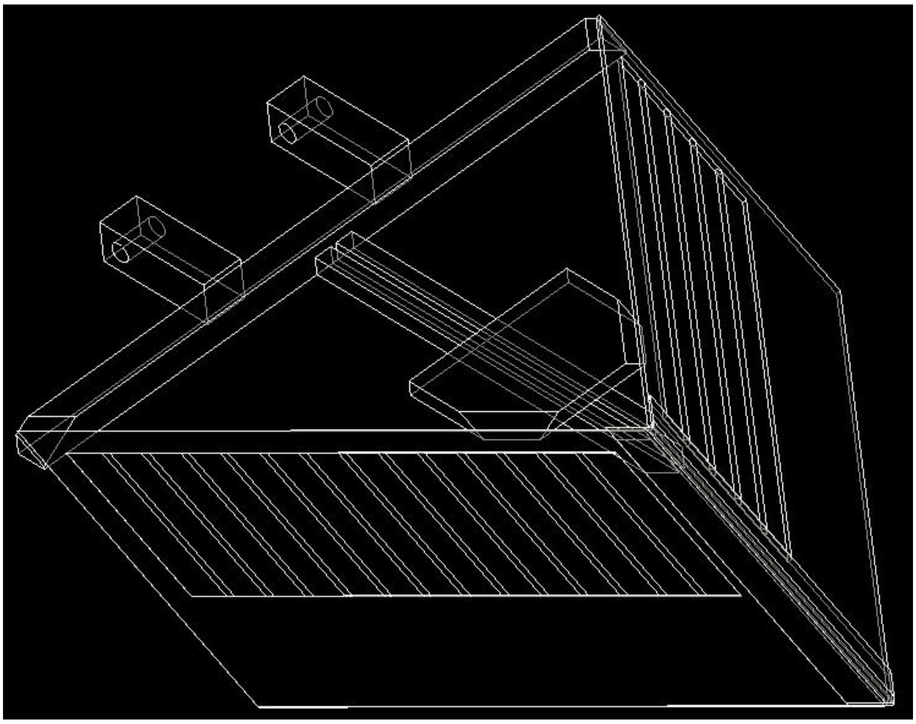


A_4
A_2
PRT_CSYS_DEF
98
Ø12
15
30
85
62,5
5
81,24
115
25
MATERIALE ALLUMINIO
quantità: 2

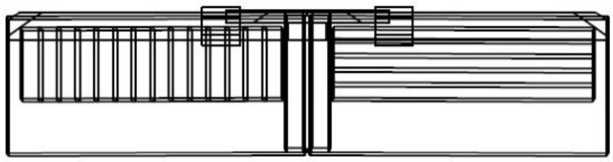

UNIGE
C
SCALA 1:1
MATERIALE ALLUMINIO
quantità 2
fori FILETTATI
M6 5 fori
Ø120
Ø54
R42,5
Ø12,5
55
9

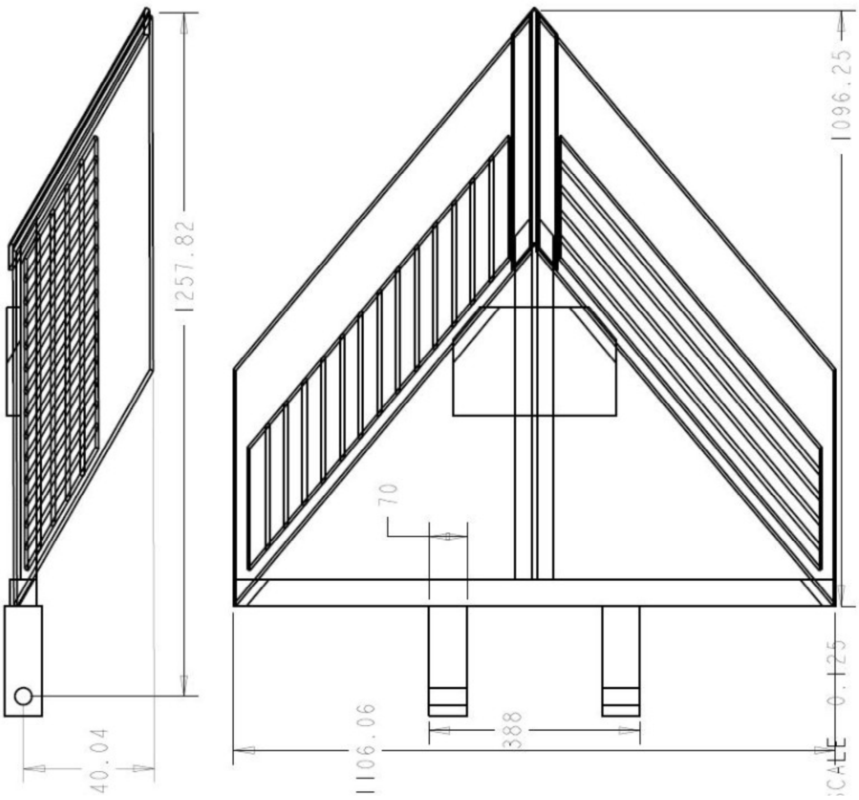

MATERIALE:
ACCIAIO
n° pezzi: 2
C 1
SALDATO
150
65
A_6
A_4
A_2
6
Ø16
69,5
21,5
Ø6
18
Ø23
8
21,5

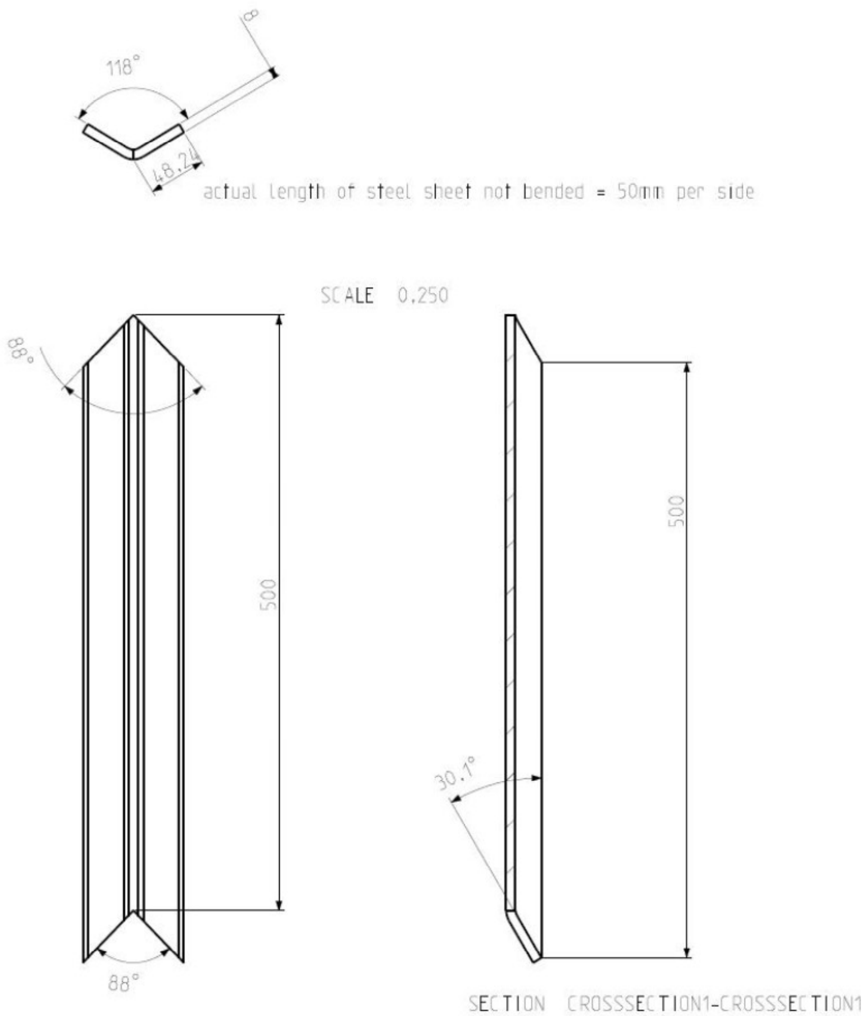
II.III. Ground processing tool and hitch



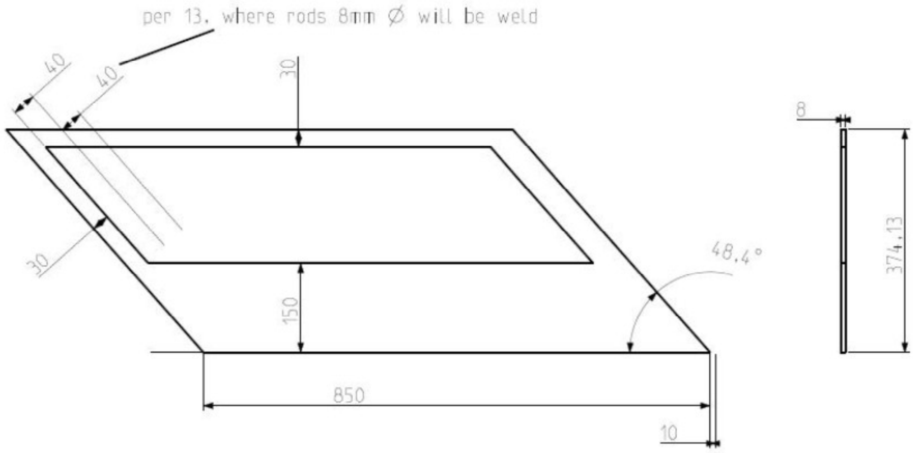
Part (and TD) name	N° of pieces	Remarks
Pt7arrow5spine	1	Steel sheet bended
Pt7arrow4 (right side plate)	1	Steel plate 8mm thick
Pt7arrow4tine	13	Steel rod 8mm thick
Pt7arrow4_2	1	Steel plate 8mm thick
Pt7arrow4_2longtine	4	Steel rod 8mm thick
Pt7arrow5wrod2	1	Square 50mm
Pt7arrow5hitchconnect	2	Square 70mm
Pt7arrow5hrod	1	Square 30mm
Pt7arrow5hrod_2	1	Square 30mm
Pt7arrow5fwheelplate	1	Plate 200x25mm




