Area: Engineering

Coordinator: Diego Fernando Galavíz Lopez.

Members of the Area: Diego Fernando Galavíz Lopez.

Dates of update:

- March 12 - May 19
- May 19 - June 2
- June 2 -July 25
- July 25 - September 12

Objectives

- Underpin the possible implementation of the project through the design of an internal device and easy to use.
- Decrease the amount of parts and electronic control with the aim of reducing costs.
- Increase the quality of life of the users, by means of an easy to use device
- Design modular containment device of bacteria sub-dermal.
- Make an approximation of the interstitial fluid on the sub-dermal container.
- Design communication, removal and replacement module of bacteria.
- Simulate and analyze through CAD type software parts of the device.
- Submit plans and selection of materials and processes for their manufacture.
- Build a prototype of the external module of the device.

General Information on the device and methodology.

The implementation of the treatment is carried out through a modular mechanism designing from mathematical models of interstitial fluid studied and modeled by means of mechanical means of continuous and fluid mechanics, as well as simulations of the loads that act on the device through the application of the method of finite element analysis (FEA) by its acronym in English.

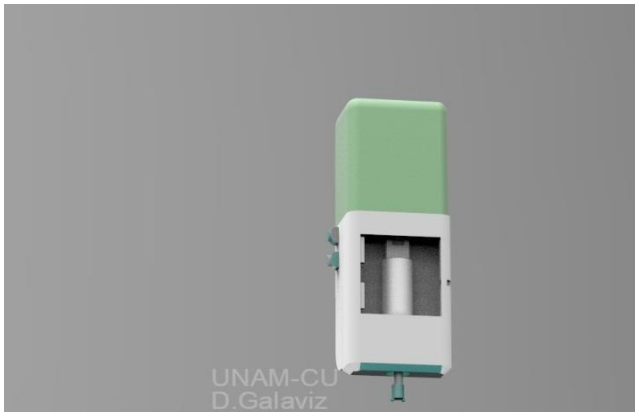
The modular mechanism that consists of three main modules, was governed under the goals to increase the quality of life of the patient to be as independent as possible, simple and easy to use, the lower parts and electronics to reduce costs and the principal that is to provide an effective containment of the bacteria inside of the human organism enabling them to conduct a proper sensing of glucose levels and at the same time provide a safety for the user to be biocompatible with the agency.

Broadly the device is composed of: containment module which is the column structure of the device to contain the bacteria inside of the human body, specifically in the area where the interstitial fluid. This is a porous polymer biocompatible with the human body in pill form which allows, through its pores step of interstitial fluid like insulin, keeping confined to bacteria

The next module will call communication, by connecting the container with a hose of a biocompatible polymer and whose dimensions are of the order of millimeters, with the dermis in which there is a gate with a diameter of 6.5mm that is a mechanism iris (similar to the lens cameras), which are two notches on the outside that serve as key to connect to the extraction module being open and avoiding contact with the outside and thereby reducing potential infections, as you can find a similarity between this module and a catheter, which we realized they have problems in this area and so we designed this "seal" or totally mechanical gate allowing greater aseptic to make the change of bacteria.

Finally the module removal and replacement of bacteria, which in a nutshell we can say is a "sniffer" automatic and mechanical which consists of two buttons (one for extraction and one for injection) that control a single electric motor 25X12x10 mm dimensions which drives a spur gear mechanism with two eccentric shaft that transform transnational circular motion, similar to a Scotch yoke mechanism, with an investment of five bars mechanism engaged, reducing control by electronic and thus decreasing costs.

The measures and units used in this document adhere to SI excluding measures of length and angles in the planes of manufacturing, in that case are presented in millimeters and degrees respectively.



Modeling and simulation of the interstitial fluid.

Initial considerations.

As an element within a stream of fluid for the mechanical design based on what I have first been doing is the model of the flow of interstitial fluid, through the application of fluid dynamics and continuum mechanics, develop step by step equations, until you reach the appropriate model that performed the best approximation to how it behaves the interstitial fluid I omitted some steps because they would require the explanation of tensor calculus, algebra tensor and indexical notation, similarly try to place less omissions and mention them explicitly while the mathematical development.

The objective of this first part was getting to an equation that model the behavior of the fluid on the container and connect this equation with the equation of deformation of solid hookeans $e = \frac{1}{2\mu_e} * \left(\boldsymbol{T} - \frac{\lambda_e \quad I_T}{3\lambda_e \quad +2\mu_e}\boldsymbol{1}\right)$ and thus get critical points of effort in container, however as mentioned in end of this first section this goal was not met due to lack of experimental data.

