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isep




MACHINE FOR VISUAL INSPECTION

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MACHINE FOR VISUAL INSPECTION

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Second person is Professor Rui Fazenda, CEO of Gislotica Company. You accepted me in your company like I would be professional engineer and you taught me well. Also other people in Gislotica, like Tiago, Pedro, Alexandre tried to help me and made my time there comfortable and well spent. Thank you all!

The last group of people I want to thank is my friends. I have spent a great time with you travelling and having fun, with you I got to know Portuguese culture, you gave me energy for doing my job. Thank you very much for everything!

Abstract

The project was made during the Erasmus+ Program in Instituto Superior de Engenharia do Porto, Portugal. I had a pleasure to do this in Gislotica Mechanical Solution, Lda.

This document presents a process of design a vertical inspection station for truck tires. The first part contains an introduction. There are information about Gislotica Company and also first analysis of problem. In next part is presented way to figured out the task and described all issues connected with designed machine. In last part were made some conclusions about problems and results. There is a place not only for sum up design process but also my develop during the project. I repeatedly pointed out which issues were new for me. A lot of times I focus on myself and gained experience and information about design process.

Keywords

Tires industry, Visual Inspection, Retreading, Gislotica Mechanical Solutions, Design process, Material selection

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List of Symbols and Abbreviations

a	*real distance between chains wheels, mm*
a’	*assumed distance between chain wheels, mm*
a_{df}	*acceleration of dynamic frame, m/s^2*
a_f	*acceleration of dynamic system, m/s^2*
AC	*alternating current*
CEO	*Chief Executive Officer*
d	*piston diameter, mm*
ECTS	*European Credits Transfer System*
EU	*European Union*
EUR	*euro, currency*
F	*minimum actuator force, N*
f_1	*coefficient included work conditions*
f_2	*coefficient included number of teeth driving wheel*
g	*acceleration of gravity, m/s^2*
h	*stroke of pneumatic cylinder, mm*
ISEP	*Instituto Superior de Engenharia do Porto*
K	*number of chain links*
k_i	*price coefficient*
M	*number of potential decisions (features comparison)*
M_1	*Output gearmotor torque, Nm*
m	*mass of lifted up system, kg*
m_{df}	*mass of dynamic frame part, kg*
m_t	*mass of tire, kg*
N	*number of potential decisions (material comparison)*
n_1	*rotational speed of driving shaft, rpm*
P	*sum of points for each material (material selection)*
P_c	*corrected power, kW*
P_1	*input power, kW*
PA6	*Polyamide Type 6*
p	*operating pressure, Pa*

Q	*sum of points for each feature (material selection)*
SWOT	*Strengths, Weakness, Opportunities, Threats*
u	*ratio of chain transmission*
w	*number of chain rows*
v	*circumferential velocity of chain wheel, m/s*
Z_1,Z_2	*number of teeth*
α_i	*coefficient of each feature importance*
β_i	*coefficient relatively comparing materials*
γ_i	*usefulness coefficient of material*
γ_c	*corrected usefulness coefficient of material*

1. INTRODUCTION

1. Introduction

This work was carried out based on an ERASMUS PROJECT in order to get 30 ECTS in the academic year of 2015/2016, first semester. This is an equivalent of second semester on the Master’s level in Wroclaw University of Technology in Poland.

1.1. Company characterization

My ERASMUS PROJECT was realised in Gislotica – Mechanical Solutions, Lda. This is a company which makes complex mechanical solutions – beginning with the idea through the project, calculationand construction, up to delivery. The company cooperates with clients, thanks to that is able to fulfil highest requirements and make a vision come true. Building of Gislotica is presented on fig. 1.1.1.

Fig 1.1.1. Gislotica Company [1]

The company was established in 2000. In those days people worked on 100 square meters, today total area is 16000m^2. During these years the company developed and is still developing. In Gislotica work 40 people, most of them are working in the production. The employment structure is presented on diagram below (Fig. 1.1.2). Numbers means how much people work in described area.

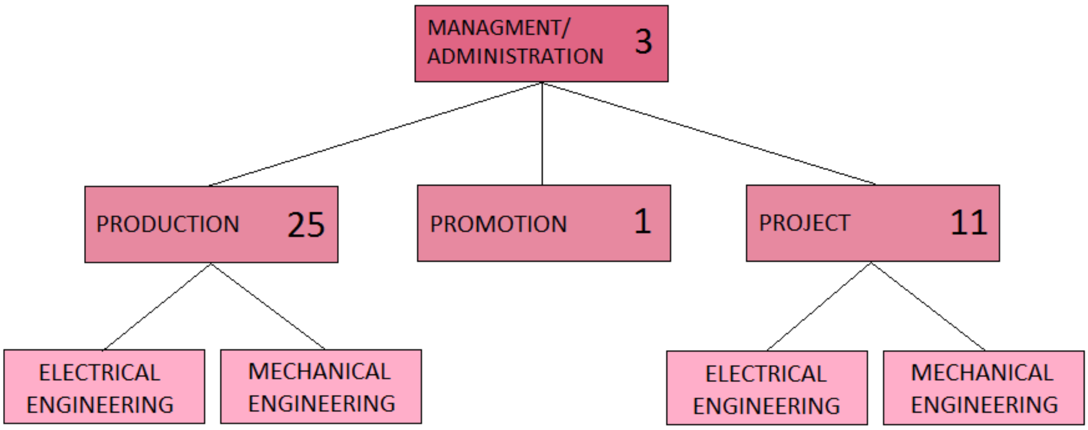


Fig. 1.1.2. Organization chart

Production and project fields are divided on the next two areas: mechanical and electrical construction.

Gislotica cooperates with external companies. They buy typical mechanical parts, like screws or nuts. The main suppliers of those products are Spanish companies. They also collaborate with Festo (pneumatic solution), Ina (bearings), etc.

Besides goods, Gislotica's engineers need services. They are able for welding and painting, but for lathing, milling, laser cutting they subcontract another companies.

The Gislotica's main market is tires industry. They produce machines supporting production and checking of tires. A few examples are presented in the Fig. 1.1.3 and 1.1.4. They design and execute groups of series production machines or devices for special clients'needs as well as individual projects.

Fig. 1.1.3. Marker station [2]

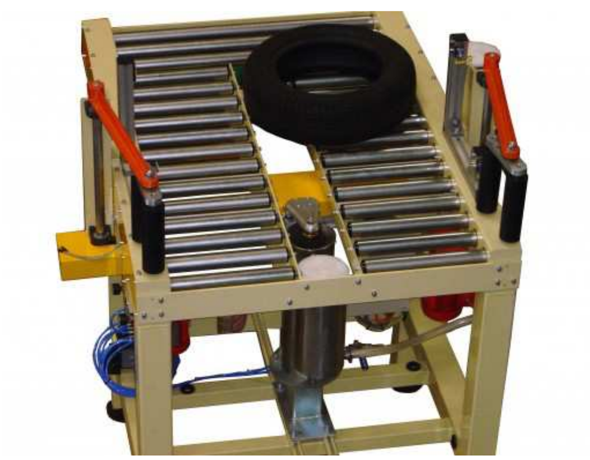


Fig. 1.1.4. Soap machine [3]

They operate not only in Portugal, even not only in Europe. They have contractors in a lot of countries in the world, for example India, China, Germany, France and Brazil. Gislotica Company gathers professional workers who are appreciated by co-workers for a huge involvement and fantastic results.

Most of engineers, who work there, were Mr Fazenda's students. They impressed him during studies and he proposed them job in his company. In this case he is certain that people who work there are the best and they make high quality projects.

The company is located in Perafita – small, cosy town, situated by the ocean, which is the part of Porto agglomeration. The building of company is still renovated and improved. Now, on the ground floor there are two huge industrial halls (one is designed for welding and painting and the second one for other kinds of treatment machine parts and materials, for example assembling), kitchen and canteen for employees. There is also an unfinished area, which in the future will be a reception. On the first floor you can find an office area, where engineers and administrative staff work. There is also a small place where you can take a break and drink some coffee.

The initiator of a whole investment is Rui Fazenda. He is an absolvent of University of Porto, more precisely Faculty of Engineering. Now he is a professor of ISEP, Oporto Polytechnic Institute and also CEO in Gislotica. Besides being a director he is also a main engineer. He makes the hardest projects and he helps another, younger, less experienced employees. Fazenda is very involved in his work and life of company. He spends a lot of time in Gislotica and check if everything goes with the plan– in design office and also on the production hall.

1.2. The Problem

During the internship in Gislotica, the project of machine for visual inspection of tires for trucks has been doing.

Machines like that are used in production process, more precisely when the enterprise have to check properties of tire. Device is needed for example in retreading process, when is required increased control of the end product. The station is responsible for keeping tire in one, stable position and letting for inspection and, in special cases, for repair.

One of the most important things, for the companies from tires industry, in that kind of machines are electronic sensors. Those are responsible for checking properties and surface condition. In this case, for mechanical engineering student, the most important thing in internship project was to solve mechanical problems related with material resistance issues. Only basic form of machine was designed, without electronic system as mentioned.

The main goal was design of a model (as mentioned above – from the mechanical side) and preparation of technical documentation.

It must be noted that during design process of the machine similar project documentation designed by other company was used. It had to be referred to the basic assumptions from the first machine; the main dimensions were known. Project should include design of two mechanisms: one for enabling a tire rotation and second for up and down lift of main part of machine (with the tire).

1.3. Methods

The essence of this report is mechanical construction. To design and build a machine it is necessary to make a deep analysis of construction aspects. For this it is needed to have knowledge from mechanic field.

Engineers from Gislotica make projects in SolidWorks. Unfortunately I have never had any contact with this program, so first few weeks was spent for studying tutorials, trying to learn how to use this program in the simplest way.

After that there was a time for recalling formulas and laws which was acknowledged on the Wroclaw University of Technology. The first source which was helpful in this kind of job were my own notes. Subjects like Mechanic, Basic of Machine Design were a base for starting the project.

During the work it appeared that theoretical knowledge is not enough to make a good model. More important is practical experience that I did not have. Despite this there are people in the company who give assistance. Conversation with engineers was invaluable. They show how to find the best, cheapest and easiest solution. Of course it had to be done a huge work by myself, searching for information in books or consulting guides.

Product catalogues was used for looking standardized elements, for example bearings, retaining rings, etc.

In some situations it was essential to make a calculation. The examples can be transmission.

After design process of all parts and mechanisms, selection of material and so on there was time for starting making a final report.

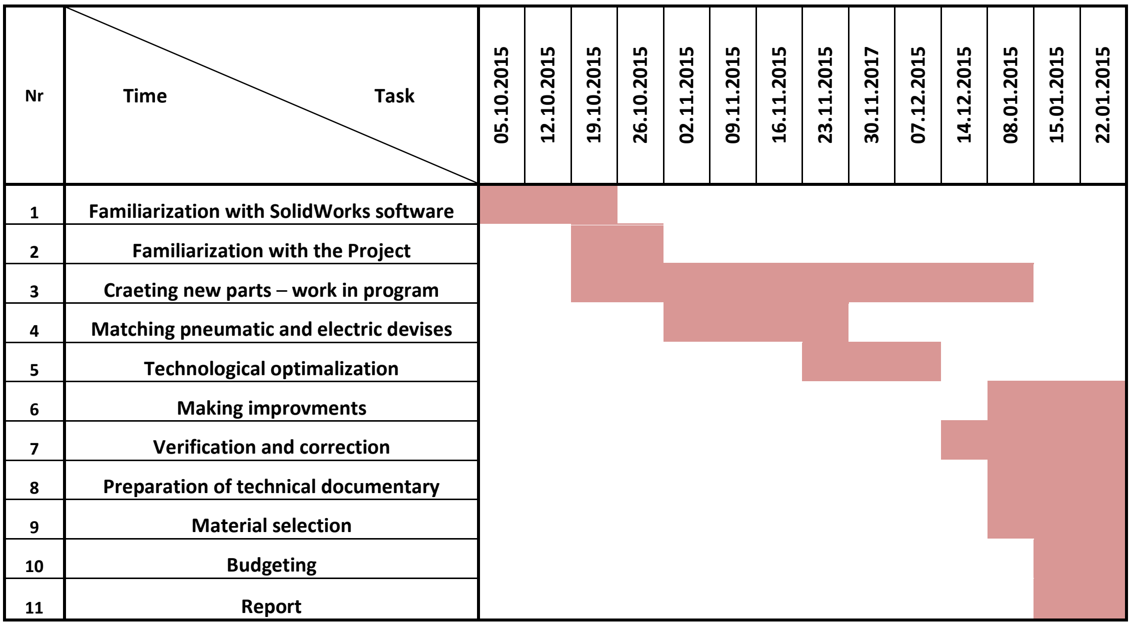
1.4. Methods

In fig. 1.4.1 is presented the GANTT diagram. It contains information about the time which was spent for doing given tasks.

Analysing this diagram is pretty clear that the most time-consuming process is making a 3D model. It may be due to low knowledge of software (doing exercises and tutorial within 2 weeks is unfortunately not enough for perfect mastery of program).

This diagram was made when project was finished. That is the reason why in the final stage the most of things was done. If everything would be planned earlier and time would be determined for particular tasks, job would have been done more efficiently.

Fig. 1.4.1. GANTT diagram



2. BACKGROUND

Tires

Material selection

Used technologies

2. Background

Gislotica Company is involved in tires industry. To completely understand the issue, a particular knowledge about tires and tires production area is needed. In this chapter will be presented and described known solutions of some elements used in design process.

2.1. Tires

Tire, in definition, is the outer part of the wheel with open section, applied to the wheel and filled with air (or other gas) under pressure. This is an element of the vehicle contacting with the ground [I].

2.1.1. History

Beginning of contemporary tire is 1839, when Charles Goodyear detected important facts about natural rubber. In 1846 Robert William Thompson submitted first patent of pneumatic tire and in 1891 B. J. Dunlop designed disassembled pneumatic tire [4]. From those times, tires industry had a long way to go and now last research of non-pneumatic tire with a honeycomb structure. The inventor and producer is Resilient Technologies. The first portion are used and tested by U.S. Army, in Humvee, fig. 2.1.1.1 [II].

Fig. 2.1.1.1. Non-pneumatic tire and conditions in which copes [II]

2.1.2. Size

Size of tires are standardized and can be described as follows. For example a 195/65R15 tire: the "195" indicates the nominal section width of the unloaded, inflated tire (millimeters). The "65" is the aspect ratio – section of tire height as a percentage of the section width. Other aspect ratio tires, for example 45, 50 series tires, are mainly used in high performance applications but are more popular in conjunction with larger rim diameter for styling enhancements in larger cars. "R" identifies radial construction ("B" is used for belted bias construction, "D" for diagonal or bias tires). Sign "15" described the rim diameter in inches. Outside Europe before number of section width is a sign "P", "T" or "LT". "P" means that it is a "passenger" car, "T"– temporary; "LT" – light truck) [III].

2.1.3. Manufacture

Process of producing tires is complicated. In short it could be described by determining a few, most important stages:

- mixing rubber, special oils, carbon black, accelerators, antioxidants and other additives – proportion of all components is a decisive factor of tire properties;
- preparation individual components of tire in extrusion process (tread, sidewalls and inner lines) or by passing the heated mixture of rubber through the set of rollers with the shape of the produced item;
- connection rubber with technical fabric (it can be also steel, then product of this feature is bead);
- cutting material to the correct width with right angle (for creating carcass ply);
- assembling individual parts of tire;
- vulcanization in temperature 190^{o}C and pressure 25 bar (time: 8 – 45 min., it depends on kind of tire);
- checking and eliminating defective elements [5, 6].