1257.82
1096.25
70
0.125
388
1106.06
40.04
SCALE

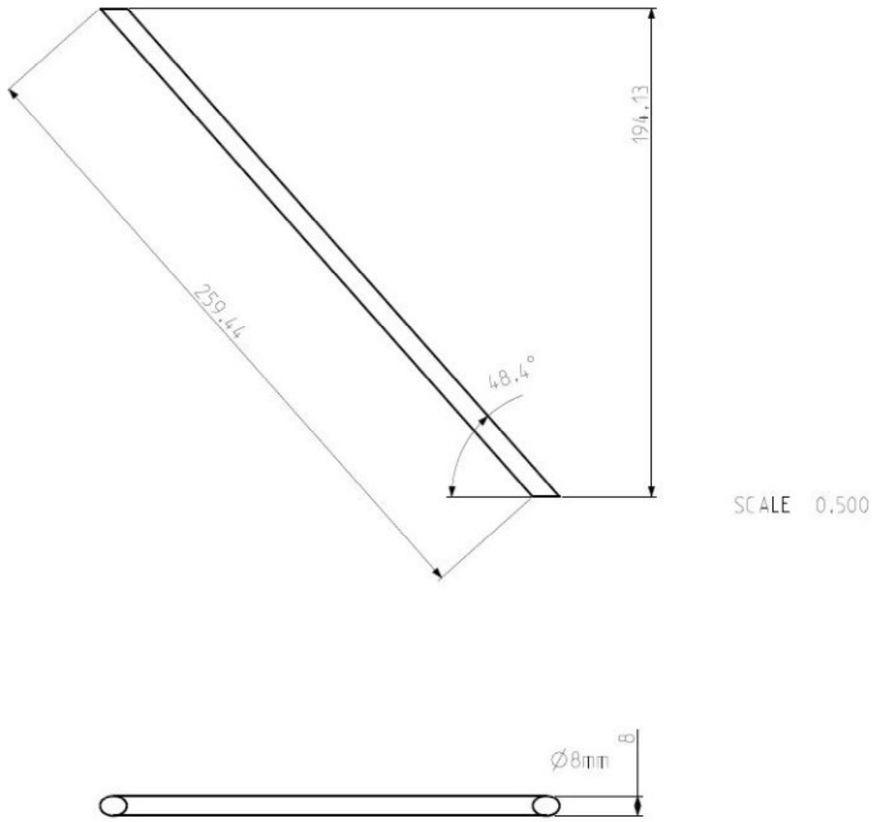


Università degli Studi di Genova DIMEC			
Progetto: PATforHD - GPT		Disegno n°: PT7ARROW5SPINE	
Scala: 0,250	N° pezzi: 1	Disegnato: Emanuela Cepolina	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: steel	Peso:

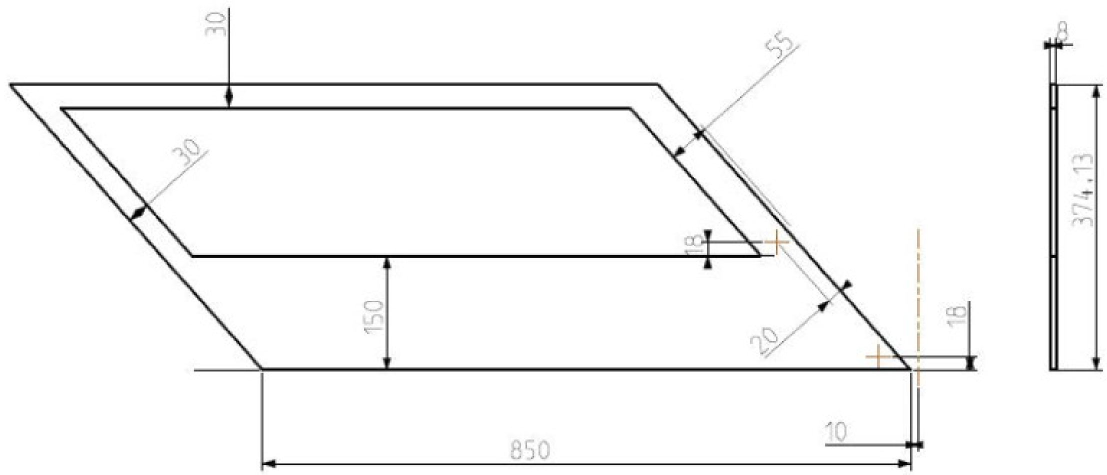


SCALE 0,125

Università degli Studi di Genova DIMEC			
Progetto: PAT for HD - GPT		Disegno n°: PT7ARROW4	
Scala: 0,125	N° pezzi: 1	Disegnato: Emanuela Cepolina	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: steel	Peso:



Università degli Studi di Genova DIMEC			
Progetto: PAT for HD _ GPT		Disegno n°: PT7ARROW4TINE	
Scala: 0,500	N° pezzi: 13	Disegnato: Emanuela Cepolina	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: Steel	Peso:

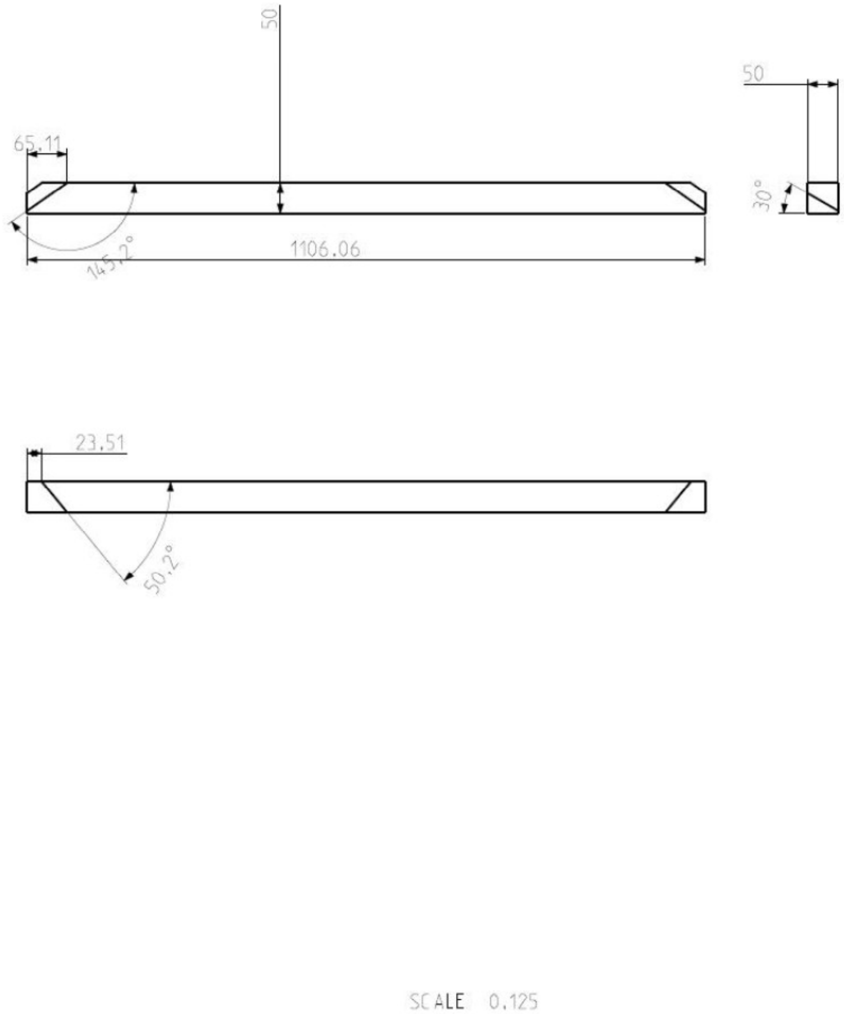


SCALE 0.125

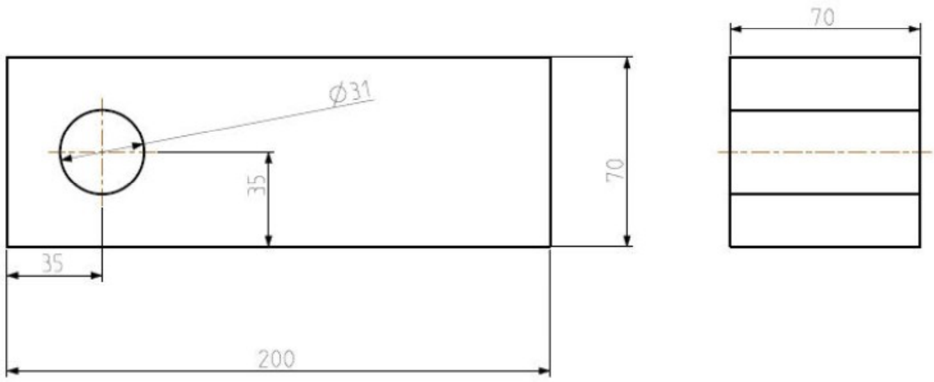
Università degli Studi di Genova DIMEC			
Progetto: PAT for HD - GPT		Disegno n°: PT7ARROW4_2	
Scala: 0,125	N° pezzi:	Disegnato: Emanuela Cepolina	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: steel	Peso:

SCALE 0.250

Università degli Studi di Genova DIMEC			
Progetto: PAT for HD - GPT		Disegno n°: PT7ARROW4_2LONGTINE	
Scala: 0,250	N° pezzi: 4	Disegnato: Emanuela Cepolina	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: steel	Peso:

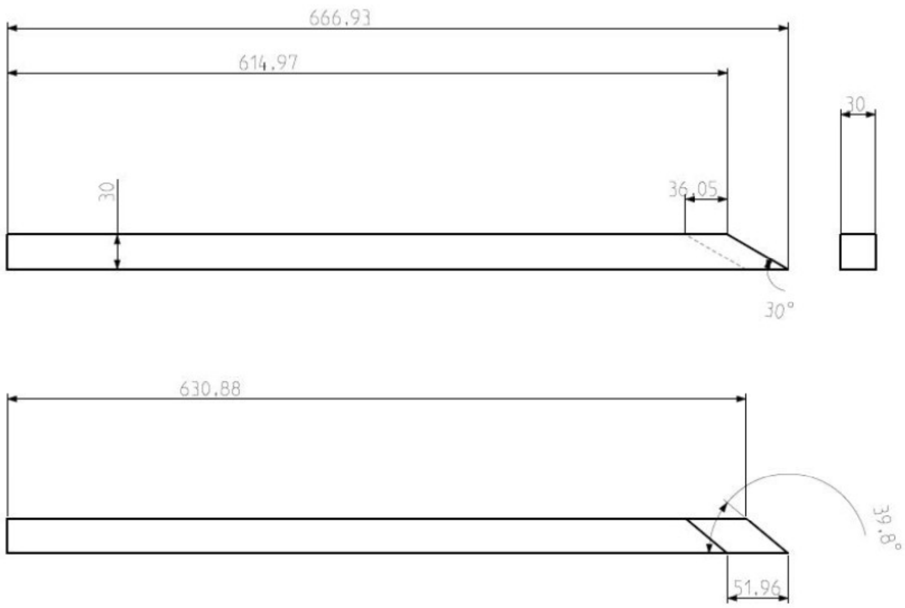


Università degli Studi di Genova DIMEC			
Progetto: PAT for HD _ GPT		Disegno n°: PT7ARROW5ROD2	
Scala: 0,125	N° pezzi: 1	Disegnato: Emanuela Cepolina	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: steel	Peso:



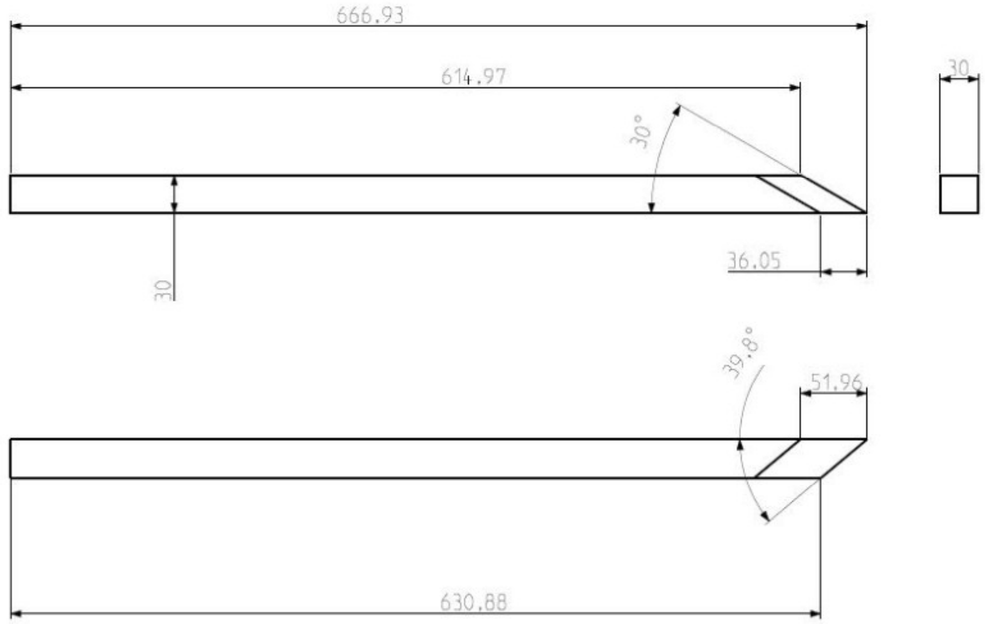
SCALE 0,500

Università degli Studi di Genova DIMEC			
Progetto: PAT for HD - GPT		Disegno n°: PT7ARROW5HITCHCONN	
Scala: 0,500	N° pezzi: 2	Disegnato: Emanuela Cepolina	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: steel	Peso:



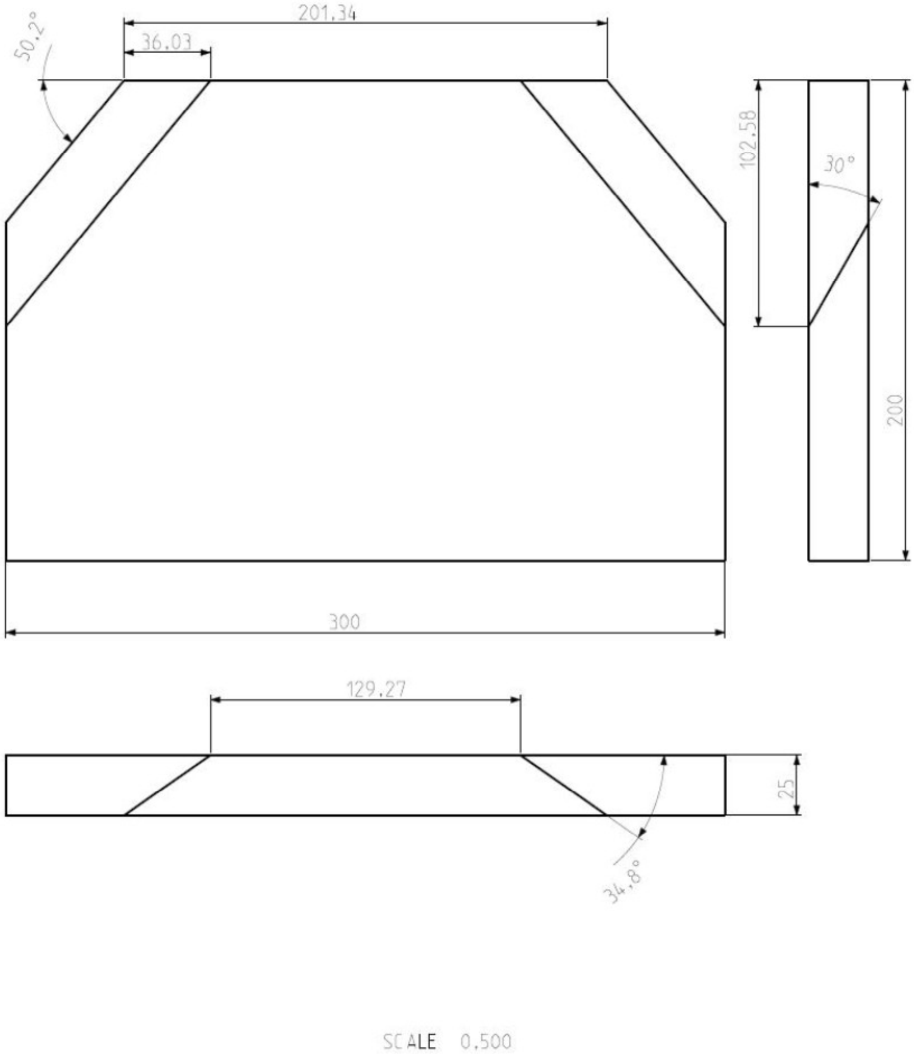
SCALE 0.250

Università degli Studi di Genova *DIMEC*			
Progetto: PAT for HD _ GPT		Disegno n°: PT7ARROW5HROD	
Scala: 0,250	N° pezzi:	Disegnato: Emanuela Cepolina	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: steel	Peso:

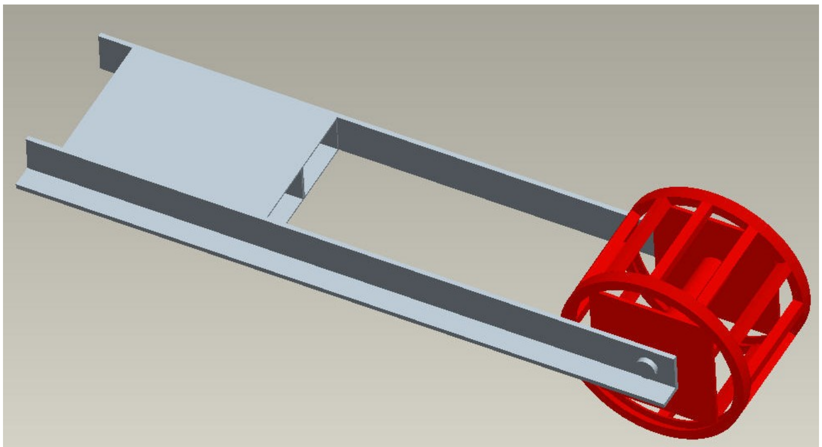


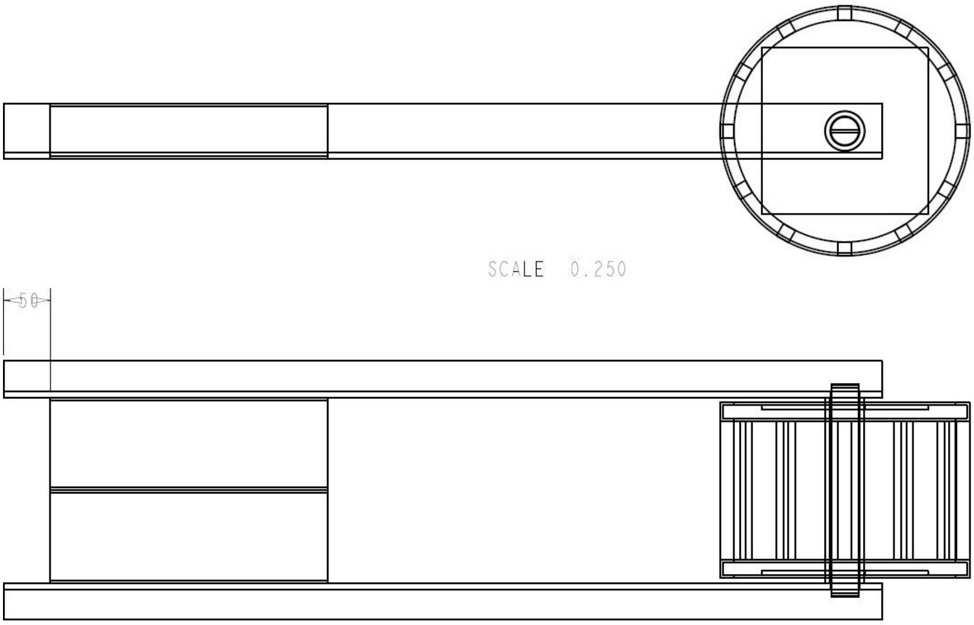
SCALE 0.250

Università degli Studi di Genova *DIMEC*			
Progetto: PAT for HD - GPT		Disegno n°: PT7ARROW5HROD_2	
Scala: 0,250	N° pezzi: 1	Disegnato: Emanuela Cepolina	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: steel	Peso:

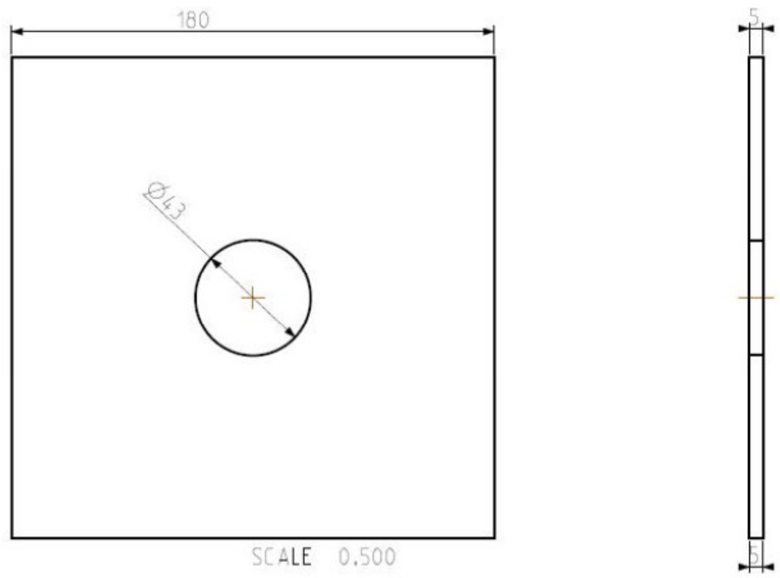


Università degli Studi di Genova DIMEC			
Progetto: PAT for HD - GPT		Disegno n°: PT7ARROW5FWHEELPLATE	
Scala: 0,500	N° pezzi: 1	Disegnato: Emanuela Cepolina	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: steel	Peso:

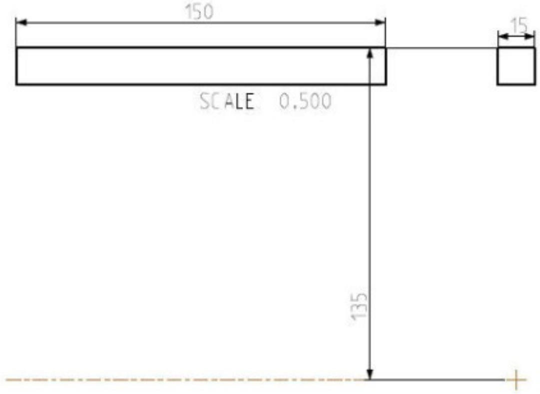




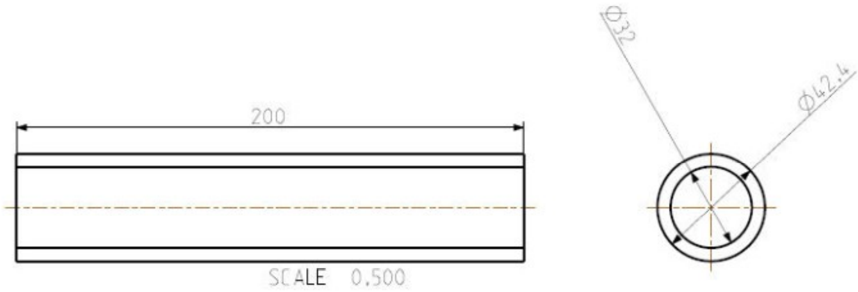
Part (and TD) name	N° of pieces	Remarks (welding)
Pt7arrowfwheelsquare	2	Steel plate 5mm thick
Pt7arrow5fwheellug	10	Steel square 15mm thick
Pt7arrow5fwheeltube	1	Tube 32mm, 42,4mm
Pt7arrow5wheelaxle	1	Rod 30mm
Pt7arrow5fwheelsideplatesl	1	Angle 40x60x7mm
Pt7arrow5fwheelsideplatesl_2	1	Angle 40x60x7mm
Pt7arrow5fwheelbox	2	Box 100x60x3 mm



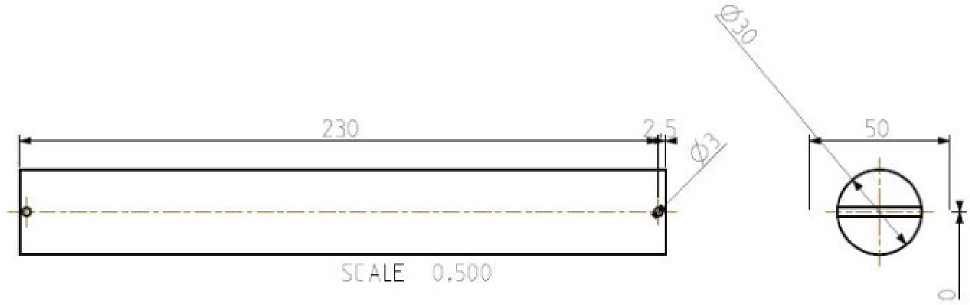
Università degli Studi di Genova DIMEC			
Progetto: PINZA LEAPFROG		Disegno n°: PT7ARROWFWHEELSQUARE	
Scala: 0,500	N° pezzi: 2	Disegnato:	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: steel	Peso:



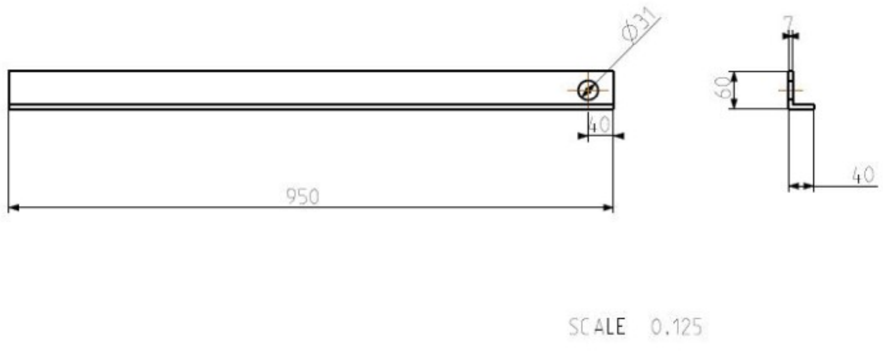
Università degli Studi di Genova DIMEC			
Progetto:		Disegno n°: PT7ARROW5FWHEELLUG	
Scala: 0,500	N° pezzi:	Disegnato:	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: steel	Peso:



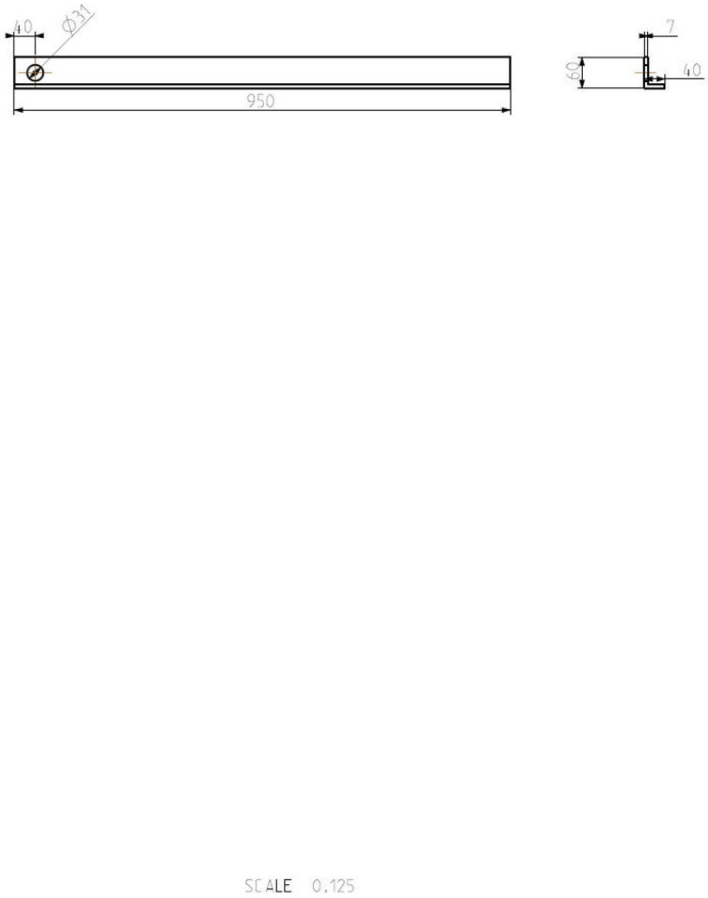
Università degli Studi di Genova DIMEC			
Progetto: PINZA LEAPFROG		Disegno n°: PT7ARROW5FWHEELTUBE	
Scala: 0,500	N° pezzi: 1	Disegnato:	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: steel	Peso:



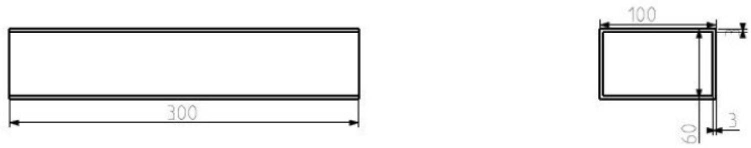
Università degli Studi di Genova DIMEC			
Progetto: PINZA LEAPFROG		Disegno n°: PT7ARROW5FWHEELAXLE	
Scala: 0,500	N° pezzi: 1	Disegnato:	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: steel	Peso:



Università degli Studi di Genova DIMEC			
Progetto:		Disegno n°: PT7ARROW5FWHEELSIDEPLATESL	
Scala: 0,125	N° pezzi: 1	Disegnato:	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: steel	Peso:

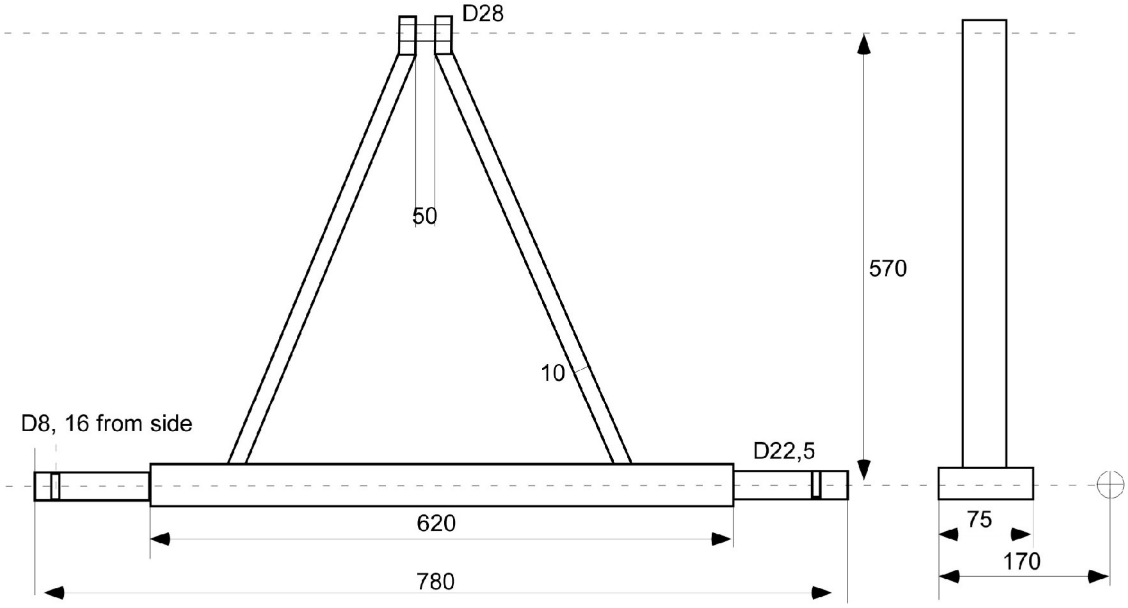


Università degli Studi di Genova DIMEC			
Progetto:		Disegno n°: PT7ARROW5WHEELSIDEPLATESL_2	
Scala: 0,125	N° pezzi: 1	Disegnato:	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: steel	Peso:



SCALE 0.250

Università degli Studi di Genova DIMEC			
Progetto:		Disegno n°: PT7ARROW5FWHEELBOX	
Scala: 0,250	N° pezzi: 2	Disegnato:	
	QUOTE SENZA INDICAZIONE DI TOLLERANZA: GRADO DI PRECISIONE UNI 2768/1	Materiale: steel	Peso:



Part name (tot n°)	N°	Modifications	Verifications
Pt7arrow5			
Pt7arrow4tine	13	D 10mm instead of 8mm	They exceed of 2mm the side plate thickness. This might cause differences in soil and mines translocation. But I can weld the rods tangent to the blade externally. The space between tines is reduced to 30mm instead of 32mm.
Pt7arrow4_2longtine	4	D 10mm instead of 8mm	I mistake the side to which weld tines. The plate with 13 vertical tines is correctly weld, with tines tangent to external surface. The plate with 4 horizontal tines is not correctly placed, causing tines to be tangent to the internal plate surface.
Pt7arrow5hrod (High carbon steel)	1	32x25 instead of 30x30	It is not symmetric anymore. I put the longest side vertically has it has to resist the bending moment induced by the Soil tool force. Angles change as in pt7arrow5rodnew.prt. Distance of top upper surface from top plane at the bottom of the tool kept equal to 230mm. Distance from side surface to the middle plane of GPT is changed to 10mm.
Pt7arrow5hrod_2 (High carbon steel)	1	32x25 instead of 30x30	It is not symmetric anymore. I put the longest side vertically has it has to resist the bending moment induced by the Soil tool force. Angles change as in pt7arrow5rodnew.prt Distance of top upper surface from top plane at the bottom of the tool kept equal to 230mm. Distance from side surface to the middle plane of GPT is changed to 10mm.
Pt7arrow5hitchconn (High carbon steel ??)	2	60x60 instead of 70x70	Ok still space for welding.
		Hole: 33mm instead of 31	A bar 32mm has to pass through. Minimum meat on the side of the hole is enough: 13.5mm
		New cut, 25mm high and approx 80mm long	For adapting the frame available into the workshop to the GPT, we mounted the hitche connections on the frame welding them to the lower bar mounted on the

			two lower linkages (25mm thick), welded symmetrically wrt the frame middle plane, 400mm apart (taken from their middle planes) to fit with the plates already welded to the frame.
Pt7arrowfwheel			
Pt7arrow5fwheeltube	1	D43mm, d28mm L changed to 235mm as the actual width of the front wheel is 210mm, not 190mm	More thick, more weight but more resistant. Now pt7arrow5fwheelplate (25mm thick, 300mm wide and 200 mm long) is not wide enough to support angulars.
Pt7arrow5fwheelaxle	1	D 25mm instead of 30mm L changed to 320mm as the actual width of the front wheel is 210mm, not 190mm	Now pt7arrow5fwheelplate (25mm thick, 300mm wide and 200 mm long) is not wide enough to support angulars.
Pt7arrowfwheelsquare	2	Hole D 44mm instead of 43mm	Ok enough meat
Pt7arrow5fwheelbox	2	C shape std profile instead, welded near to the fwheel (approximately 335mmm from the axis of front wheel to the middle plane of the C shape) to prevent lateral divergence of angulars. They don't have boxes	Dimensions: 80mm wide, 42 mm high, L to fit within the angulars. Thickness is 5mm.
Pt7arrow5fwheelsideplate	2	60x42 mm thickness 7 can be ok.	I have to weld the angular plate to the plate on top of GPT underneath and over.
Pt7arrow5fwheelplate	2	Not useful anymore as width is not enough for supporting the angulars. We use two square rods 15mm each instead, perpendicular to the hrods, welded on top of them and on the side, internally to side plates. The first with back side at 300mm from the spine and the second nearer to the spine	
Pt7arrow5fwheelplate_2	1	500mm width by 300mm long placed from spine backwards and cut to follow side plates angle. 10mm thick to achieve fwheel axis distance from top plate equal to 285mm.	

		Welded on 15mm square rods and on the side plates with some added material to fill in the gap	
Pt7arrow5hitch			
Pt7arrow5hitch	2	Plates 25x75 mm both for back plate and side plates	For adapting the frame available into the workshop to the GPT, we mounted the hitches on the tool welding them to the pt7arrow5wrod (50x50), symmetrically wrt the GPT middle plane and 400mm apart (taken from their middle plates), to fit with the hitch connections welded to the frame. This will cause the hitch connections that will be fitted on the Tbox of the tractor unit to be 5mm out from the tbox on each side (the tbox is 450mm), but it allows to use the frame without too many modifications.
		Hole: 33mm instead of 31	A bar 32mm has to pass through.

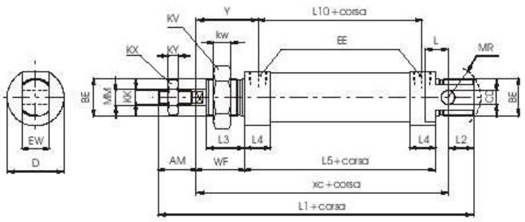
Appendix III Control data

III.I. Pneumatic part list

Code	Description
1280.25.40.M	Pneumax alesaggio 25 corsa 40 D.E. magnetico ammortizzi fissi di serie
468.52.0.1.M2	E/valvola Pneumax 5/2 vie sol.-molla 1/8"G
1513.63.15	Cilindro compatto a corsa breve alesaggio 63 corsa 15 molla post. S.E.magnetico
1291.16.40.M	Microcilindro Pneumax alesaggio 16 corsa 40 S.E.molla ant. magnetico
468.32.0.1.M2	E/valvola Pneumax 3/2 vie sol.-molla 1/8"G
1280.10.40.M	Microcilindro Pneumax alesaggio 10 corsa 40 D.E. magnetico
468/1.53.31.00.M2	E/valvola Pneumax 5/3 vie sol.sol. centri chiusi 1/8"G
MB 4	Bobina 12 Vdc
305.11.00	Connettore per bobina
TR8x6x25T	matassa tubo rilsan 8x6 colore neutro
17206B.C.C	Filtro/regolatore Pneumax 3/8"G
1500.63.17F	Nipplo ISO per cil.corsa breve
6.01.18/1N	Regolatore di flusso bidirezioanel f/f 1/8" G
010818	Raccordo rapido diritto Titan d8 1/8"G
6.01.18N	Regolatore di flusso unidirezionale f/f 1/8"G
010838	Raccordo rapido diritto Titan d8 3/8"G

Where, actuator code numbers are designed in the following way:
• first set of digits describes actuator type,
• second set of digits specifies the range in [mm],
• third set of digits gives the value of range in [mm],
• additional characters describe additional features of the cylinder for example
'M' means magnetic material inside stroke which allows to easily attach limit switches to this construction.
The standard cylinder used in acceleration, differential and brakes is shown below.

Versione base magnetico



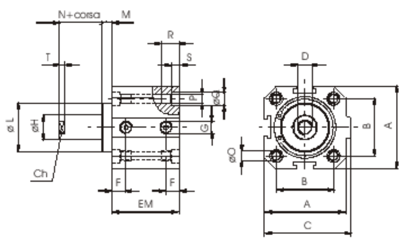
Esecuzione standard, perfettamente conforme alle norme ISO. Accetta tutti i tipi di ancoraggio previsti. Per i tipi a semplice effetto la corsa massima è di 50 mm., oltre la quale gli ingombri aumentano in lunghezza in maniera non proporzionale alla corsa (e comunque non oltre corsa 100).

Codice di ordinazione	Descrizione
1280.Ø.corsa.M	Versione base magnetico
1291.Ø.corsa.M	Ver. base molla ant. magnetico (max corsa 50 mm)
1292.Ø.corsa.M	Ver. base molla pos. magnetico, dal ø16 (max corsa 50 mm)
12– –.Ø.corsa.A.M	Versione con ammortizzi e pistone magnetico, dal ø16
12– –.Ø.corsa. . . .T	Versione con guarnizioni Therban

Clutch cylinder is shown below. This is special designed cylinder because of extraordinary working conditions: high force and low range. This also increases the cost of this cylinder.