Modeling of the interstitial fluid and container module.

Balance equations.

Equations or global balance laws are those that govern and describe the deformation and flow of the entire body as a whole. In the case of interstitial fluid despise electromagnetic interactions because they do not create a significant response on the fluid, leaving only thermo-mechanical interactions, with significant simplifications effected, subsequently, to reach the right model that approximates the behavior of the interstitial fluid.

Balance equations

- Conservation of mass.
- Balance momentum
- Balance moment of momentum
- Energy conservation
- Second law of thermodynamics

Conservation of mass.

Considering the absence of sources and sinks, ie the mass is constant; this law states that the total mass of half is retained while the medium is deformed. Where ρ is the density.

$$\int\int\int_V \rho(\mathbf{x},t)\,dv = \int\int\int_V \rho_0(\mathbf{x},t)\,dv$$

And since the density is a material property and is a derived material is carried out and obtain the rate of change of the total mass.

$$\frac{D}{Dt}\left(\int\int\int_V \rho(\mathbf{x},t)dv\right) = 0$$

Applying the Reynolds transport theorem, which is the speed of temporal-material change in the volume integral of a tensor order to obtain the spatial form of the law of conservation of mass.

$\int\int\int_V \frac{D}{Dt}(\rho\,dv) = \int\int\int_V (\frac{\partial\rho}{\partial t} + \mathbf{\nabla} * (\rho\mathbf{V})dv)$=$\int\int\int_V (\frac{D\rho}{Dt} + \rho\,\mathbf{\nabla} * (\mathbf{V})dv)$=0

V is the velocity field.

Getting comprehensive forms of conservation of mass

Because it is a universal law must be met for each element of the volume of the body, so the axiom applies for local law crazy mass balance as the most general form of this law it is that the integrand is zero.

Differential forms (balance local law).

$$\frac{D}{Dt} + \rho\,\mathbf{\nabla} * (\mathbf{V}) = \frac{\partial\rho}{\partial t} + \mathbf{\nabla} * (\rho\mathbf{V}) = 0$$

And this equation is also known as the continuity equation in fluid mechanics that will be critical for modeling the behavior of the interstitial fluid.

Act global balance of momentum.

From classical mechanics, based on the second equation of motion of the fast newton temporary change of momentum of a body experiencing deformation or flow is obtained. $\int\int\int_V \rho\,\mathbf{v}\,dV \triangleq$ total linear movement in a given time

$$\frac{D}{Dt}\int\int\int_V \rho\,\mathbf{V}\,dv \quad = \quad \int\int_S t_{(n)} dA + \quad \int\int\int_V \rho\,\mathbf{f}\,dv$$

$t_{(n)}$ It is the vector of forces and can be defined as t _ ((n)) = n * T, where n is a normal vector to the surface under study.

Total linear motion + = surface forces body forces.

For the (local) differential form the surface integral is expressed as a volume integral using the divergence theorem and the definition of the vector of efforts with the stress tensor.

Now the Reynolds transport theorem applies to left side, is simplified and clears.

$$\frac{D}{Dt}\int\int\int_V \rho\,\mathbf{v}\,dv = \int\int\int_V \frac{D}{Dt}(\rho\,\mathbf{V}\,dv\,) = \int\int\int_V (\frac{D\boldsymbol{V}}{Dt}\rho\ \ dv + \boldsymbol{V}\ \frac{D}{Dt}\rho\boldsymbol{V})$$

Is simplified due to the conservation of mass is known zero.

$$\int\int\int_V (\frac{D\boldsymbol{V}}{Dt}\rho\ \ dv)$$

Developing the derivative material.

$$\int\int\int_V (\frac{D\boldsymbol{V}}{Dt}\rho\ \ dv)$$

$$\int\int\int_V \rho\,(\frac{\partial\boldsymbol{V}}{\partial t} + \boldsymbol{V} * \boldsymbol{\nabla}\boldsymbol{V})\,dv$$

Changing notation of the term of the derivative material, to reduce the size of the expression.

$$\int\int\int_V (\dot{\boldsymbol{V}}\rho\ \ dv)$$

Clearing the right side and grouping the entire expression.

$$\int\int\int_V (\boldsymbol{\nabla} * \boldsymbol{T} + \rho\big(\boldsymbol{f} - \dot{\boldsymbol{V}}\big))\ \ dv)\ = 0$$

Similar to the law of conservation of mass, the axiom applies location as it is a universal law and must comply in any part of the body, the differential form is obtained.

$$\nabla * \boldsymbol{T} + \rho(\boldsymbol{f} - \dot{\boldsymbol{V}}) = 0$$

That it is known as the first law of motion Cauchy.