The above description is not detailed; in practice process is much more complicated. On the fig. 2.1.3.1 is presented information about tire construction.

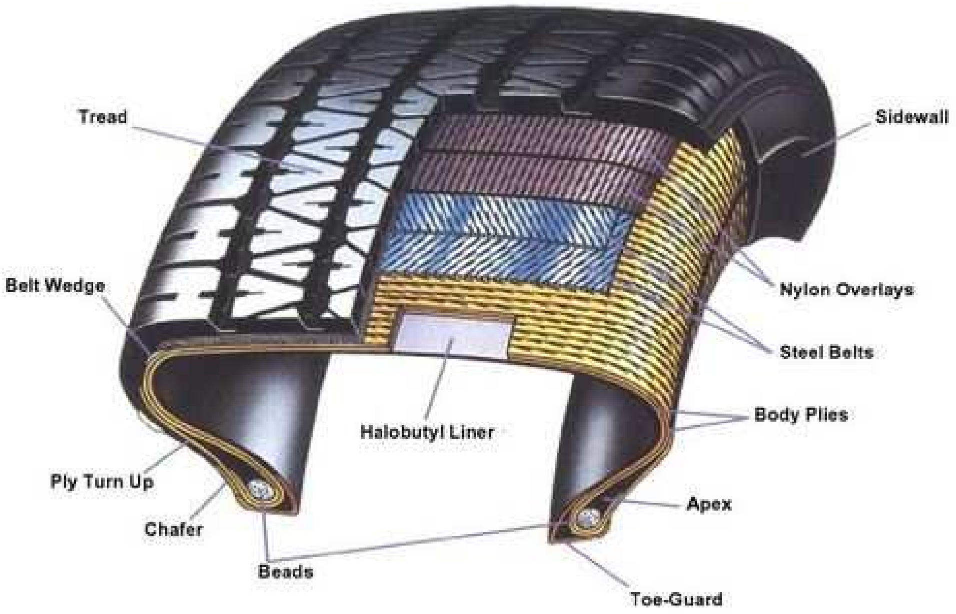


Fig. 2.1.3.1. Construction of tire [IV]

2.1.4. Retreading process

Why tires are that important and which features are the most significant? First of all – tires have to ensure the safety of traveling. The system is responsible for carrying the weight of the vehicle; amortization should be as well as possible. Breaking distance should be reduced to minimum. Except that, exist a lot of other significant properties, which should be provided by the tire: having a very good grip in dry conditions and better exercising on wet road, using less fuel, having better mileage, having good behaviour on fragile snow and ice. Producers are trying to meet the requirements, the tires industry is still developing. Of course high quality and great features are associated with the price [IV, 7].

Responsible for high level of most properties is tread. Depth of this is important factor determining the change of tire [8]. Process of formation tread is carried out in many stages by a lot of machines. Giving tire a second life – retreading – is also laborious process. On fig. 2.1.4.1 presents simplified drawing and the operation can be described by designate every action: tire clean firstly dry tire → inspecting tire → buffing tire → buffing outer wound of tire → buffing inner wound of tire → secondly inspecting tire → repair inner wound → brushing adhesive on roof of tire → secondly drying tire → repair outer wound → affix middle rubber piece → tread building →assemble envelop → assemble inner tire → assemble curing rim →

inspecting inner tire and curing rim → curing→ disassemble curing rim→ disassemble inner tire → disassemble envelop → inspect end product → embellish tire→ store tire [9].

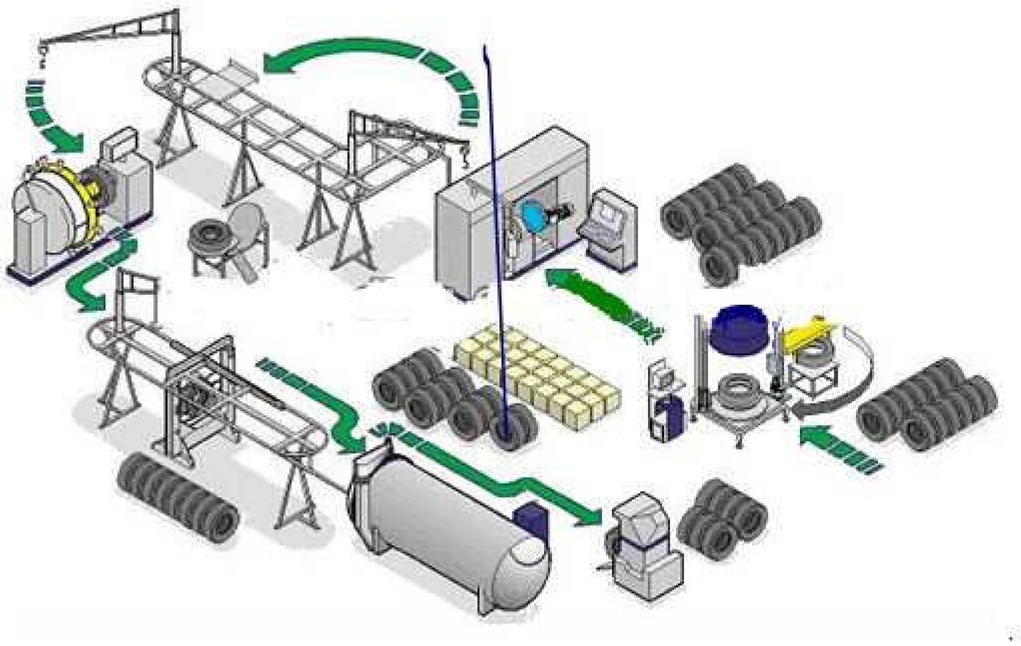


Fig. 2.1.4.1. Retreading process [9]

It is easy to see the inspection is very important part of whole process. It occurs very often because is important to make sure the end product will be able to use. Checking takes place in special machines using pressure and visual inspection [IV].

Few examples of visual inspection stations are showed on fig. 2.1.4.2 and 2.1.4.3. Devices are adapted in work in different conditions – it depends on stage of production. Some of those also are letting for repairs. The machine like that is a subject of this elaboration.

Fig. 2.1.4.2. Tire nail inspection spreader [11]

Fig. 2.1.4.3 Tire charger with bead rollers [11]

2.1.5. Companies

Statistically speaking, for one person living on the earth, there is almost 7 cars (6.75) [12]. In most of countries on the world for one car there is a 2 pairs of tires (different one for winter and summer). Each car has (at least) 4 tires. This simple calculation shows how huge is demand for tires. Thecompanies have to constantly develop to meet the needs of customer. There are a lot of companies which produce tires, the greatest are: Continental, Bridgestone and Michelin. Full information about capital is presented in tab. 2.1.5.1.

Tab. 2.1.5.1. Producents of tires [13]

The company	The capital
CONTINENTAL, Germany	15.03 mld EUR
BRIDGESTONE, Japan	13.80 mld EUR
MICHELIN, France	12.00 mld EUR
HANKOOK, Korea	4.90 EUR
NOKIAN, Finland	4.70 EUR
MAXXIS, China	4.20 EUR
PIRELLI, Italy	3.70 EUR
GOODYEAR TIRE, USA	3.10 EUR
FALKEN, Japan	2.30 EUR
YOKOHAMA, Japan	1.40 EUR

The companies supporting tires industry have also a lot of work. Above it was described in simplified way process of tire production. In reference to that it is easy to imagine how many kinds of machines are used in this process; different kinds of mixers, cutting machines, sprinklers, etc.

2.2. Ashby's Method

Differentiation of work conditions is huge. The most of devices, for example mixers, have to have a high resistance to chemicals, which are used in manufacture process with natural ingredients. Some part of machines also has to be thermo-resistant. The vulcanization process is carried out in temperature higher than 150^{o}C.The production is serial – the machines have to be prepared for long work with the same load. In conclusion – design process of each machine is different, special and precise. The same applies to selection of material for every part of that machine, those issues are related.

In a first stage material selection process is always the same. Designer has to decide which properties are the most important in future work of machine. There are a lot of examples of such a properties, which can be grouped in few, most important fields: general features (density, relative cost), mechanical features (strength, hardness, yield strength, Kirchhoff module etc.), physical features (thermal conductivity, diffusivity, heat capacity etc.) and chemical features (resistance to corrosion, resistance to chemicals).

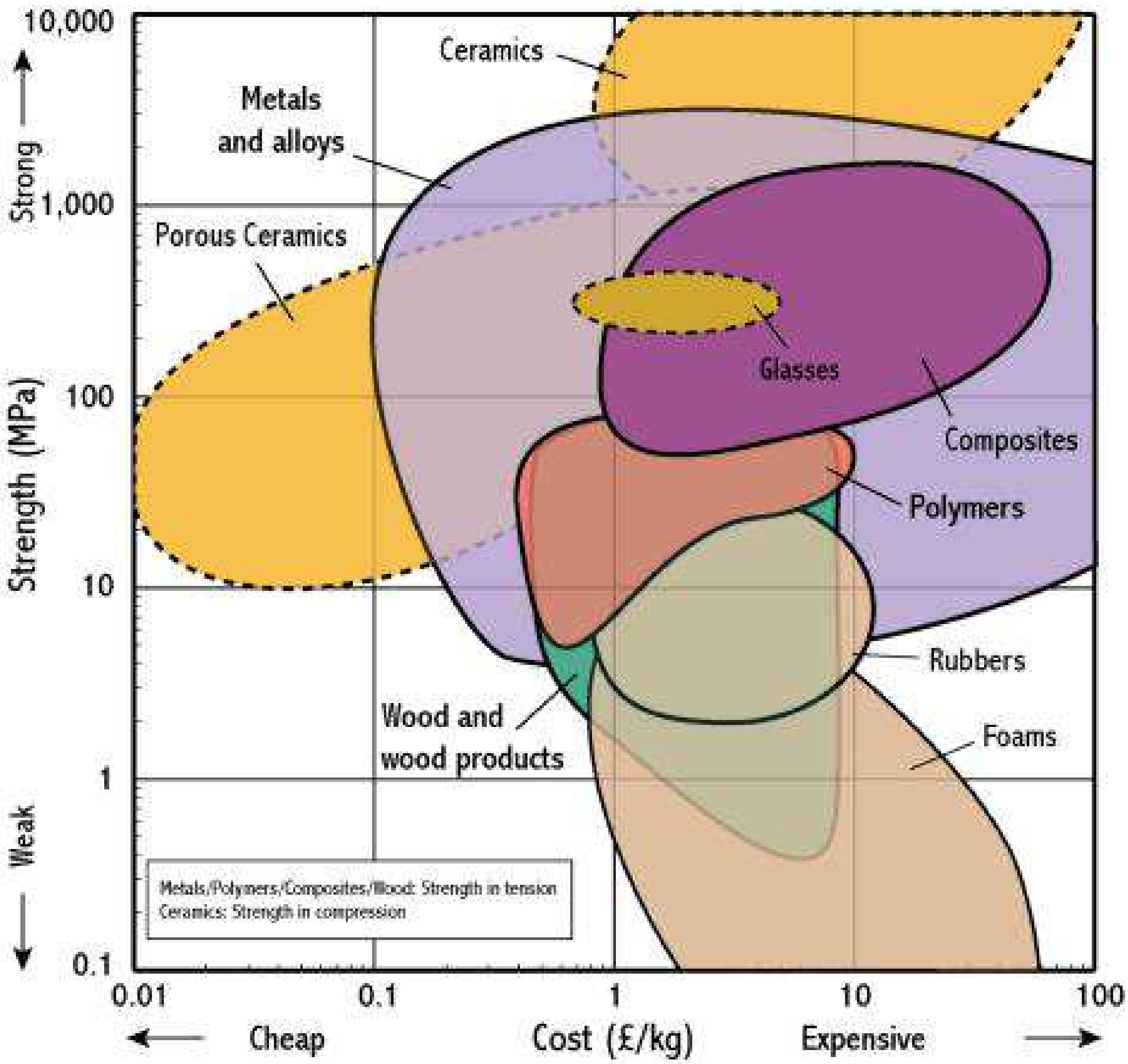


Fig. 2.2.1. Material selection chart: dependence strength and cost [14]

After selection the most important properties, it is time for choosing a few groups of materials which best meet given conditions. The easiest way to define is using material selection charts. They have following characteristics: the scope of axes is chosen to show all group of materials on one chart, data for a specific type of material are concentrated in one defined area, within a field occupied the chart for each type of material included information for a representative of the set –the set consists of materials most commonly and frequently used, selected to be subject to the full range of properties of the group [V]. An example of chart is presented on fig. 2.2.1. This graph is used in project part, in chapter 3.

In this elaboration was used Ashby's method for material selection. This is focused on choosing one from each material group and comparing it with each other. The first step is comparison of two features and giving a grade: 1 for more and 0 for less important (in special cases is acceptable to give 0.5 – when the total score for one feature would be 0). In reference to that a factor is appointed of related validity of property. After that there is a significant to compare materials according to every chosen feature. The grade system is the same as in previous case. When those two factors are designated, it is possible to know usefulness coefficient – the product of multiplication of two described factors. Generally it is necessary to modify coefficient by price of material and this is the aim of whole activity in this subject. The material with the greatest value should be applied for constructing described part [VI].

2.3. Technologies applied

Not every single part of machine can be manufactured in Gislotica. A large part of components applied in mechanical solution is a standardized parts or mechanisms. Products like motors, parts for transmissions, bearings, retaining rings and other components are delivered to company. It should be briefly mentioned how those used mechanisms would work and develop the main mechanism.

2.3.1. Pneumatic drive

The drive is called pneumatic when the working medium is air, over- or underpressure. This system is very popular, mainly due to availability and cheapness of this medium [IX]. The drive is consisting of a lot of components and groups; scheme of acting system is presented on fig 2.3.1.1. Correct work would be impossible without any of subsection. Subject is important and curious, but in this sub-chapter will be further describe only actuator.