Versione semplice effetto molla posteriore con pistone magnetico

Codice di ordinazione
1513.Ø.corsa



Valves code numbers are designed in the following way:

• first set of digits describes valve series,

• second set of digits describes the valve type, for example ’52’ means valve with five connections and two positions,

• additional characters describe features in similar way to described for actuators.

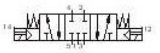
The valve used for the acceleration double acting cylinder with 5 connections and 3 positions is shown below.

Solenoide
Solenoide

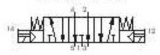
5/3

Codice di ordinazione

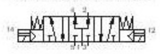
468.53.31.0.0.M2
Centri chiusi

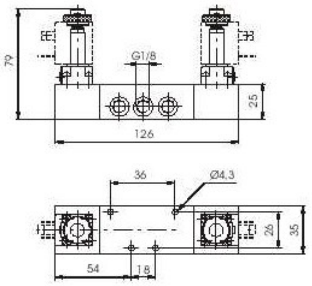


468.53.32.0.0.M2
Centri aperti



468.53.33.0.0.M2
Centri in pressione



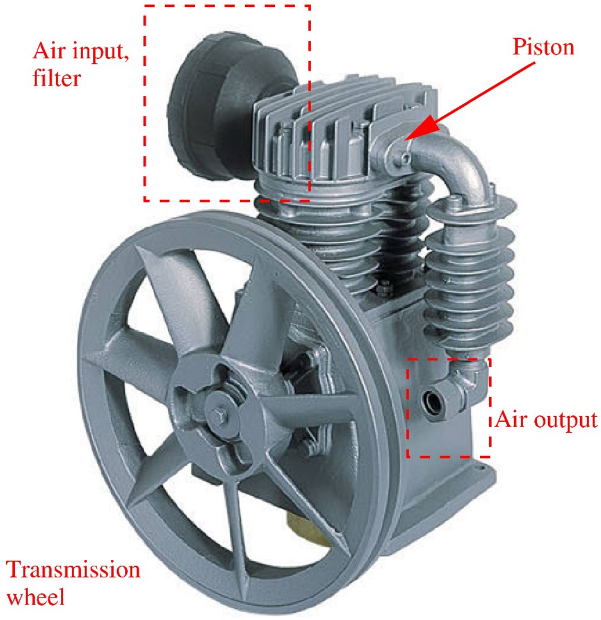


III.II. Electric part list

Part type	Part nb.	Quantity	Notes	EUR/Part
Em. Stop	IN-23E01	1	Relay	3
	IN-233E	1	Fixture	0.6
	PU-C23ED01	1	Button	0.4
RC switches	PU4-6515	2	Right/left brake (black)	1.5
	PU4-6505	1	Stop (red)	1.2
	IN-339	1	Acc. (lever) - chk	4.8
Ignition	INC-NS15	1	Main on/off switch	4.5
Limit switch	INSM105	4	Limit switches for clutch, differential and acceleration actuators	2.4
Contactor	RLCAR-SH112D	1	Flip–flop for emergency stop circuit, small switch current regarded	2.5
Potentiometer 470 Ω	TMV470	7	Potentiometers for valves and flip–flop's coils	0.4
Diode	DD1N4007	7	Diodes for valves and flip–flop's coils	0.12
Panel socket	CNCB8FV	4	Standard	2.4
Pin	CNCB8MP	4	Standard	2.2
12 [V] battery		1	Main power supply, > 30 [Ah]	
200x150x40 [mm] cage	MOWALL3	1	Cage for remote control panel	6.3
300x200 [mm] universal CB	PCSF-30X20	1	Universal CB	13.75
Voltmeter 0–12 [V]	SS38-15V	1	Standard class 2,5	14.1
Total:				94.59

III.III. Air compressor

Air compressor type:

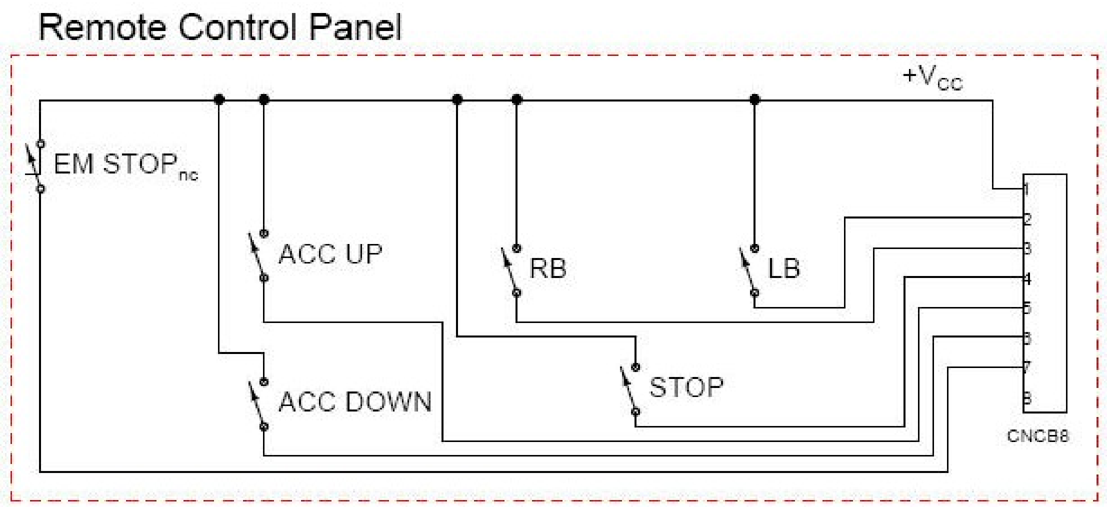


Data sheet for model MK102:

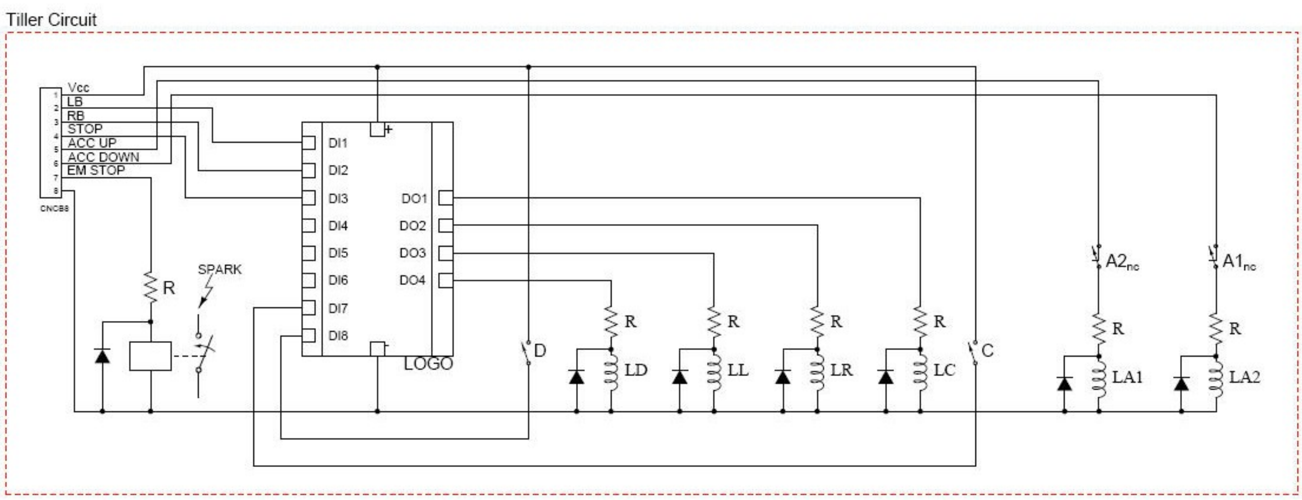
TRAINO CINGHIA MONOSTADIO | *SINGLE-STAGE BELT-DRIVEN*

ℓ	Codice / Code	Prodotto / Product	Volt/Ph	kW	HP	Model	l/min.	m³/h	c.f.m.	bar	p.s.i.	R.P.M.	n°	n°	dB(A)	LwA	L x D x H (cm)	kg	lbs
CILINDRI PARALLELI | *PARALLEL CYLINDERS*																			
-	5131690200	MK 102	-	1,5	2	-	250	14,7	11.3	10	145	1420	2	1	76	-	27 x 26 x 28	7,3	16
-	5131670200	MK 103	-	2,2	3	-	377	22,62	13.3	10	145	1420	2	1	79	-	27 x 26 x 30	8,3	18
-	5131640000	MK 113	-	4	5.5	-	584	35,04	20.6	10	145	1440	2	1	81	-	31 x 30 x 36	16	35
CILINDRI A V DI 90° | *90° V POSED CYLINDERS*																			
-	5131720000	SKM 10	-	1,5	2	-	205	12,3	7.2	9	130.5	1240	2-V	1	73	-	23 x 40,5 x 30	12	26
-	5131750000	SKM 12	-	2	3	-	325	19,5	11.5	9	130.5	1460	2-V	1	73	-	26 x 34 x 30	16	35
-	5131810000	SKM12 - S	-	3	4	-	345	21	12.2	10	145	1200	2-V	1	80	-	26 x 34 x 30	16	35
-	5131730000	SKM 14	-	4	5.5	-	650	39	23.0	10	145	1425	2-V	1	77	-	32 x 34 x 40	23	50.6