Balance moment of momentum

From defining moment or torque Mo = p × f where p is the distance from the point to the force that causes the f couple are the forces, you can get temporary speed at the time of the total momentum of a body around the origin while this undergoes deformation or flow.

$$\frac{D}{Dt}\int\int\int_V \boldsymbol{p} \times \rho\, \mathbf{V}\, dv = \int\int_S \boldsymbol{p} \times t_{(n)} dA + \int\int\int_V \boldsymbol{p} \times \rho\, \mathbf{f}\, dv$$

Applying the Reynolds transport theorem to left.

$$\int\int\int_V \frac{D}{Dt}(\boldsymbol{p} \times \rho\, \mathbf{V}\, dv)$$

Developing.

$$\int\int\int_V (\frac{D\boldsymbol{p}}{Dt} \times \rho\, \mathbf{V}\, dv + \boldsymbol{p} \times \frac{D\boldsymbol{V}}{Dt}\, \rho dv + \boldsymbol{p} \times \frac{D}{Dt}(\rho dv))$$

Put simply, because ultimately the conservation of mass is zero appears, and similarly the term (DP) / Dt can be rewritten in the form u = pP being offset field or in our case the fluid displacement Interstitial being py P vectors of positions in the reference states and deformed, that is what the position of a point to start and what was the end, developing the expression with its material derived p = u + P, (Dp) / (dt) = (Du) / Dt - (DP) / Dt.

Because it is in material coordinates, the material derivative is a partial derivative therefore partial respect to time of the displacement field gives us the speed, it will have a very important role in our model and simulation of interstitial fluid and because we are seeing the phenomenon in the reference state that is in the initial deformation or flow before the derivative of the position vector in the reference state with respect to time is zero, so that term would be like:

$$\frac{D\boldsymbol{p}}{Dt} = \boldsymbol{V} - \boldsymbol{0}$$

And because it is affecting the term $\frac{D\boldsymbol{p}}{Dt} \times \rho\, \mathbf{V}$ remain as $\boldsymbol{V} \times \rho\, \mathbf{V}$, since the density is a scalar quantity and a vector cross product is zero himself finally the left side would be as follows.

$$\int\int\int_V \left(\boldsymbol{p} \times \frac{D\boldsymbol{V}}{Dt}\, \rho dv\right)$$

Rewriting the derivative notation newton material to reduce the size of the expression.

$$\int\int\int_V (\boldsymbol{p} \times \dot{\boldsymbol{V}}\, \rho dv)$$

Working the right of the original expression, similar to the law of balance amount of time is necessary to convert the side surface integral to a volume integral, this is done by applying the divergence theorem, and for this a normal vector is required thereby defining efforts vector used with the stress tensor and the normal vector, thus being the following expression for the term.

$$\int\int_S \boldsymbol{p} \times t_{(n)} dA = -\int\int\int_V \boldsymbol{\nabla} * (\boldsymbol{T} \times \mathbf{p}) dv$$

It integrating developing, changing from direct indicial notation to facilitate tensor calculus and algebra, developing the cross product between tension appears Levic’s tensor Evita and I omit implications are performed by placing the outcome of such operations.

$$-\int\int\int_V \nabla * (\boldsymbol{T} \times \mathbf{p}) dv = \int\int\int_V \mathbf{p} \times (\nabla * \boldsymbol{T}) + \boldsymbol{\varepsilon} : \boldsymbol{T}\, dv$$

Clearing and grouping all terms, where ε is the tensor of Levic- Evita.

$$\int\int\int_V \mathbf{p} \times \left(\nabla * \boldsymbol{T} + \rho(\boldsymbol{f} - \dot{\boldsymbol{V}})\right) - \boldsymbol{\varepsilon} : \boldsymbol{T}\, dv$$

As you can be seen the first term is the first law of motion Cauchy previously developed and is equal to zero and hence the expression eventually freezes.

$$\int\int\int_V -\boldsymbol{\varepsilon} : \boldsymbol{T}\, dv = 0$$

And he is known as the second law of motion Cauchy.