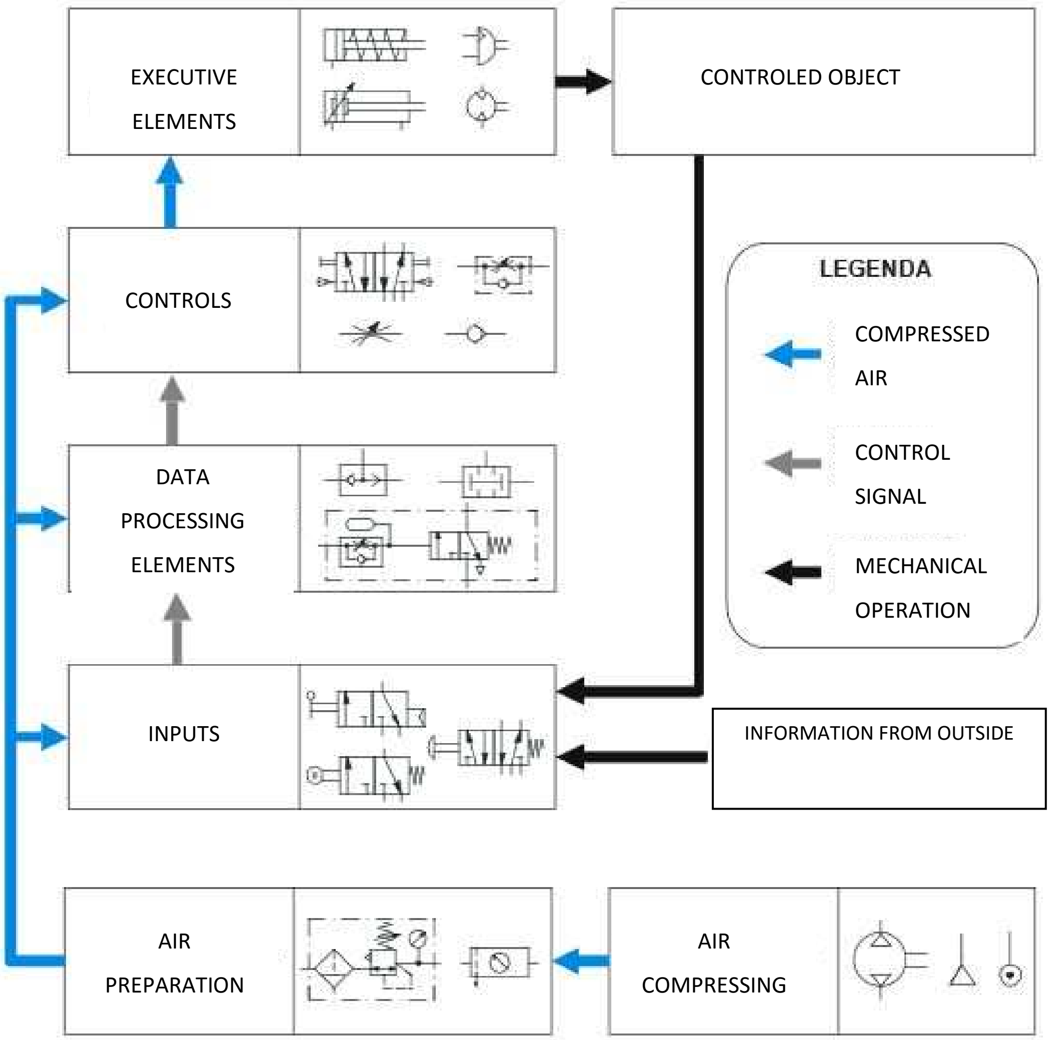


Fig. 2.3.1.1. Scheme of pneumatic system [VII]

Simple definition of this device is as follows: mechanical device which convert energy of compressed air or other gas to kinematic energy and cause motion of element. This is linear motion or rotation.

It is hard to make one division into section – few the most important, are division due to construction, possibility of exercising their power, the nature of the change in the force acting on the actuator, number of strictly defined positions of the working piston or type of motion carried by the actuator [VIII]. On the fig. 2.3.1.2 is showed construction of actuator in most general case – double-acting cylinder. It works in simple way: compressed air act on the piston surface, what causes movement of this piston. After finished work followed by connection with the atmosphere and return to the start position (way of return to the first position depends on kind of cylinder, in presented case exists a possibility to act on second side of piston). To understand how it exactly work and how air behaves is significant to know a several laws, the most important are Joule-Thompson's Law, Clapeyron's Law, continuity equation, Bernoulli's equation, Pascal's Law for fluid in standby mode and law of conservation of mass [IX].

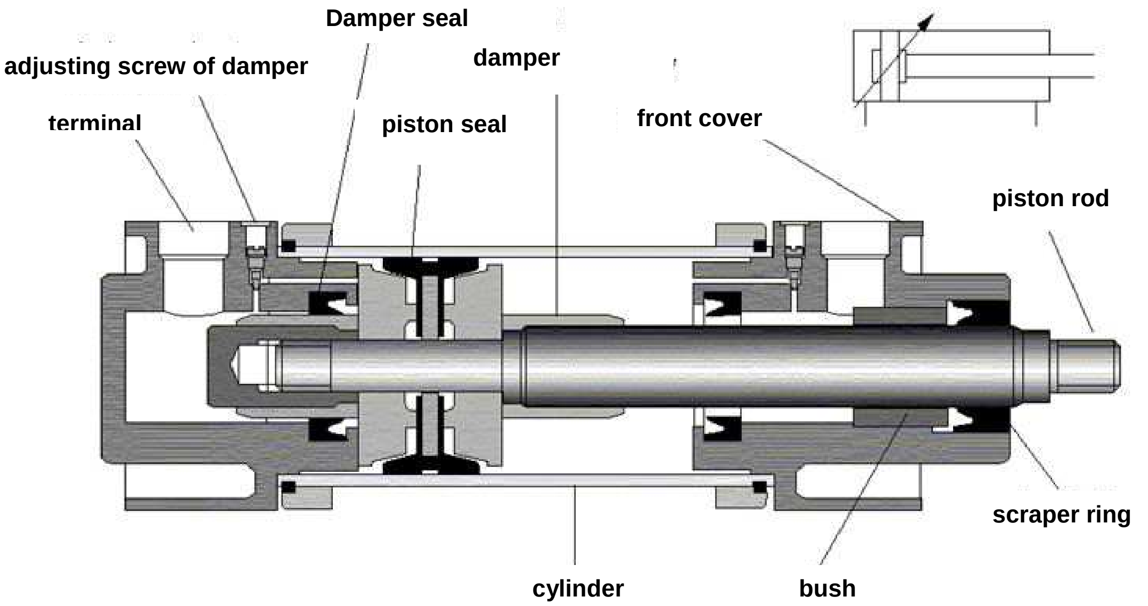


Fig. 2.3.1.2. Cylinder construction [IX]

2.3.2. Transmission

Transmissions are used when is necessity of change torque or rotational velocity of driven shaft. This is also applied when is need to connect two shaft in extraordinary position, in this case it fulfill the same task as clutch.

There are a lot of kinds of mechanical drives, the most popular and most frequently used are: belt (flat or V-belt), friction, gear, chain and worm transmission. Applying of particular kinds depends on work conditions and requirements.

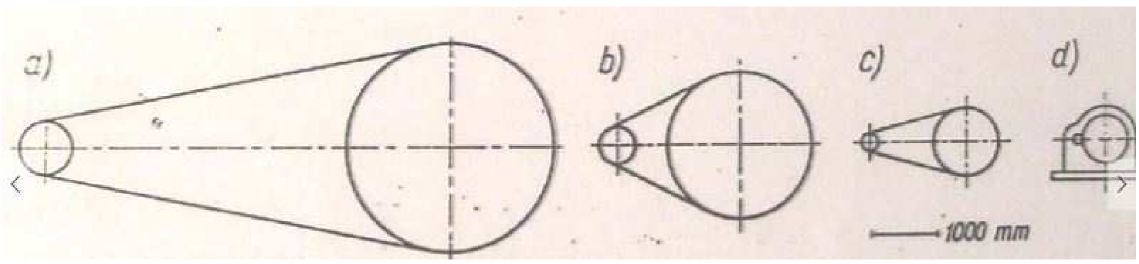


Fig. 2.3.2.1. Transmissions – comparison of dimensions: a) transmission with flat belt, b) transmission with V-belt, c) chain transmission, d) gear transmission [XI]

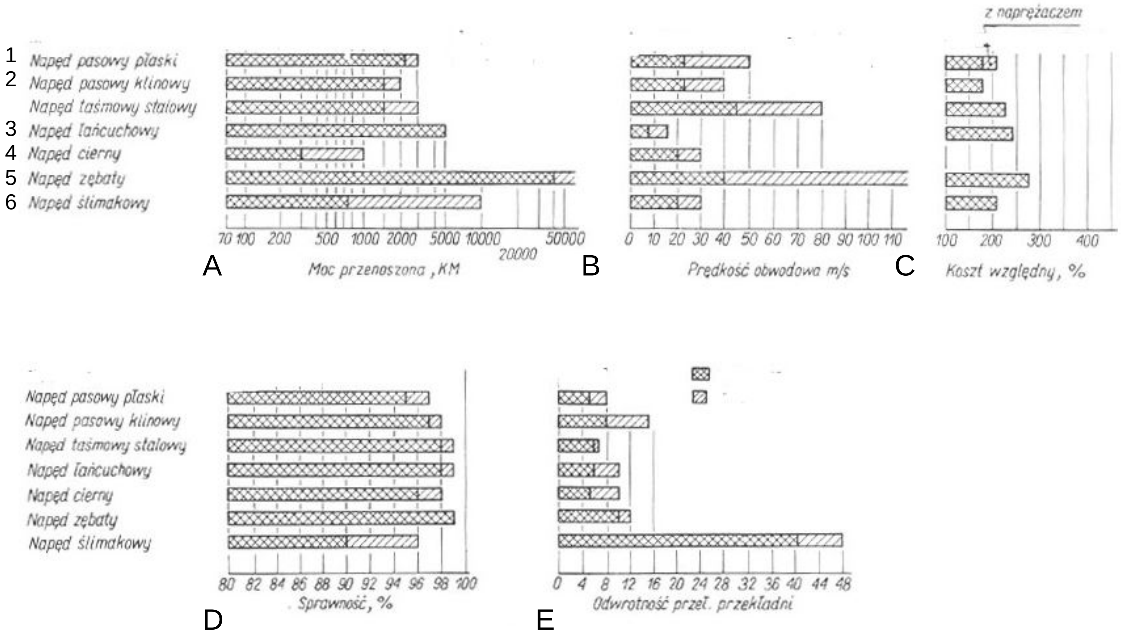


Fig. 2.3.2.2. Comparison of main drive features: A – transmitted power, B – circumferential force, C – relative cost, D – efficiency, E – transfer ratio (inverse); 1 – transmission with flat belt, 2 – transmission with V-belt, 3 – chain transmission, 4 – friction transmission, 5 – gear transmission, 6 – worm transmission [X]

First factor in comparison will be price. The most expensive is a gear transmission. This system also characterizes the best efficiency and ability to transmit the greatest power. Power transmitted has a value 0.37 kW, so it is not necessary to take this condition into account; efficiency equal to about 99% can be also reached by chain drive. The ideas with friction, worm and flat belt transmission was rejected and the reason why was just lower efficiency.

First important condition is compact construction. Because of lack of space there is a need to applying as small as possible system. The fig. 2.3.2.1 presents comparison of dimensions the main drives. It is easy to see that the smallest one is gear transmission. According to cost this drive was rejected. The next one is chain transmission. The only problem can be a permissible circumferential force, so it has to be checked (chapter 3). On the fig 2.3.2.2 is presented composition of other important features.

3. DEVELOPMENT

3. Development

The first information, which should be mentioned, is that the process of creating the project is unusual. Normally, engineer gets an order for machine. In this situation an important thing is only final effect.

In this case work was a quite different. An overview 3D model of machine was available and the main aim was to design everything, mechanic parts and mechanisms included but with keeping basic assumptions. This presents only a preliminary design and the only thing that is possible to conclude out of it is shape (with main dimensions) of the machine.

3.1. Problem analysis

It is necessary to design the vertical inspection station. Destiny of this machine is facilitating of tire inspection and in case of abnormalities–repair.

The main goals are as follow: enabling a tire rotation by connection (not directly) with the motor and lifting up and down the main part of station. If those two conditions are fulfilled, the machine fulfils function.

In this case the choosing the best, the cheapest and appropriate for the first conception idea is the main task. This machine can be built in thousands ways and every company has an own idea how to do this. My job was to do this with the Gislotica’s guidelines. Extended description and overcoming the problems will be described in the next point of this report.

3.2. The main ideas

There is a place for brainstorming. As mentioned above – in this case was a preliminary design 3D model of the machine and the most important basic assumptions could not be changed. That is why this subsection will not be finished with the only one correct solution. In this subsection will be presented ideas, (some of that are right, the others are wrong) and the way of making decisions. First stage of thinking process is describing and after consideration of advantages and disadvantages - choosing the best option. It has to be noticed that there are presented only problematic (for inexperienced designer) questions; description of obvious and clear issues author declined.

3.2.1. Frame with components

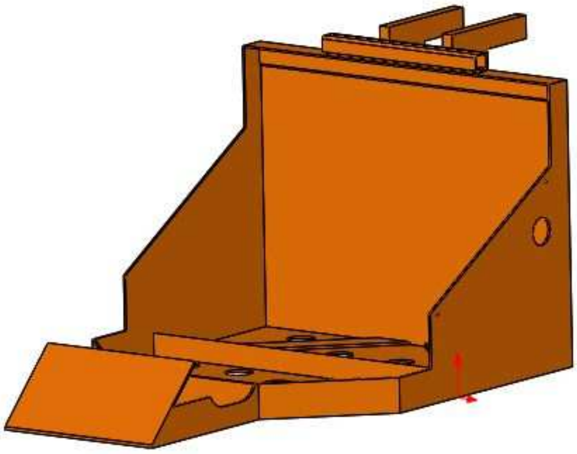


Fig. 3.2.1.1. Prototype of dynamic frame part

First step with design machine was the dynamic part of frame. The fig. 3.2.1. presents how it looked in prototype. On the next figure 3.2.1.2 and 3.2.1.3 reader can observe vision of this part – 3D model and the flat pattern of part.

As you can see on the fig. 3.2.1.2 first idea was adding a special bending on the edges. This is a place for hiding wires, it is very practical. After observing the fig. 3.2.1.3 appears next conclusions. The first one: bending of sheet metal in this way is impossible. This is noticeable for example on the corners. It is necessary to make additional cuts (the correct solution will be shown in the next part of work). The next inference is that buying a huge part of metal is impossible or at least very expensive. It was decided to divide that metal sheet for two smaller parts.

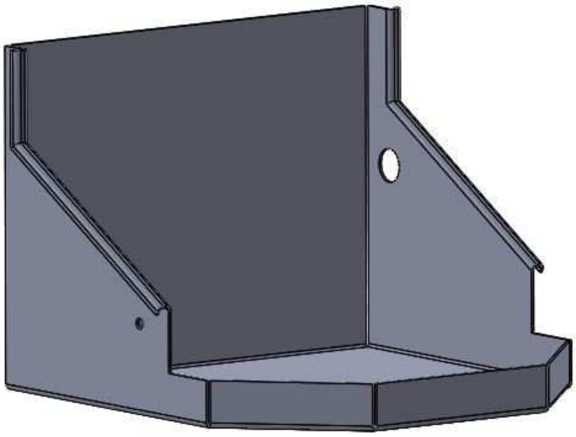


Fig. 3.2.1.2. First vision of dynamic part

After this incident was paid more attention for this kind of mistakes. After designing two parts instead the one, sheet was spread again; the fig. 3.2.1.4 and 3.2.1.5 presents it.