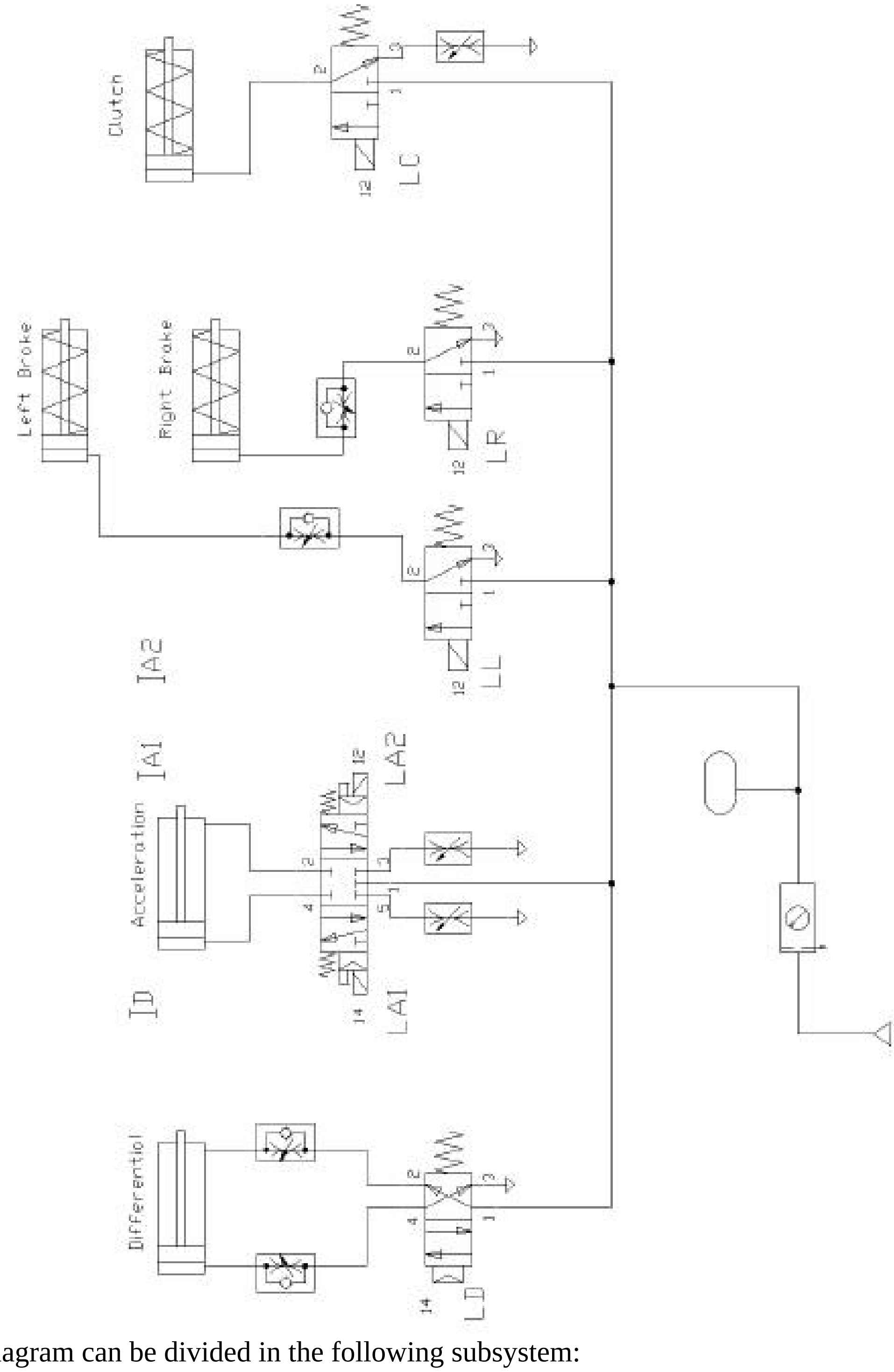
III.IV. Remote control panel: electric circuit diagram



III.V. Valve bay: electric circuit diagram



III.VI. Valve bay: pneumatic system diagram



The diagram can be divided in the following subsystem:
1. differential,
2. acceleration,

3. left / right brake,
4. clutch,
5. air preparation.

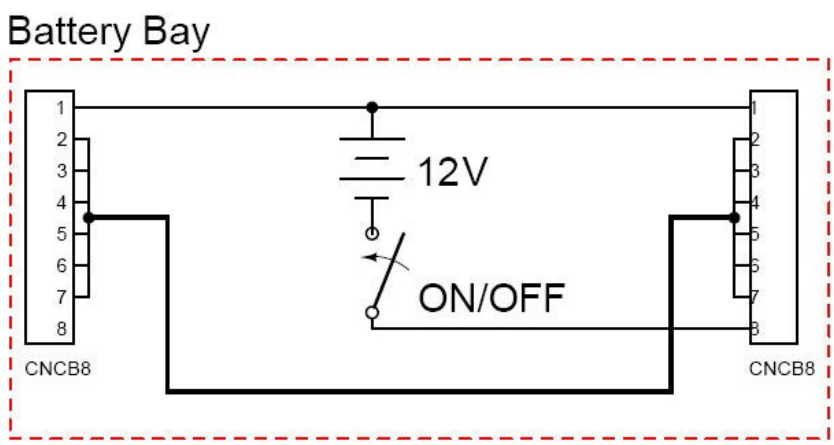
Differential system consists of 4/2, electrically actuated valve, two throttle, directional valves, limit switch detecting position when differential is switched on and double acting cylinder. This approach allows us to use only one signal to define both positions of differential. Throttle valves with respect to pneumatic cascade idea influence the cylinder speed in both directions. Acceleration system consists of 5/3, electrically actuated valve, two throttle valves, two limit switches and double acting cylinder. In this construction system is adjusted for making small and not frequent changes with position handling capability. Two signals are needed for both directional movement. Throttle valves allow to define speed in both directions. Left and right brake systems are done in the same way with usage of 3/2 electrically driven valves, throttle, directional valves and single-acting cylinder with return stroke by spring. This approach allows us to decrease switch on speed of the brake. Switch off speed is not modulated.

Clutch system consists of 3/2 electrically driven valve, throttle valve, limit switch and single-acting cylinder with return stroke by spring. One signal is needed to control the clutch position. Return speed can be modified with throttle valve. Clutch on signal is indicated be limit switch. Service unit is attached directly to air compressor. It consists of:

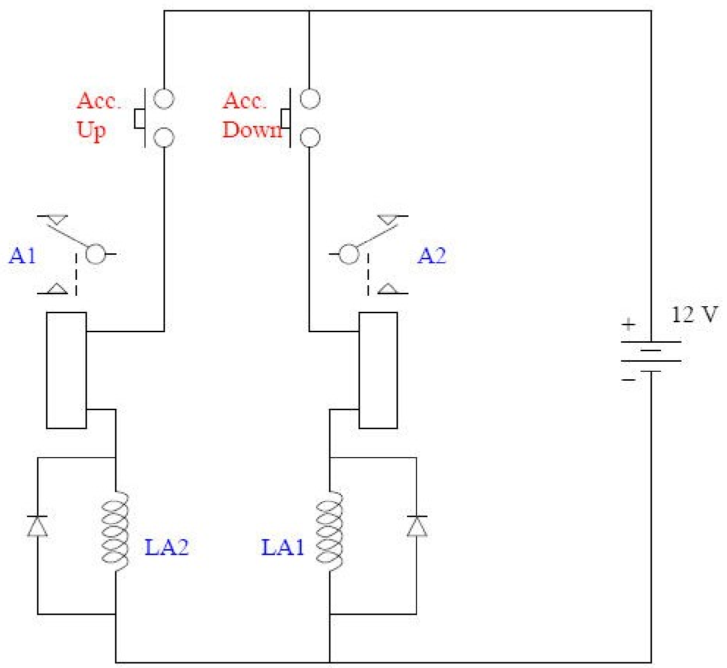
- filters,
- lubricator,
- regulator.

Filters are especially important because of working conditions — they have to be chosen in the way that guarantees clean and dry air not depending from dust or rain. Lubricator allows cylinders to work in wet friction conditions as well as preserves valves from deadlocks. Regulator is needed to keep system pressure in desired borders. In this application it is desirable to resign of air receiver. This device is very sensitive to destruction during explosion (stones, acceleration, impact etc.) and is difficult to mount. If it is possible to avoid using it will benefit construction in other way it always can be added to the system.

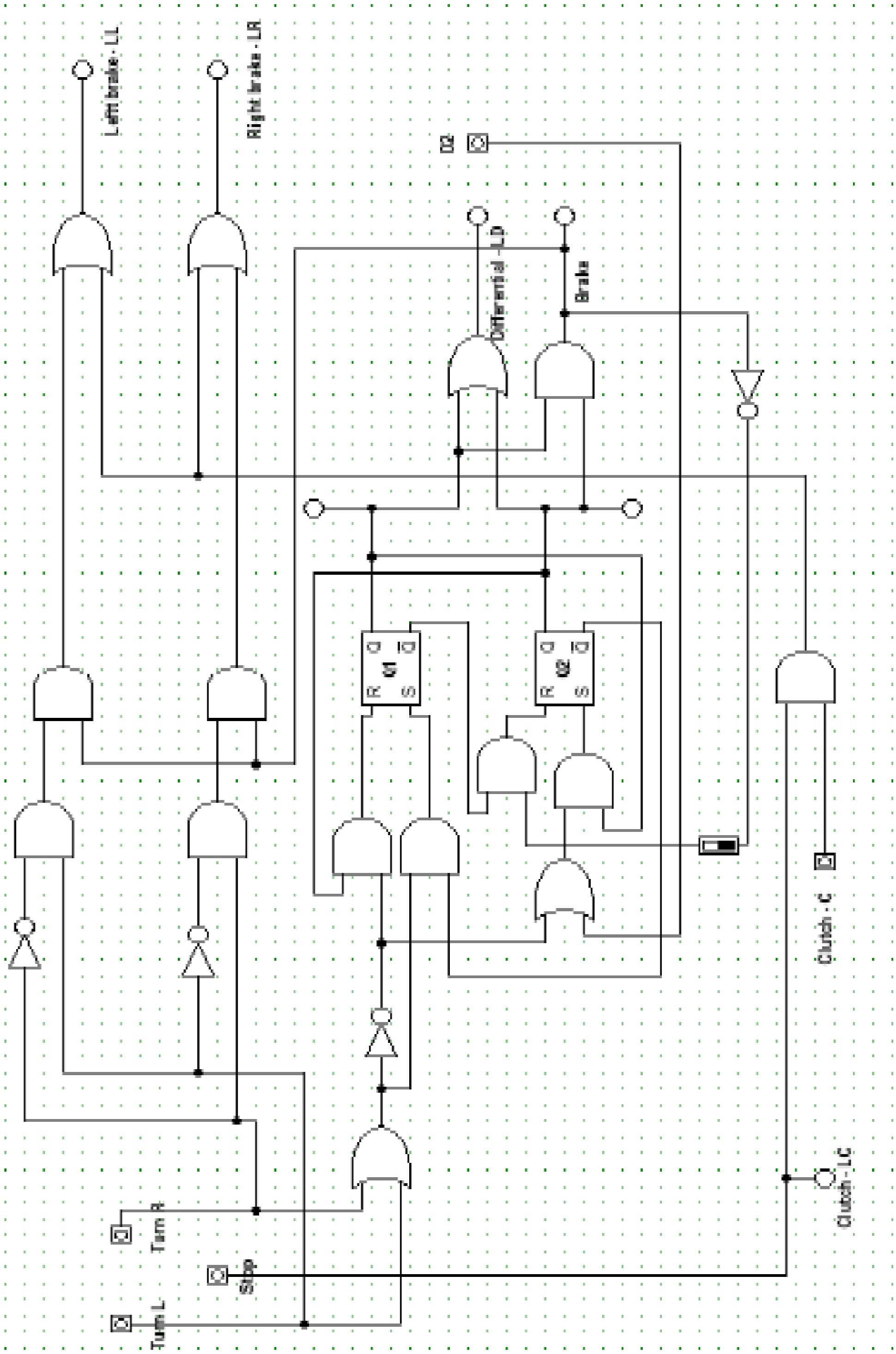
III.VII. Battery bay: electric circuit diagram