The next group of components is holder for keeping the tire in the right,

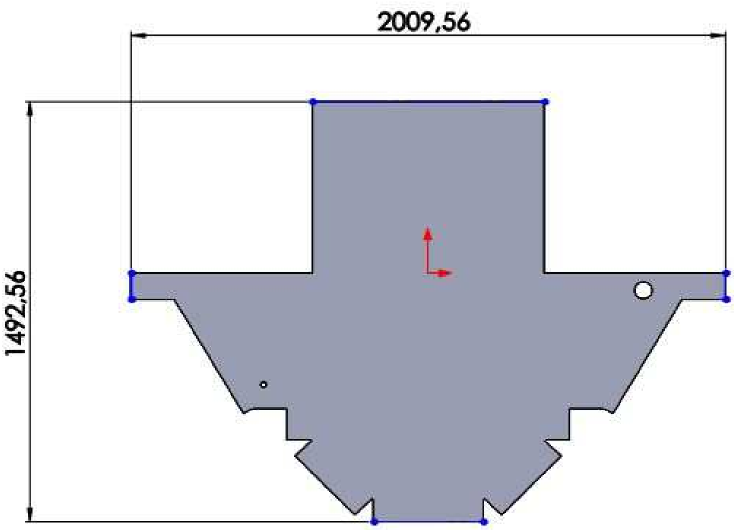


Fig. 3.2.1.3 Flat pattern of dynamic part

vertical position. The final effect of my job is introduced on fig. 3.2.1.6.

It is required to determine the way of moving the holder. Screws allow moving the gantry up and down, depending on tire size. It is also possible to change position of the upper part of holder. This part can be moved forward and backward.

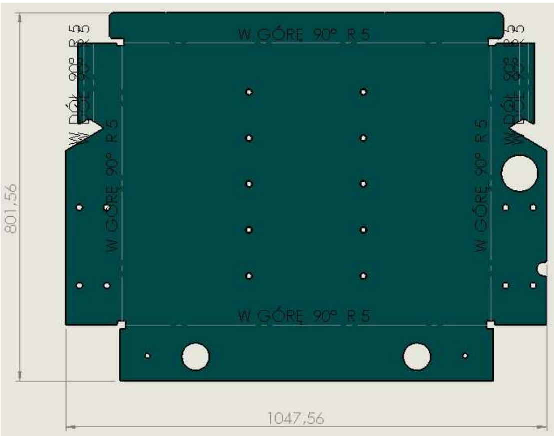


Fig. 3.2.1.4. Spread part of moving frame

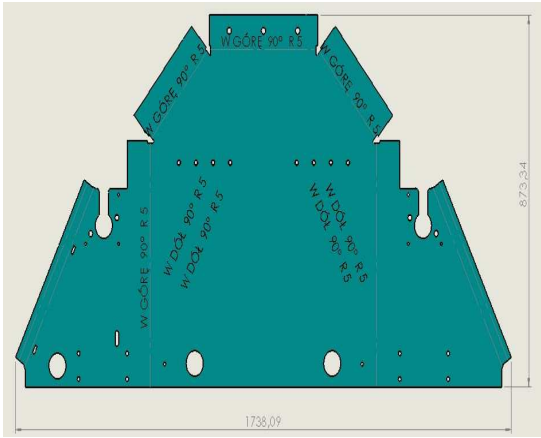


Fig. 3.2.1.5. Spread part of moving frame

The second problem to solve was how to enable movement of this holder from the inside and outside. In this case was necessary to consider pneumatic actuator or moving it by hand, by the screws. Pneumatic cylinder is more convenient, this solution require a minimal work. It also has more possible positions. Disadvantages of that solution are high price (in comparison with the solution with screws) and increased failure. This system is for sure more complicated than the second option.

Fig. 3.2.1.6. 3D holder model

Taking into consideration this features and the fact that there is not necessary to have so efficient system, the solution with the bolts was selected. Thanks to possibility to move inside/outside, up/down and forward/backward exists in a lot of position machine can be used in many cases.

Pad of holder and gantry is connected with square tube and also with the top of moving part of the frame by the same screws.

To the shaft is fastened a pipe, which has a contact with tire. First idea was connection the shaft and the tube by expandable assemblers. Later Fazenda told that it was good idea, but in Gislotica they use another solution. They proposed design of two additional pads and shaft connection with the pipe by welding (using pads). The pads are chamfered like it is presented on fig. 3.2.1.7 – this helps penetration of binder and makes weld more durable. Pipes like that are delivered to company from Chagas [XII]. It is showed on the fig. 3.2.1.8. In this case is no necessary to use separable joint. Thanks to that is not require making a very precise shaft and production of this is cheaper.

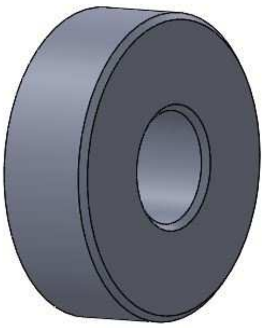


Fig. 3.2.1.7 Special, chamfered pad

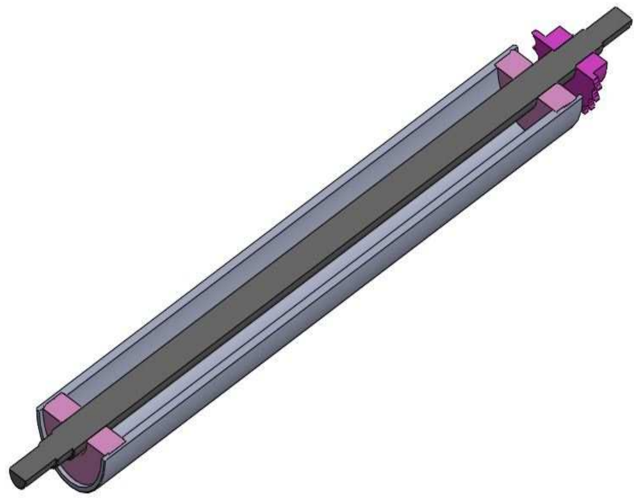


Fig. 3.2.1.8. Shaft and the pipe connected by welding

It has to be taken into consideration how to put on and take out the roller on the right place. In the first solution it is not necessary to using special methods for this, the constructions allows for removing it without problems. But in second option it would be very difficult to remove the solid without interference in another, earlier designed parts. That is why is necessity to cut special, additional openings on the frame.

The openings have a special shape. Reason of this is a bearing [15]. It is pretty clear that for connection frame and the shaft are needed bearings. In this case frame is thin-walled, so it excludes a using a typical, simple bearings. For this construction the best will be housing unit (fig. 3.2.1.9 and fig. 3.2.1.10). Thanks to that unnecessary is using other fixing elements. Model UCFL was chosen, mainly because of lack of space for using a bigger (with three or four screws) one. This model needs a gap with specific diameter to make this connection more stable.

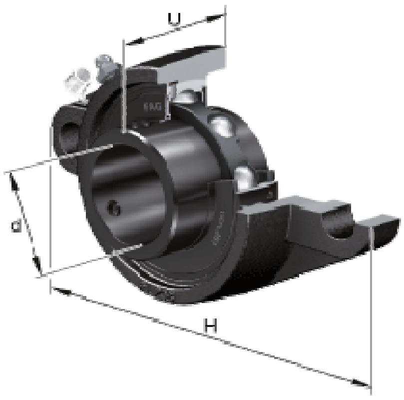


Fig. 3.2.1.9 UCFL bearing with housing [15]

Fig. 3.2.1.10. Kinds of housing units [16]

When are used housing units is necessary to check the kind (and size) of screws. As mentioned the frame walls are thin and there is necessity to use additional pads. Otherwise there will not be connection between the housing of bearing and the frame. One pad from both sides is added. It must be noticed that the pads needs also connection with the frame. Designed part of frame is showed on fig. 3.2.1.11.

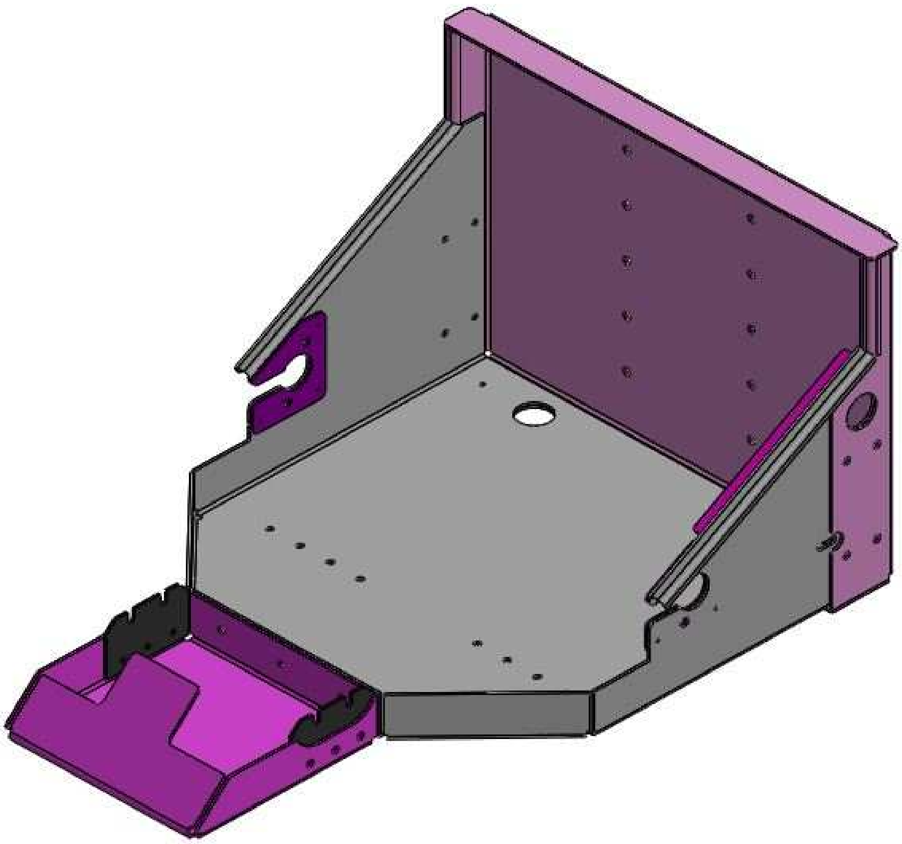


Fig. 3.2.1.11. The last version of dynamic frame part with openings and pads

The tire needs a second fulcrum. In this case is other roller. This one is driven by the tire. Designer has two possibilities: to unite roller with shaft or to separate this two elements. The second option requires space for seating bearings. Part of the machine where the shaft will be attached to is thin-walled so it is essential to use the housing units, not typical bearings. It also requires more space.

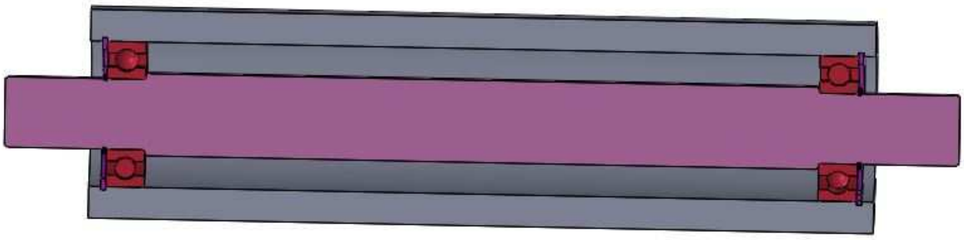


Fig. 3.2.1.12. Cross section of the shaft

The roller and the shaft are independent parts, only roller has to rotate. The shaft are stationary, it permits for connection this elements by bearings. The typical, ball bearings are hidden inside roller and act like connectors between tube and shaft. It is the next advantage – this case does not need other couplers like keys or expandable assemblers. Connection is presented on fig. 3.2.1.12.

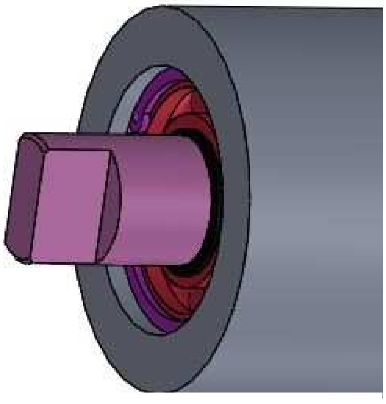


Fig. 3.2.1.13. Connection with static frame

Two ends of shaft are not circular, there are some cuts and the shape of this is presented on the fig. 3.2.1.13. This is very simple solution which makes possible removing the roller and change location of this assembly in every minute. There was considered also thread joint, but this solution seemed to be easier.

There is a place for presenting some comments about the static frame. This is an assembly which is support for every part of this machine, so it has to be stiff and durable.

The most of parts from this huge frame are standardized profiles. It is a huge facilitation, thanks to that no one has to make profiles for example by bending metal sheet.

The plates and pads are prepared for welding. Surfaces of those parts possess a small slits. Dimensions of this slits allows for definitely determining position of welded parts. The static frame is presented on fig. 3.2.1.14.

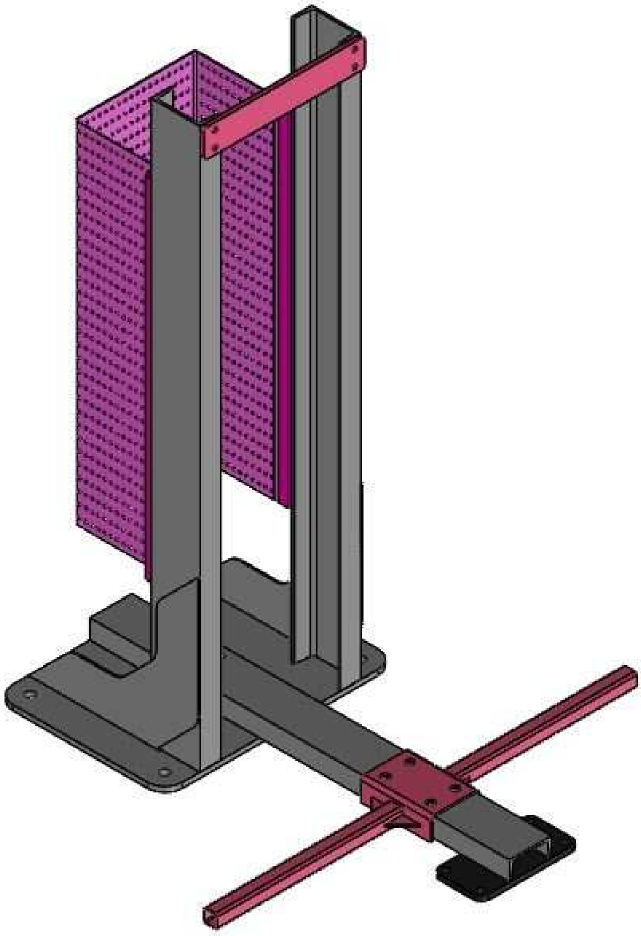


Fig. 3.2.1.14. Static part of frame

3.2.2. Lifting system

The machine has to be able to lift up and lift down dynamic part of frame with tire. To make it possible is necessary using one of the drives: pneumatic cylinder, hydraulic cylinder or electric motor.

Pneumatic devices use compressed air as working medium. The medium has a good dynamic properties and very low viscosity, is easy accessible [17]. There is also a possibility to connect system with the atmosphere after finished cycle, which allows for return to initial conditions [18].

This solution has a lot advantages like big operational reliability, simply construction, low price (in compared to hydraulic cylinder) or low device and medium mass. On the other side it is hard to obtain a uniform motion because of high compressibility of air. The system is very susceptible for any changes of load. Also the force and torque are lower than in hydraulic system [18].

The second option for providing a progressive motion of the frame is electric motor. This system is characterized by construct simplicity and small size of power supply and control system, high reliability, low noise during the work. In additional maintenance is very simple. The disadvantages of proposed solution can be: unfavourable ratio of power and mass (increased by increasing the power), big rotational speed, which force to apply a transmission (the system is more complicated). The dynamic properties are worse than by using pneumatic and hydraulic cylinders.

Fig. 3.2.2.1. Pneumatic cylinder [19]

There is no place for further description of hydraulic system. This is used when big force is needed. Simplified equation presented below (3.2.2.1) shows, that weight to lift up can be lift up by pneumatic cylinder (mass values are estimated).Result was two times increased in terms of safety coefficient; in equation must be included weight from people that repair. Above are compared most important features of two systems with the hydraulic one.

$$F = 2 \cdot m \cdot a_f = \left(m_{df} + m_t\right) \cdot \left(a_{df} + g\right) = (100 + 100) \cdot (1 + 9{,}81) = 4324\ N \tag{3.2.2.1}$$

Was made a decision the best will be using a pneumatic system (like on fig. 3.2.2.1) – relatively cheapest option for demanded properties. Equation 3.2.2.2 presents way of calculation piston diameter of actuator. For good selection was necessary to make some assumption and describe requirements – tab. 3.2.2.1. Every single part of pneumatic cylinder will be delivered by Festo Company.

Tab. 3.2.2.1 Requirements

stroke h	700 mm
pressure p	6 bar

- diameter of pneumatic cylinder

$$d = \sqrt{\frac{4 \cdot F}{p \cdot \pi}} = \sqrt{\frac{4 \cdot 4324}{6 \cdot 3{,}14}} = 96 \text{ mm} \qquad (3.2.2.2)$$

Based on information above, actuator DSBC-100-700-PPVA-N3 [20] was selected. Information about device are presented in tab. 3.2.2.2.

Tab. 3.2.2.2. Main features o selected pneumatic cylinder [20]

Stroke	1 – 2800 mm
Piston diameter	100 mm
Piston rod thread	M20 x 1,5
Cushioning	PPV; pneumatic cushioning adjustable at both ends
Assembly position	Any
Conforms to standard	ISO 15552
Position detection	For proximity sensor
Operating pressure	0,4 – 12 bar
Mode of operation	double - acting
Weight for stroke 0 mm	3,665 kg

First task connected with this solution was how to fasten moving part of frame to actuator. It had to be chosen which part, piston or cylinder, should be stationary. After consideration pneumatic cylinder was selected.

There were some doubts how to join frame with the actuator, but after consultation some things were easier. The idea with moving piston was declined due to one, important reason. In this case the frame would have to be fixed on the end of part. That makes a construction taller, needed more space and, as a consequence, more expensive.

As mentioned, was a problem with fixed frame to the cylinder. There was tried to design some special nut with the same profile as actuator has, but Professor Fazenda suggested another, good solution. He told that exists a nut which is designed specially for that kind of connection [21, 22]. Ways of connection are presented on fig. 3.2.2.3 and 3.2.2.4.

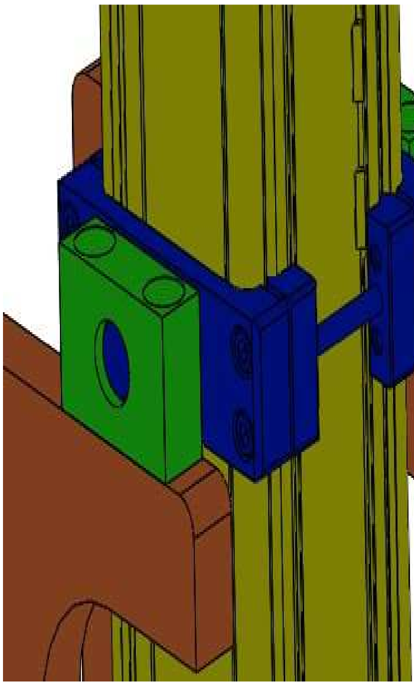


Fig. 3.2.2.3. Connection with dynamic frame

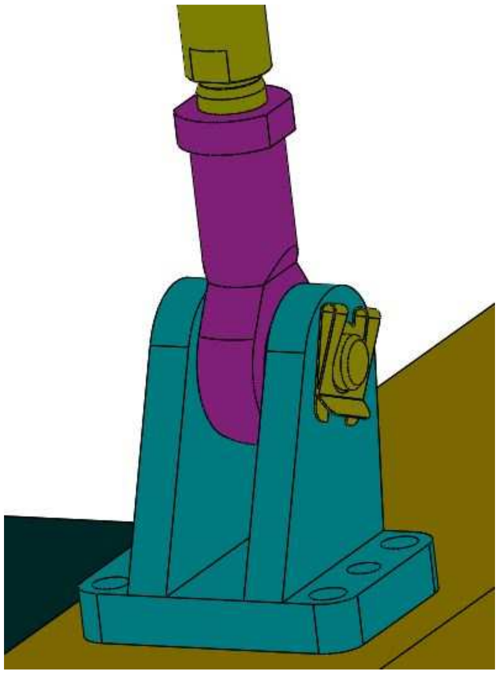


Fig. 3.2.2.4. Connection with static frame

Above is description of two frames – one is static and the second one is dynamic. This move occurs due to energy of compressed air brought to pneumatic cylinder. Now, weight of the whole machine is on the piston with diameter 25 mm. To avoid damaging of the pneumatic device and the rest of parts existed a necessity of design a providing system.

This system consists of eight conic rollers (presented on fig. 3.2.2.5 and with cross section on fig 3.2.2.6) which are able to roll on at vertical the C channels. Each side has four wheels, included two on each C profile.

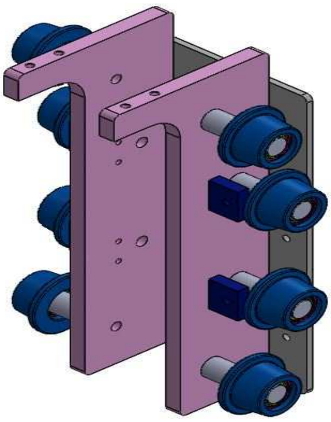


Fig. 3.2.2.5. Providing system

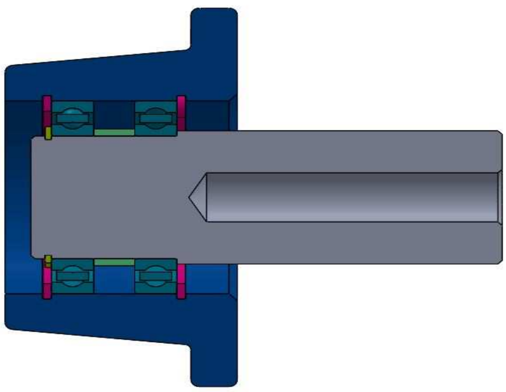


Fig. 3.2.2.6. Roller cross section

The system has to be very precise, otherwise there will be deviations. The wheels must have exactly the same angle as C channel, then system will be tangency. To increase the structure accuracy, contact pressure has to be increased. For this was considered two solutions: centric screws and monkey screws. The price was a decisive factor in this deliberation, monkey screws were selected.

To ensure sufficient contact pressure is enough to press two from four wheels. The position of the others is completely determined by applying a pocket in holder.

3.2.3. Rotating system

The second mechanism is equally important as this described above. This time is not a pneumatic system; the drive of the structure is an electric motor. The reason is one – in this case we need a rotational motion and the simplest way to get this kind of move is apply an electric motor.

The motor selection based on two values: motor power (0.4 kW) and rotational speed (55 rpm). According this information was chosen gearmotor model KAF19/TDRS71S4/TH/LN (fig. 3.2.3.1 and fig. 3.2.3.2); tab. 3.2.3.1 showed most important features.

Fig. 3.2.3.1 Electric gearmotor SEW, K series [23]

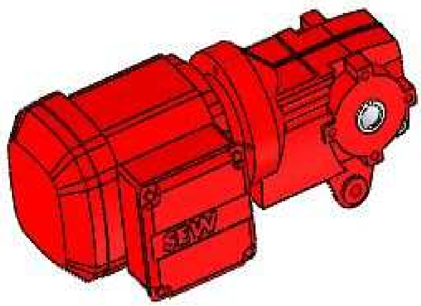


Fig. 3.2.3.2. 3D model of applied gearmotor KAF19/TDRS71S4/TH/LN

Tab. 3.2.3.1. Gearmotor KAF19/TDRS71S4/TH/LN properties [23]

Rated motor speed	1365 rpm
Output speed	62 rpm
Overall gear ratio	21.98
Output torque	61 Nm
Motor power	0.4 kW
Efficiency(50/75/100% P_n)	59.1/65.3/66.6 %
Motor voltage	230/400 V
Frequency	50 Hz
Cos Phi	0.74
Permitted output overhung load with	4500 N
Net weight	12 kg

This model is connected to the rest of machine by flange (with bolts). There is a possibility to choose different solutions in this matter – special torque arm. Furthermore, the engine is equipped with noise-reduced fan guard type LN and motor high-temperature protection – winding thermostat TH.

The aim of this mechanism is a tire rotation. There is no possibility for driving directly (lack of space), so there is a necessity to apply a transmission. Selection of the transmission was based on information included in subchapter 2.3.2. Below (equations 3.2.3.1 – 3.2.3.5), a way of calculation and selection concrete values is presented. Whole calculation process based on [XI]. The motor has the same rotational speed as driven shaft so there is no need to increase the ratio of the system and it has a value $u = 1$; the wheels have the same dimensions. In tab. 3.2.3.2 are showed input parameters.

Tab. 3.2.3.2. Input parameters

Power P_1	0.4 kW
Torque M_1	61 Nm
Rotational speed n_1	62 rpm
transmission ratio u	1
number of teeth Z_1	23
assumed distance between axis a'	367 mm

- number of teeth on driven wheel

$$Z_2 = Z_1 \cdot u = 23 \cdot 1 = 23 \quad (3.2.3.1)$$

For calculation corrected power is significant to know values of two coefficient f_1 and f_2. For the machines working uniformly $f_1 = 1$; f_2 factor can be read taken graph from fig. 3.2.3.3 and is equal $f_2 = 0.75$.

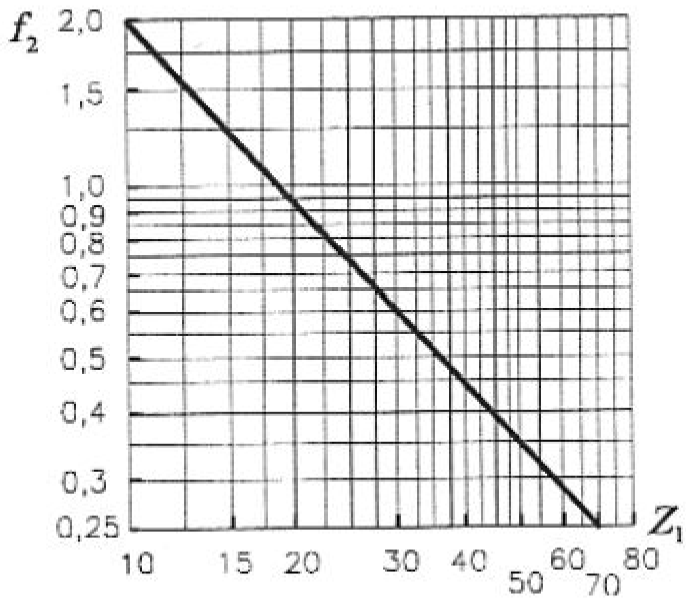


Fig. 3.2.3.3. Dependence f_2=f(Z_1) [XI]

- corrected power

$$P_c = P_1 \cdot f_1 \cdot f_2 = 0{,}4 \cdot 1 \cdot 0{,}75 = 0{,}3\ \mathrm{kW} \quad (3.2.3.2)$$

Next step is selection of kind of chain and the graph in fig. 3.2.3.4 was used for this choice. Selection of kind of chain is recommended to be below signed pink point.

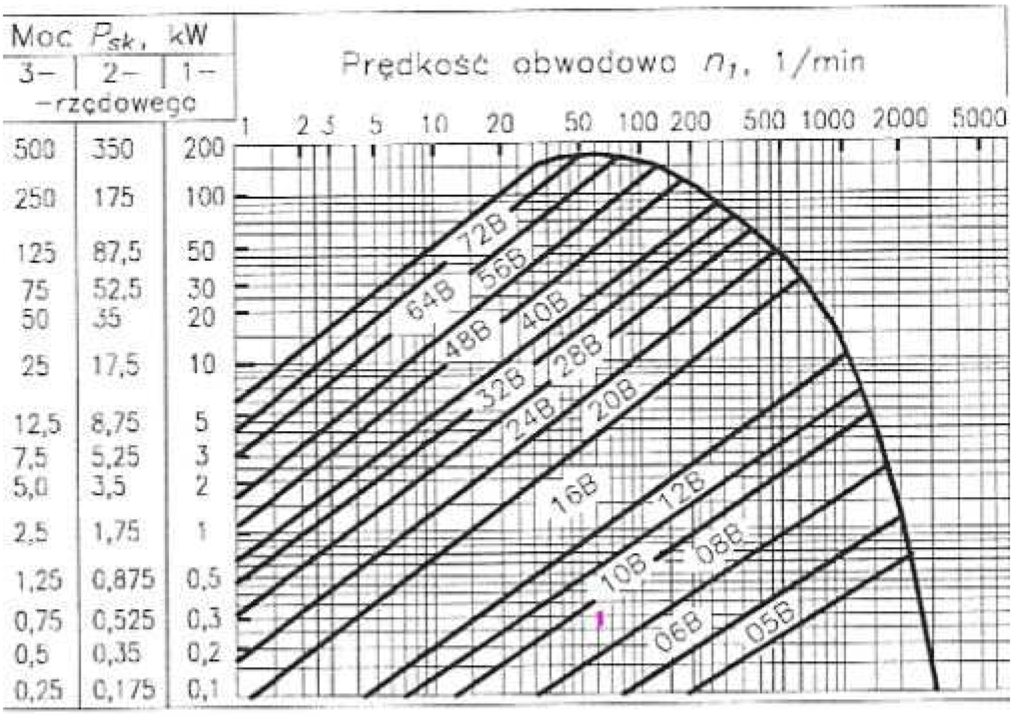


Fig. 3.2.3.4. Graph to select right kind of chain, $P_c = f(w,n_1)$ [XI]

The output information about chain 08B construction are showed in fig. 3.2.3.5 and 3.2.3.6

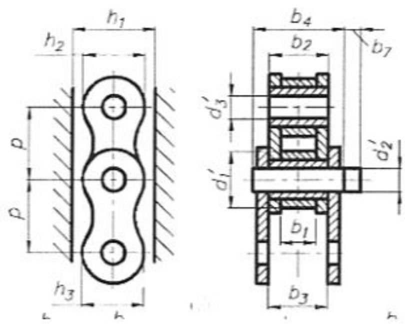


Fig. 3.2.3.5. Dimensions and breaking load for w = (1,2,3) [XI]

Numer łańcucha ISO	p	d_1'	d_2'	d_3'	h_1	h_2	h_3	p_t	b_1	b_2	b_3	b_4	b_5	b_6	b_7	Obciążenie zrywające F_r 1-rzęd.	2-rzęd.	3-rzęd.
	mm															kN		
05B	8,00	5,00	2,31	2,36	7,37	7,11	7,11	5,64	3,00	4,77	4,90	8,6	14,3	19,9	3,1	4,1	8,0	11,4
06B	9,525	6,35	3,28	3,33	8,52	8,26	8,26	10,24	5,72	8,53	8,66	13,5	23,8	34,0	3,3	9,1	17,3	25,4
08A	12,7	7,95	3,96	4,01	12,33	12,07	10,41	14,38	7,95	11,18	11,31	17,8	32,3	46,7	3,9	14,1	28,2	42,3
08B		8,51	4,45	4,50	12,07	11,81	10,92	13,92	7,75	11,30	11,43	17,0	31,0	44,9		18,2	31,8	45,4
081		7,75	3,66	3,71	10,17	9,91	9,91	–	3,30	5,80	5,93	10,2	–	–	1,5	18,2	–	–
082									2,38	4,60	4,73	8,2			–	10,0		
083			4,00	4,14	10,56	10,30	10,30		4,88	7,90	8,03	12,9			1,5	12,0		

Fig. 3.2.3.6. Parameters of chain 08B [XI]

.