III.VIII. Accelerator electric circuit diagram

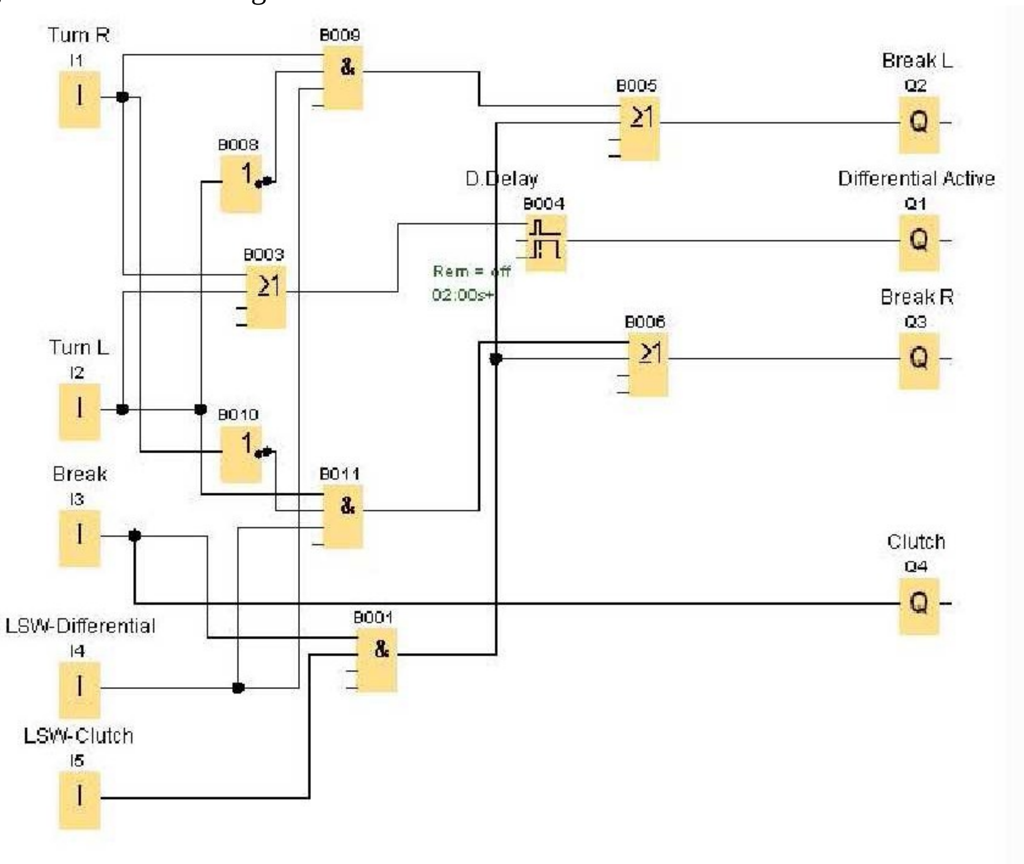


III.IX. Control system diagram

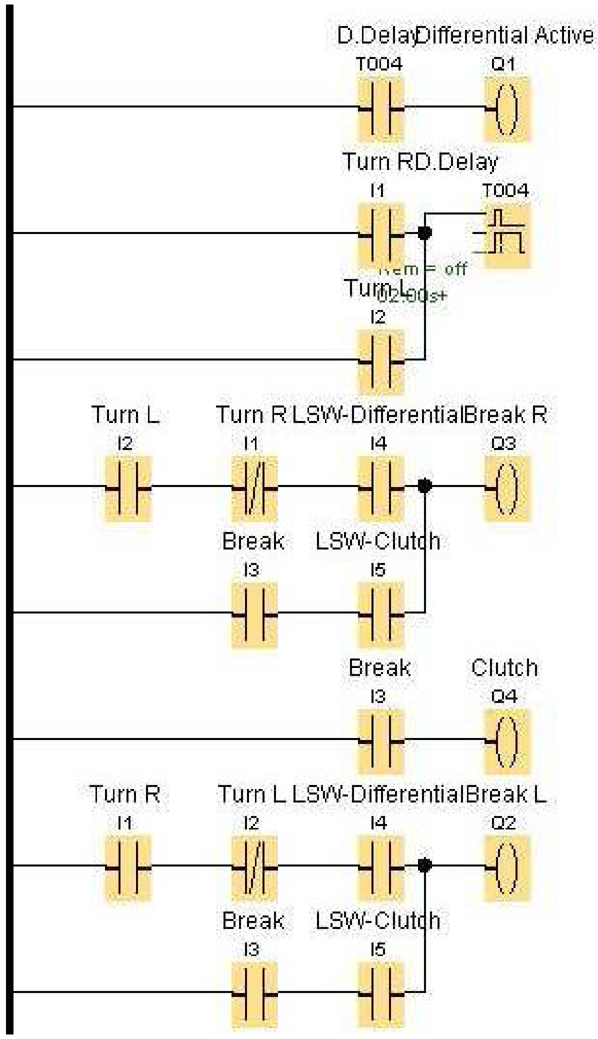


III.X. Controller program

Logo! Block control diagram



Logo! Ladder diagram


D.Delay
Differential Active
T004
Q1
Turn R
D.Delay
I1
T004
Rem = off
02:00s+
Turn L
I2
Turn L
I2
Turn R
I1
LSW-Differential
I4
Break R
Q3
Break
I3
LSW-Clutch
I5
Break
I3
Clutch
Q4
Turn R
I1
Turn L
I2
LSW-Differential
I4
Break L
Q2
Break
I3
LSW-Clutch
I5

III.XI. Forces exerted by cylinders and calculation for air demand

Cylinder	Required Force	Load Factor	Theoretical Force
Differential Cylinder	100N	40%	250N
Clutch Cylinder	1200N	60%	2000N
Acceleration Cylinder	20N	60%	33.33N
Brake Cylinder	80N	60%	133.33N

F_t= P*π*(D^2-d^2)/4
F_t= Theoretical Force
D= Bore Diameter of the Cylinder
d= Piston Rod Diameter
P= Internal Pressure

Cylinder	Bore Diameter (mm)	Stroke (mm)	Volume (m^3)
Differential Cylinder	25	40	1.96E-05
Clutch Cylinder	70	12	4.62E-05
Acceleration Cylinder	15	40	7.07E-06
Brake Cylinder Left	20	40	1.26E-05
Brake Cylinder Right	20	40	1.26E-05

Action	Air Usage (m^3)	Usage Factor (per Second)	Air Demand (m^3/s)
Stopping	7.13E-05	0.02	1.43E-06
Acceleration	1.41E-05	0.07	9.89E-07
Left Brake	5.18E-05	0.05	2.59E-06
Right Brake	5.18E-05	0.05	2.59E-06
		Mean Air Demand	7.60E-06
		Peak Air Demand	1.89E-04

Appendix IV Budget

CODE	DESCRIPTION	Unit cost €	Quantity
A	A. MATERIAL		
	Power tiller, second hand	100,80	1
	Carburator pin	30,00	1
	4 tines rake	10,00	1
	long rake	15,00	1
	various material for first test (plastic containers, wooden and foam rubber protections)	30,00	1
	Flanges	70,00	2
	Breakable connection	70,00	2
	Breakable connection support	50,00	1
	Accelerometer +-50g	120,00	1
	Accelerometer +-500g	341,00	1
	Various material for second test (plastic containers, wooden and foam rubber protections)	30,00	1
	Disk brake, second hand	45,00	2
	LOGO! PLC controller	153,36	1
	electric components	94,57	1
	pneumatic components	762,76	1
	alluminium 100x40x1000 mm	75,86	1
	manufacturing on pieces already made	10,00	1
	fuel	12,50	1
	wooden plate for valve bay	6,35	1
	electric components	17,25	1
	screws and nuts	5,50	1
	manufacturing of components	50,00	2
	pneumatic components (all small parts plus magnetic sensor)	127,93	1
	tracks	0,00	2
	5 wheels	150,00	1
	cardboard	6,70	1
	sand	3,13	1
	Screws and nuts	6,00	1
	Nipple	0,25	2
	Manufacturing of wheels lugs	0,00	50
	Manufacturing of frame parts (Angelo)	0,00	5
	Manufacturing of frame parts (Davide)		4

	Manufacturing of control parts (Davide)		4
	Components and assemblying of wheels and frame (Guglielmo Barabino)	900,00	1
	Spare parts (starter spray, steel cable, brake oil)	25,58	1
	Spare parts (engine oil, spark plug)	17,50	1
	Bearings, fastening rings and protective rings for stub axles	131,10	1
	Manufacturing of new stubaxles parts	384,00	1
	Welding of new stubaxles	180,00	1
	Hiring of Tractor for Test (Risha, Aqaba, Jordan)	60,00	1
Tot	TOTAL	4327,39	