- number of chain links (for condition $Z_1 = Z_2$)

$$K = \frac{2 \cdot a'}{p} + Z_1 = \frac{2 \cdot 367}{12{,}7} + 23 = 80{,}8 \approx 81 \quad (3.2.3.3)$$

- real distance between axis (for condition $Z_1 = Z_2$)

$$\mathrm{a} = 0{,}5 \cdot (\mathrm{K} - \mathrm{Z}_1) \cdot \mathrm{p} = 0{,}5 \cdot (81 - 23) \cdot 12{,}7 = 368{,}3\ \mathrm{mm} \quad (3.2.3.4)$$

- circumferential velocity

$$\mathrm{v} = \frac{\mathrm{p} \cdot \mathrm{Z}_1 \cdot \mathrm{n}_1}{6 \cdot 10^3} = \frac{12{,}7 \cdot 23 \cdot 62}{6 \cdot 10^3} = 3\ \frac{\mathrm{m}}{\mathrm{s}} \quad (3.2.3.5)$$

Circumferential velocity was condition to check. Achievable value for this kind of transmission is 18 m/s, normal work is to 8 m/s. The condition is fulfilled. Elements of transmission will be delivered by ROLISA [XIII].

If chain transmission is applied exists a necessity for chain tensioning. Special tensioner was designed. It is a simply construction (fig. 3.2.3.7), works thanks to thread joint. If there is a need for tensioning, it is enough to turn over the nut. Wheel goes up and makes a chain more tensioned. Self-locking of thread makes the system stable.

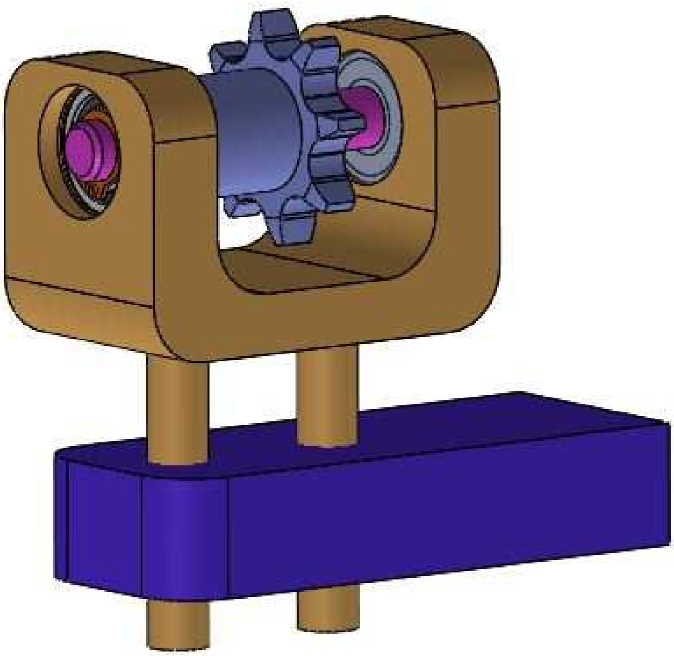


Fig. 3.2.3.7. Designed tensioner

However in project was chosen another solution. There is a device – tensioner for chain – and it is possible to buy it, without modeling and construction new parts. In this case handle with chain wheel is connected with the rest of device by spring. It is a very popular solution. In addition in frame is a gap which permits for horizontal displacement of a whole tensioner. On the fig. 3.2.3.8 is showed chain transmission with the applied tensioning system.

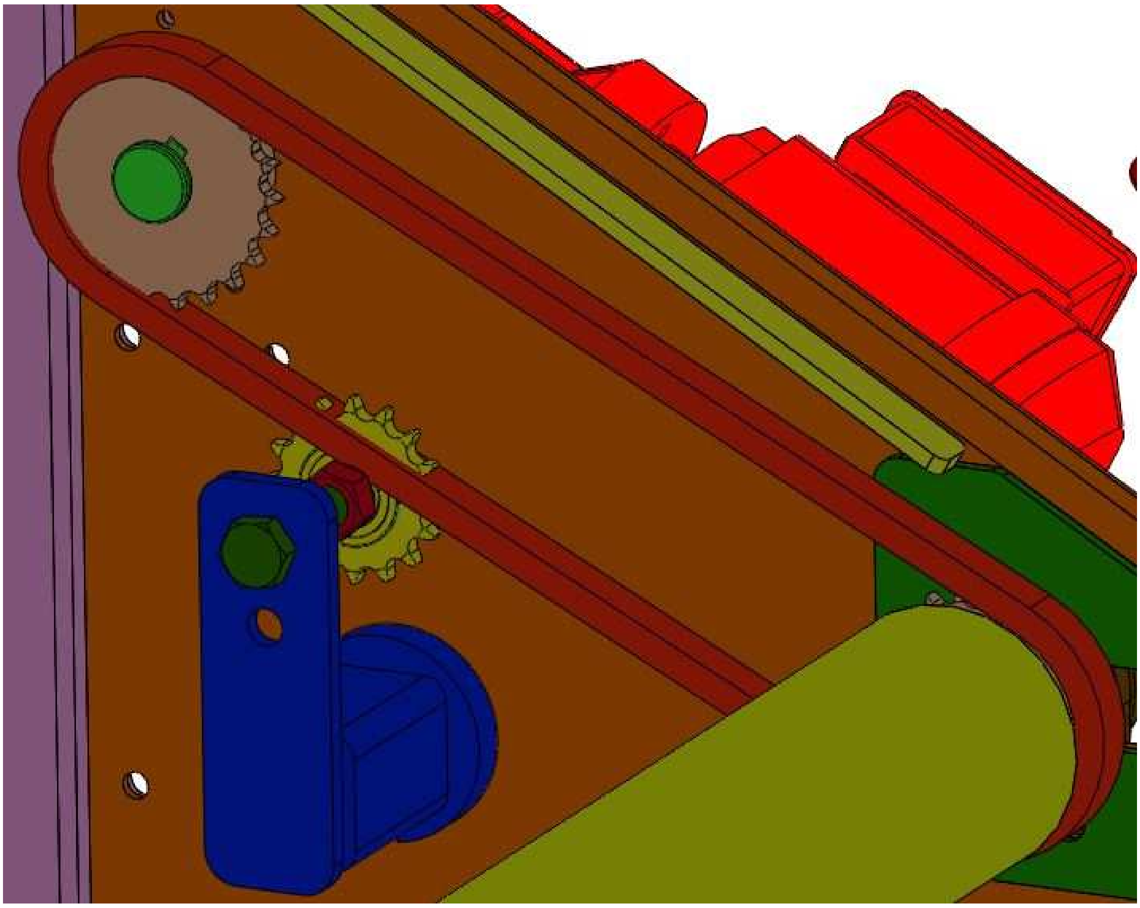


Fig. 3.2.3.8. Simplified view of chains transmission with tensioner

3.2.4. Materials selection

When was necessary to do material selection all parts ware divided for three groups: roller elements, shafts and rest of parts (parts which can be done from material for general use). For choice of the right material was used Ashby's method. Below is presented scheme for this method and as example is used the first case – roller elements. Method is further described in chapter 2.

There have been chosen several most important features, which were taken into account during selection:

- general properties: relative cost;
- mechanical properties: strength, hardness, wear resistance, Young's modulus;
- technology properties: workability.

According the fig. 3.2.4.1 and 2.2.1 the three groups of material were selected: metal and alloys, composites and polymers. The representatives of material will be in sequence: Fe-Cr-Ni alloy, high strength carbon fibre composite, polyamide type 6. The tab. 3.2.4.1 presents the main features of those materials. The workability is assessed in special scale: 1 is the best material,

3 – the worst material. All information contain in tab 3.2.4.1 have a source in program CES EduPack 2005 – program for material selection. The strength value is yielding strength for metals and also polymers and the tensile strength for composites.

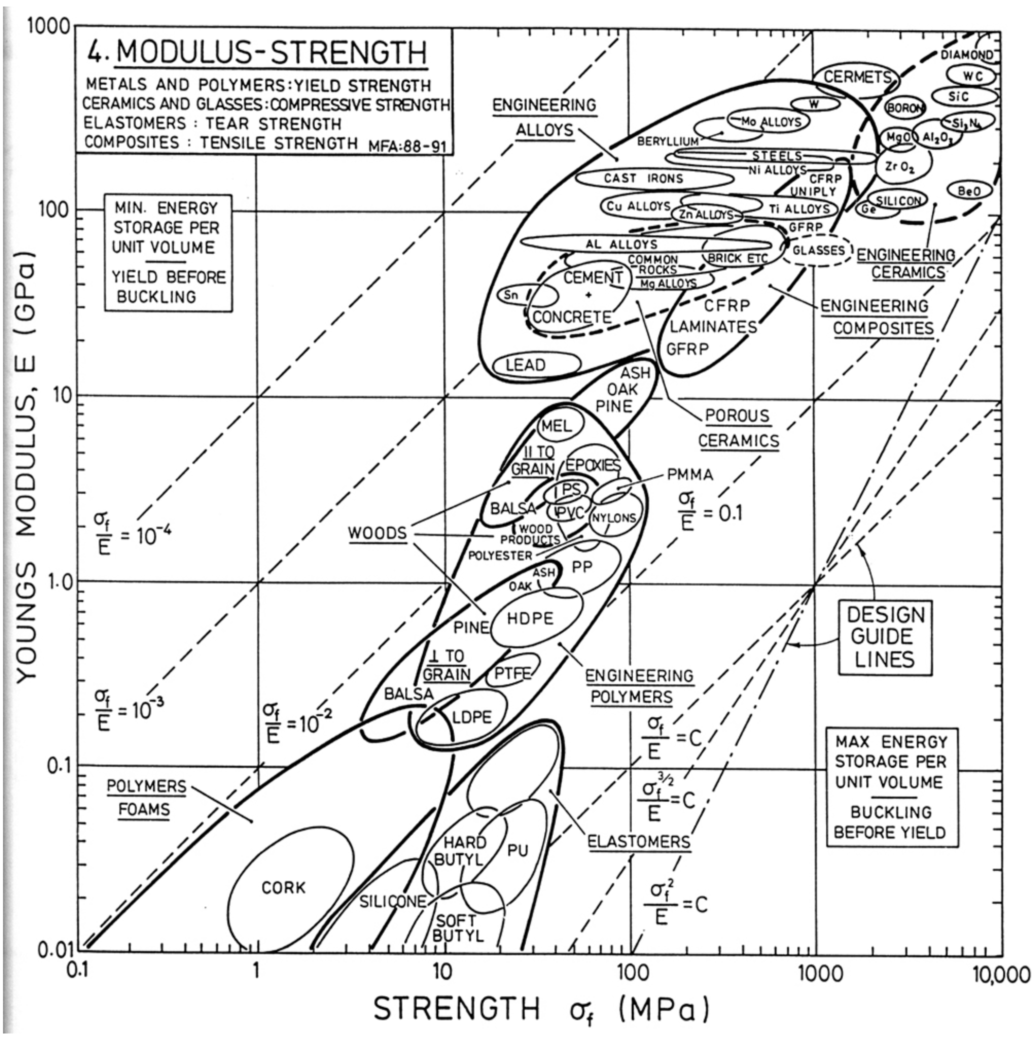


Fig. 3.2.4.1. Dependence Young Modulus E=f(strength) [24]

Tab. 3.2.4.1. Meterial properties

	Fe-Cr-Ni alloy	high strength carbon fibre composite	polyamide type 6
relative cost	15 EUR/kg	90 EUR/kg	3.2 EUR/kg
strength	330 MPa	1720 MPa	128 MPa
hardness – Vickers	400 HV	30 HV	38.5 HV
wear resistance	Good	average	Good
density	8300 kg/m^3	1590 kg/m^3	1320 kg/m^3
workability	1	3	2

The next step in Ashby's method selection is comparison of the features. There is required analysis about importance of each property. The tab. 3.2.4.2 presents results of that. Number of possible decisions is equal N = 10. To designate α is necessary to use equation 3.2.4.1.

- importance of each feature

$$\alpha_i = \frac{Q}{N} \tag{3.2.4.1}$$

Tab. 3.2.4.2. Features comparison

Requirement	1	2	3	4	5	6	7	8	9	10	Q	A
strength	1	0	1	1							3	**0.30**
hardness – Vickers	0				0	1	0				1	**0.10**
wear resistance		1			1			1	1		4	**0.40**
density			0			0		0		0.5	0.5	**0.05**
workability				0			1		0	0.5	1.5	**0.15**

In next stage of material choosing, materials are compared due to each property. Results are showed in tab. 3.2.4.3. The number of possible decisions is M = 3. The equation 3.2.4.2 presents calculation way of β.

- importance of each feature

$$\beta_i = \frac{P}{M} \tag{3.2.4.2}$$

Tab. 3.2.4.3 Material comparison

		Fe-Cr-Ni alloy	high strength carbon fibre composite	polyamide type 6
strength	1	0	1	
	2		1	0
	3	1		0
	P	1	2	0
	β	0.33	0.67	0.00
hardness – Vickers	1	1	0	
	2		0	1
	3	1		0
	P	2	0	1
	β	0.67	0.00	0.33
wear resistance	1	1	0	
	2		0	1
	3	0.5		0.5
	P	1.5	0	1.5
	β	050	0.00	0.50
density	1	0	1	
	2		0	1
	3	0		1
	P	0	1	2
	β	0.00	0.33	0.67
workability	1	1	0	
	2		0	1
	3	1		0
	P	2	0	1
	β	0.67	0.00	0.33

At the endis necessary to use all collected information. According to equation 3.2.4.3 was prepared the summary with data about usefulness coefficient of each material (total score is placed in tab. 3.2.4.4). To designate corrected values (tab. 3.2.4.6) the price must be taken into account. Way of calculation price coefficient is presented in equation 3.2.4.3 and effects of this are showed in tab. 3.2.4.5. The equation 3.2.4.4 presented how to relate two features.

- usefulness coefficient of material

$$\gamma_i = \sum_{i}^{5} \gamma_i = \sum_{i}^{5} \alpha_i \cdot \beta_i \tag{3.2.4.2}$$

Tab. 3.2.4.4. Usefulness coefficient of material

	Fe-Cr-Ni alloy	**high strength carbon fibre composite**	**polyamide type 6**
relative cost	0.099	0.201	0.00
strength	0.067	0.000	0.033
hardness – Vickers	0.200	0.000	0.200
wear resistance	0.000	0.017	0.034
density	0.101	0.000	0.050
$\sum$	0.366	0.218	0.267

- price coefficient

$$k_i = \frac{\text{price of the cheapest material}}{\text{price of the material}} \tag{3.2.4.3}$$

Tab. 3.2.4.5. Price coefficient

	Fe-Cr-Ni alloy	**high strength carbon fibre composite**	**polyamide type 6**
$\mathbf{k_i}$	0.213	0.036	1.000

- corrected usefulness coefficient

$$\gamma_c = k_i \cdot \gamma_i \tag{3.2.4.4}$$

Tab. 3.2.4.6. Final results of corrected usefulness coefficient calculation

	Fe-Cr-Ni alloy	high strength carbon fibre composite	polyamide type 6
γ_c	0.079	0.008	0.267

The selection is finished with unequivocal result. After price consideration material PA6 was proved to be the correct one. The same method was used for selection material for shafts and the rest of parts; the best solution for first group is alloy steel C45E and for second group structural steel St37.

3.3. Instalation

Installation should be carried out by technicians from Gislotica or people approved by this Company, any guidelines about assembling are included in technical documentation.

Before installation, it is necessary to check if there are no missing or damaged components. If parts issue is correct, please check if parameters of electricity (400 V, AC, 50 Hz) and compressed air (6 bar) are proper. The machine needs space: surface area with 1400x1800 mm and height 2000 mm. The device should be fixed to the floor. It is possible thanks to holes (M20) in plates.

Below are presented a few general conditions:

- The machine can be operated only by specially trained staff;
- Temperature in place where machine works should be included in section (-5^{o}C, +40^{o}C), recommended humidity is < 50 %;
- Using the equipment outside is not allowed.

If any problems appear during the work, safety stop button should be pushed as soon as possible.

3.4. Budgeting

As mentioned in project part the important factors of selecting parts and mechanism were price and costs. In this subchapter a price collation will be made.

The tab. 3.4.1 is a small part of collation generated by SolidWorks (the first six columns) – it presents an assembly number 9 (whole table is attached in appendixes). There is a number of assembly, name, reference number, material, description and quantity. In material rubric is inscribed a symbol of materialor the reference number of standardized, bought part. In next column is information about demanded treating of material to make a part/assembly or the name of brand which produce described component.

Tab. 3.4.1. Information about assembly nr 9

Nr	Name	Ref. Nr	Material	Description	Qn.	Part Price (EUR)	Work Time (h)	WorkCost (EUR)	Sum (EUR)
9	Assembly 012	**20160019-100**		assembling	1		3	15	45.00
	roller 012	**20160019-103**	St37	lathing	1	32.00			32.00
	shaft 012	**20160019-105**	C45E	lathing	1	28.00			28.00
	bearing 6206	**20160019-104**	6206	INA	2	3.50			7.00
	retaining ring E30	**20160019-101**	E30	INA	2	0.08			0.16
	retaining ring I62	**20160019-102**	I62	INA	2	0.40			0.80

The next four columns present a purchase cost, work time, work cost and the sum. Information placed in these rubrics are real prices of materials and parts, whole section was created with cooperation with an experienced worker of Gislotica, according to previous cooperative between companies.

Total cost of the investment is about 5300 EUR. This amount includes a cost of productions and cost of materials, but without screws, nuts, washers and keys. I made a chart (fig. 3.4.1) which allows imagining how much will be spend for each issue: parts manufactured from outsourcing (made and also bought, standardized components), actions or part made in Gislotica.

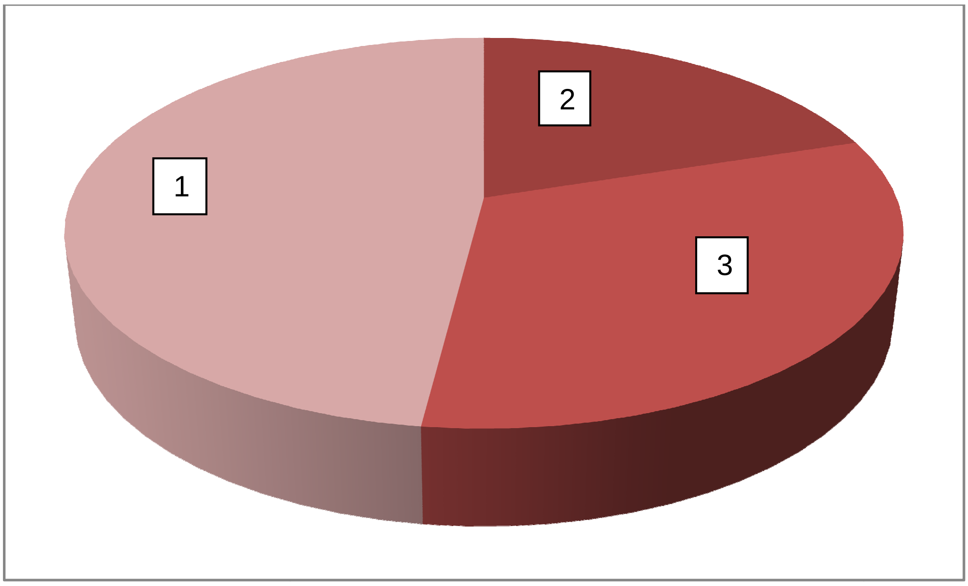


Fig. 3.4.1. Chart presented percentage of total cost of investment: 1 – standardized components delivered by external companies, 2553 EUR – 48 %, 2 –the work done by Gislotica (assembling, welding), 1065 EUR – 20 %, 3 – work done by other companies (lathing, milling), 1700 EUR – 32 %

3.5. Critical analysis and prospects for improvement

Process of machine execution is not started yet, now is lasting designing stage. Regarding that, is hard to make some conclusion and determine mistakes. However there is one objective, which should be modified, if there would be more time.

Above is described system of tire holders, which is fixed to the lath by screws. In this case for changing position of holders it is necessary to remove bolts every time. Now it is possible taking into consideration applying small pneumatic system again. It would establish new positions there would make changing of it easier. Of course necessary is further deliberation in this subject, included costs and requirements etc.

Moreover it is necessary to describe what should be changed in procedure of designing. The issue is very important and the first and decisive matter is making a smart work plan. It permits for better using of time and greater efficiency. It allows also for avoiding accumulation of work in final stage what is always confusing.

Planning is very important, not only if it is about time in project. For example a lot of components are finished by feature bending. At first, it is good to think over which edges will be bended to ensure the best solution. Thanks to that there will be no mistakes and this will avoid re-designing of metal sheet. The effect of this is the cheapest way of part design and then – machine design.

The project was based on the knowledge and experience of people working there. It is hard to imagine, but it could be also disadvantage. After a few years of doing similar project job can be a routine. Then could appear a mistakes caused by not-checking and inadvertence. This could also provide development stopping. Repetition of the same solution and collaboration with the same people and companies may result in overlooking of easier, cheaper or more efficient solution.

I performed a SWOT analysis for that project, which result is a diagram presented below, on fig. 3.5.1. It permits to determine main objectives, then to optimize a work process to achieve the aims in the most efficient way.

	STRENGTHS	WEAKNESS
EXTERNAL FACTORS	• simple construction of the machine • collaborating with mechanical construction leaders (INA, SEW) • low materials cost • designing with a good background and experienced team	• moving parts – covers need • long design time
	OPPORTUNITIES	**THREATS**
INTERNAL FACTORS	• gaining experience • getting good reputation in tire industry environment • earning money	• loosing reliability when project will failure • newer technologies – possibility to make another, more efficient machine
	POSITIVE	NEGATIVE

Fig. 3.5.1. SWOT diagram

3.6. Maintenance Guidelines

Maintenance has a huge meaning for each machine. This word contains inspection, conservation, which are necessary to provide a good and safe work. The effect of correct treatment is a safe, long lifetime of device. It also allows for demanding acceptation of liability by company when machine would be damaged or destroyed (assuming a correct using).

The general rules have to be followed:

- Everyparts or devises produced by another companies, like motors or bearings, has an own manuals and statute. Every rule about using and maintenance has to be realized.
- It is not allowed to do unauthorised repairs. It may cause destroying of the machine and Gislotica cannot accept the liability.
- It is not allowed to remove and change original equipment for another; in this case proper work is not provided.

During normal, daily work it is necessary to do inspection, more or less often. Tab. 3.6.1 presents the most important ways for checking chosen components.

Tab. 3.6.1. Main maintenance

COMPONENT	ACTION	TIMING
GEAR-MOTOR	Checking physical conditions	QUARTERLY
	Checking noise	WEEKLY
	Checking temperature	WEEKLY
BERINGS	Checking physical conditions	QUARTERLY
	Checking noise	WEEKLY
CHAIN TRANSMMITION	Checking physical conditions	QUARTERLY
	Lubrication	QUARTERLY
	Checking tension	MONTHLY
PROVIDING SYSTEM	Checking physical conditions	QUARTERLY
	Checking position	WEEKLY
FRAME	Checking physical conditions	QUARTERLY

The most loaded mechanism of this model is pneumatic actuator which is able to uplift 200 kg. The movable part is fixed to pneumatic cylinder by four screws. It is absolutely necessary to use providing system. The system is based on special elements which are rolling at the surface, so it is significant to do periodical inspections of the position of the frame. There has to be kept parallelism, to enable move of rollers.

For ensuring a proper acting of the chain transmission there is necessity for lubrication. This feature help:

- to avoid to excessive wear of chain and wheels;
- to decrease friction between components of transmissions;
- to guarantee move precision [10, 25].

In this case (low linear velocity and low transmitted power) it is enough to use period (quarterly), manually lubrication. The lubricate could be lithium grease, aluminium grease or gear oil.

4. CONCLUDING REMARKS

4. Concluding remarks

I presented the results of my job that is a project of machine for visual inspection, which, in my opinion, was a huge challenge for person without any practical experience. Of course it could have been done faster, better, more efficiently and economically, however for me it was a priceless lesson which will have a great influence on my career, in the future.

My first conclusion (I noticed it in first week of my Erasmus time in Portugal) was that it is an exceptional way and an excellent idea to change classes in University for project/internship in company. Student has a possibility to make contacts, learn more and obtain an experience.

In Poland students does not have a chance to spend time on internship like that. The employers are used to treat students unprofessionally. Only a few companies make internships which enable to gather invaluable experience and allows for development.

The list of my new skills is really long. Before my Erasmus+ I used (if we are talking about program for modeling) only AutoCadfor 2D drawings and Catia for 3D drawings. Now after four month of work in SolidWorks I am very intermediate in usageof that program. That is a great advantage, because this software is very popular in Poland as well as in the rest of the world. I had also possibility to learn how to use this program in smart way – faster and more efficient. During my internship I have found out that design process in practical aspect differs from the way it was shown in the University.

In Gislotica I have learnt a lot of new things, not only improved my mechanical skillsbut also I have learnt to be patientand precise. I had to learn that my work is not the most important in the company, everyone has an own project to do, so sometimes there was nobody to help me. I had to solve a lot of problems by myself that were consulted later with my tutor Fazenda, so I have learnt how much responsible and hard are making up a right decisions and design process.

I am a positively surprised with attitude for Erasmus students. In Gislotica everyone was really kind and helpful, engineers tried to explain every problem in possible easiest way. People from production hall showed me everything that I needed. They spoke with me about birth of the machine, assembling, disassembling and delivery. It was a really great that I had a possibility for watching building of machine, not only on the paper.

The main goal of my stay in Portugal was of course to learn as much as possible. But after internship I had a lot of time for meeting fantastic people andexploring beautiful country. I visited a lot of great places like Lisbon, Faro (whole southern coast), Coimbra, Aveiro, etc.

Curious and exotic (for Polish people) architecture, friendly people – there are only two advantage of Portugal.

Life and communication with foreignpeople (in work and after that) was interesting experience. However overcoming language barrier was not so easy. Even if you speak English very well, some things you have to hear a few times to understand it duly. In situations like that Portuguese people were incredible patient.

Spending time in Portugal was a pleasure. In educational aspect is nothing to regret – I have gained a lot of precious skills and experience. Cooperation with ISEP was easy;Professor Silva and people from International Office helped me since first day.

I have spent there unique and unforgettable moments with lovely people, with delicious food. Area and weather was great (even in winter). It was a great adventure and I will do the same one more time, if I would only have a possibility.

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6. APPENDIXES

6. Appendixes

[A] Machine for visual inspection – assembly

[B] Machine for visual inspection – exploded view

[C] Part summary

Attachment A

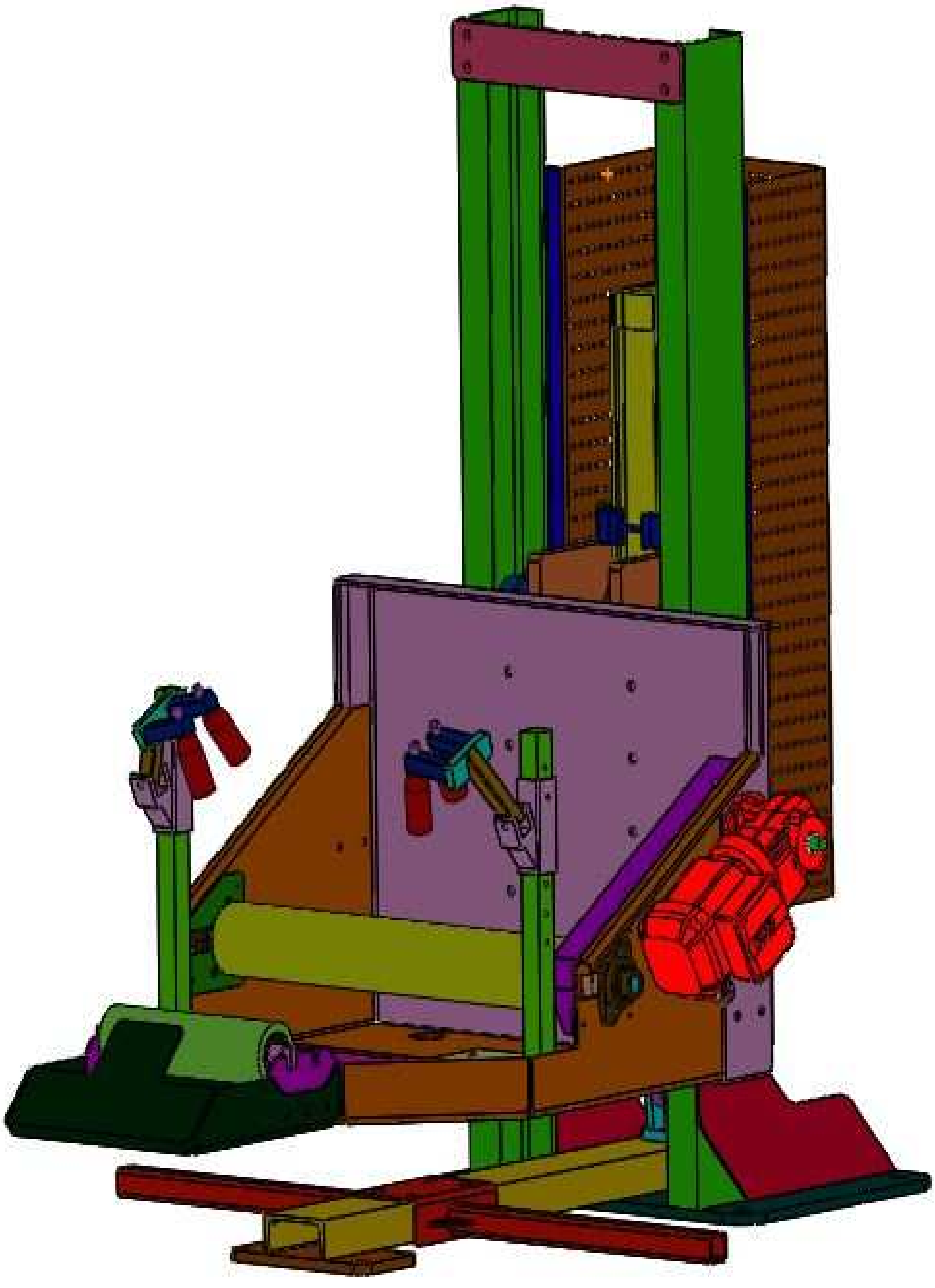

Fig. A. Machine for visual inspection - assembly

Attachment B

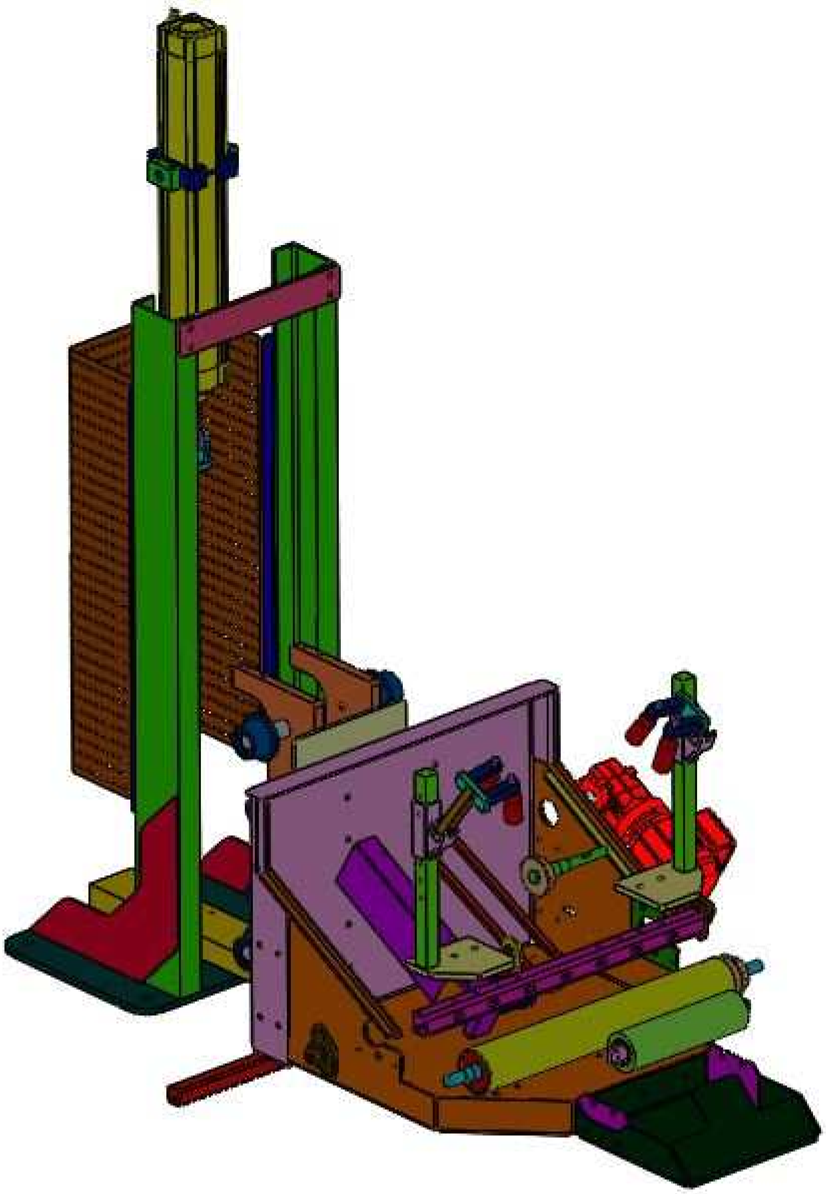

Fig. B. Machine for visual inspection – exploded view

Attachment C

Tab. C. Part summary

Nr	Name	**Ref. Nr**	Material	Description	Qn.	Part Price (EUR)	Work Time (h)	WorkCost (EUR)	Sum (EUR)
1	lath 001	**20160019-123**	c50 x 50 x 5.0	cut	1	16			16
2	Assembly 07	**20160019-025**		assembling	1		2	15	30
	Assembly 03	**20160019-037**		welding	1		0.5	15	7.5
	plate 13	**20160019-038**	St 37	laser cut	1	22			22
	bar 13	**20160019-039**	St 37	cut	1	31			31
	gantry	**20160019-040**		welding	1		0.5	15	7.5
	gantry'spipe	**20160019-041**	tube 40x40x5	cut	1	8			8
	gantry's handle	**20160019-042**	St 37	laser	1	35			35
	Assembly 019	**20160019-125**		welding	1		3	15	45
	bar 14	**20160019-035**	St 37	laser	2	6			12
	bar 24	**20160019-036**	St 37	laser	1	9			9
	bar 34	**20160019-034**	St 37	laser	1	6			6
	Assembly 05	**20160019-027**		assembling	2		1	15	30
	shaft 15	**20160019-031**	Ck 45	lathing	1	9			9
	bush 15	**20160019-032**	St 37	cut	1	4			4
	housing 15	**20160019-033**	PA 6G	laser	1	18			18
	bearing 61902	**20160019-030**	61902	INA	2	2.95			5.9
	retaining ring Z15	**20160019-029**	Z15	INA	1	0,05			0,05
	retaining ring W28	**20160019-028**	W28	INA	2	0.3			0,6
3	Assembly 08	**20160019-045**		assembling	1		1	15	15
	Assembly 06	**20160019-046**		welding	1		0.5	15	7.5
	plate 13	**20160019-038**	St 37	laser cut	1	22			22
	bar 13	**20160019-039**	St 37	cut	1	31			31
	Assembly 019	**20160019-125**		welding	1		8	15	120
	bar 14	**20160019-035**	St 37	laser	2	6			12
	bar 24	**20160019-036**	St 37	laser	1	9			9
	bar 34	**20160019-034**	St 37	laser	1	6			6
	Assembly 05	**20160019-027**		assembling	2		1	15	30
	shaft 15	**20160019-031**	Ck 45	lathing	1	9			9
	bush 15	**20160019-032**	St 37	cut	1	4			4
	housing 15	**20160019-033**	PA 6G	laser	1	18			18
	bearing 61902	**20160019-030**	61902	INA	2	2.95			5.9
	retaining ring Z15	**20160019-029**	Z15	INA	1	0.05			0.05
	retaining ring W28	**20160019-028**	W28	INA	2	0.3			0.6
	gantry	**20160019-040**		welding	1		0.5	15	7.5
	gantry'spipe	**20160019-041**	tube 40x40x5	cut	1	8			8
	gantry's handle	**20160019-042**	St 37	laser	1	35			35
4	Assembly 02	**20160019-073**		assembling	1		3	15	45
	Assembly 01	**20160019-084**		welding	1		1	15	15
	holder 01	**20160019-085**	St 37	laser	1	22			22

	handle left 11.SLDASM	**20160019-087**	St 37	laser	1	42			42
	handle right 11.SLDASM	**20160019-089**	St 37	laser	1	42			42
	conicwheel 01.SLDPRT	**20160019-074**		assembling	4		2	15	120
	conicwheel'sshaft 01	**20160019-077**	Ck 45	lathing	1	21			21
	conicwheel'sbush	**20160019-075**	St 37	cut	1	2			2
	bearing 61907	**20160019-076**	61907	INA	2	2.95			5.9
	retaining ring W55	**20160019-079**	W55	INA	2	0.38			0.76
	rollerhousing	**20160019-080**	PA 6G	lathing	1	75			75
	retaining ring Z35	**20160019-078**	Z35	INA	1	0,1			0.1
	conicwheel 02	**20160019-082**		assembling	4		2	15	120
	conicwheel'sbush	**20160019-075**	St 37	cut	1	2			2
	bearing 61907	**20160019-076**	61907	INA	2	2.95			5.9
	retaining ring W55	**20160019-079**	W55	INA	2	0.38			0.76
	rollerhousing	**20160019-080**	PA 6G	lathing	1	75			75
	retaining ring Z35	**20160019-078**	Z35	INA	1	0.1			0.1
	conicwheel'sshaft 02.SLDASM	**20160019-083**	Ck 45	lathing	1	21			21
	plateleft 12	**20160019-081**	St 37	laser	2	29			58
	plateright 12	**20160019-090**	St 37	laser	2	29			58
5	cover	**20160019-043**	St 37	laser	1	9			9
6	Assembly 018	**20160019-010**		assembling	1		6	15	90
	plate 118	**20160019-015**	St 37	laser	1	16			16
	Assembly 017	**20160019-012**		welding	1		2	15	30
	tube 117	**20160019-069**	40 x 40 x 3.2	laser	2	8			16
	connector 117	**20160019-013**	St 37	laser	1	11			11
	fin 117	**20160019-014**	St 37	laser	4	8			32
	Assembly 016	**20160019-017**		welding	1		3	15	45
	C chanel 140x15 115	**20160019-021**	CH 140 x 15	cut	1	40			40
	fin 116	**20160019-019**	St 37	laser	2	35			70
	C chanel 116	**20160019-022**	CH 120 x 12	cut	1	22			22
	support 116	**20160019-018**	St 37	laser	1	11			11
	C chanel 140x15 114	**20160019-024**	CH 140 x 15	cut	1	40			40
	tube 218	**20160019-065**	40 x 40 x 2.6	cut	2	16			32
	cover 118	**20160019-016**	St 37	laser	1	67			67
	support 118	**20160019-011**	St 37	laser	1	6			6
7	actuator	**20160019-047**		assembling	1		1	15	15
	60927295 1463520 DSBC-100-700-PPSA-N3---(0)D	**20160019-064**	DNC-100-700-PPVA	FESTO	1	750			750
	1463520 DSBC-100-700-PPSA_(Z)	**20160019-065**		not used	1				0
	1463520 DSBC-100-700_(K)	**20160019-066**		not used	1				0
	193152 GRLA-1_2-QS-12-D	**20160019-058**		not used	2				0

	9091119 543861 SME-8M-DS-24V-K-0.3-M8D---(DFDT3D)	**20160019-051**		not used	2				0
	543861 SME-8M-DS-24V-K-0.3-M8D---(P)	**20160019-053**		not used	1				0
	1247168 ASCF-M-23-S DM 2.1-3.4	**20160019-054**		not used	1				0
	SMx-8M-M8D---(2.9_CON)	**20160019-052**		not used	1				0
	541333 NEBU-M8G3-K-2.5---LE3--	**20160019-055**		not used	2				0
	541333 NEBU-M8G3-K-2.5-LE3---(D3M83G0)	**20160019-056**		not used	1				0
	1051830 ASCF-M-23-C DM 4.0-5.6	**20160019-057**		not used	2				0
	9264 SGS-M20x1,5---(S_0_0_100)	**20160019-050**	SGS-M20x1,5	FESTO	1	12.18			12.18
	61334895 163530 DAMT-V1-100-A---(dummy)	**20160019-059**	DAMT-V1-100-A	FESTO	1	25			25
	163530 DAMT-V1-100-A---(ZM_0_0)	**20160019-061**		not used	2				0
	242814 ZNU-100---(ST_6)	**20160019-062**		not used	2				0
	357946 ZNCM-100---(SR_6)	**20160019-063**		not used	4				0
	DIN-912 - M8x30(F)	**20160019-060**		not used	8				0
	237669071 32962 LNZG-100_125---(100SP)	**20160019-067**	LNZG-100-125	FESTO	1	45			45
	32962 LNZG-100_125---(100SP)	**20160019-068**		not used	1				0
	32962 LNZG-100_125---(100SP)_2	**20160019-069**		not used	1				0
	7466319 373500 BO-20-049,0-DA	**20160019-070**	LBG-100	FESTO	1	52			52
	373500 BO- 20-049,0-DA	**20160019-071**		not used	1				0
	209822 16 SXN 08 VERZINKT_SL	**20160019-072**		not used	1				0
	31766 LBG-100---(L)	**20160019-048**		not used	1				0
8	Assembly 013	**20160019-091**		assembling	1		10	15	150
	housing part 2	**20160019-099**	St 37	laser	1	110			110
	housing part 1	**20160019-094**	St 37	laser	1	82			82
	small housing 113	**20160019-098**	St 37	laser	1	66			66
	plate 413	**20160019-097**	St 37	laser	1	13			13
	plate 313	**20160019-092**	St 37	laser	2	6			12

	plate 213	**20160019-093**	St 37	laser	1	9			9
	plate 113	**20160019-096**	St 37	laser	1	9			9
9	Assembly 012	**20160019-100**		assembling	1		3	15	45
	roller 012	**20160019-103**	St 37	lathing	1	32			32
	shaft 012	**20160019-105**	Ck 45	lathing	1	28			28
	bearing 6206	**20160019-104**	6206	INA	2	3,5			7
	retaining ring Z30	**20160019-101**	Z30	INA	2	0.08			0.16
	retaining ring W62	**20160019-102**	W62	INA	2	0.4			0.8
10	Assembly 009	**20160019-120**		assembling	1		2	15	30
	drivingshaft	**20160019-121**	Ck 45	lathing	1	46			46
	chainwheel 109	**20160019-107**	S 1/2''x5/16''	ROLISA	1	15			15
11	Assembly 011	**20160019-106**		assembling	1		4	15	60
	Assembly 010	**20160019-108**		welding	1	95			95
	drivenshaft	**20160019-109**	Ck 45	lathing	1	28			28
	plate 110	**20160019-111**	St 37	laser	2	18			36
	pipe 110	**20160019-110**		CHAGAS	1	20			20
	retaining ring Z30	**20160019-101**	Z30	INA	1	0.08			0.08
	chainwheel 109	**20160019-107**	S 1/2''x5/16''	ROLISA	1	15			15
12	chain	**20160019-112**	08b-1	ROLISA	1	5			5
13	tensioner	**20160019-113**	S08M12	KOMERC	1	35			35
	tensioner'shouse	**20160019-118**		not used	1				0
	tensioner'splate	**20160019-115**		not used	1				0
	screw M16	**20160019-117**		not used	1				0
	nut M16	**20160019-116**		not used	2				0
	chainwheel 08b-1 z16	**20160019-114**		not used	1				0
	screw M12	**20160019-119**		not used	1				0
14	bearing RCJTZ25	**20160019-044**	RCJTZ25	INA	2	32			64
15	motor	**20160019-122**	KA19/TDRS71S4/TH/LN	SEW	1	1500			1500
								$\sum$ = **5318**	