The locality axiom applies and developing the double contraction must be that the stress tensor is equal to its transposed that is symmetrical.

$$\boldsymbol{T} = \boldsymbol{T}^T$$

Which in this case it occurs in our application because the body moments in the interstitial fluid are neglected as these are taken into account only in Ferrofluid.

Energy conservation

Based on the expression of the first law of thermodynamics, in terms of power.

$$\Delta E = \dot{Q} + \dot{W}$$

$$\Delta E = \boldsymbol{\epsilon} + K$$

From where

$$\boldsymbol{\epsilon} = \int\int\int_V \rho\epsilon \, dv$$

It is the total internal energy of the body.

K=$\int\int\int_V \frac{1}{2}\rho \, \boldsymbol{V} * \boldsymbol{V} \, dv$

- It is the total kinetic energy of the body.
- In the case of the total heat and work.

$$\dot{Q} = -\int\int_S n * q \, dA + \int\int\int_V \rho\beta dv$$

Heat flow through the surface + internal heat sources

$$\dot{W} = \int\int_S t_{(n)} * \boldsymbol{V} \, dA + \int\int\int_V \boldsymbol{\rho f} * \boldsymbol{Vdv}$$

Work due to surface forces + Work due to body forces.

Subsequently apply the Reynolds transport theorem each end, the double integral becomes a volume integral by the divergence theorem similarly performed relationships and implications including the deformation rate tensor D and as result.

$$\int\int\int_V \boldsymbol{\rho}\frac{D(\boldsymbol{\epsilon})}{Dt} - \boldsymbol{T} : \boldsymbol{D} - \boldsymbol{\nabla} * q - \boldsymbol{\rho}\beta \, \boldsymbol{dv} = \boldsymbol{0}$$

Neglecting internal heat sources, and applying the axiom of the town.

$$\boldsymbol{\rho}\frac{D(\boldsymbol{\epsilon})}{Dt} = \boldsymbol{T} : \boldsymbol{D} + \boldsymbol{\nabla} * q$$

$$\boldsymbol{\rho}\dot{\epsilon} = \boldsymbol{T} : \boldsymbol{D} + \boldsymbol{\nabla} * q$$

And expressing the internal energy in terms of enthalpy h

$$\boldsymbol{\rho}\dot{h} = \boldsymbol{T} : \boldsymbol{D} + \boldsymbol{\nabla} * q + \boldsymbol{\rho} h + \dot{p} + p\boldsymbol{\nabla} * \boldsymbol{V}$$

Where would the terms of the mechanical equivalent of heat to the fluid compression power.

Inequality of entropy (second law of thermodynamics)

"The entropy is defined as the degree of disordering suffered by the internal organization of the elements of a material body due to increased heat energy during a deformation process as time goes" (1).

The rapidity of temporal change of entropy as experienced by a body deforms or flows.

$$N = \frac{D}{Dt}\int\int\int_V \rho\,\eta\, dv \quad - \int\int_S n * \frac{q}{\theta} dA - \int\int\int_V \rho\,\frac{h}{\theta}\, dv$$

Where N is the speed of entropy production, ɵ is temperature, η is the entropy density.

Similarly developing equation is known as the Clausius-Duhem inequality is a way of expressing the second law of thermodynamics, for continuous media is reached.

$$\boldsymbol{T}: \boldsymbol{D} + P\boldsymbol{\nabla} * \boldsymbol{V} - \frac{1}{\theta}\boldsymbol{q} * \boldsymbol{\nabla}\theta \geq 0$$

Constitutive equations for approximating interstitial fluid.

The balance equations and the Clausius-Duhem inequality, given a system of equations and inequalities indeterminate support and therefore constitutive equations that help provide solutions to the system and undock certain characteristics that our case will not be considered required.

For the interstitial fluid, it is considered as a homogeneous linear fluid isotropic ie he approached a Newtonian fluid, for which already developed the constitutive equations that govern and arise from compliance with unequal Clausius Duhem and supported by the balance equations developed above, also meet all the constituent axioms.

$$\boldsymbol{T} = \left(-P + \lambda_v + (\boldsymbol{\nabla} * \boldsymbol{V})\right)\boldsymbol{1} + 2\mu_v\boldsymbol{D}$$

Where P is the pressure, is the dilatational λ_v viscosity μ_v 1 is the dynamic viscosity and is the identity tensor.

Taking the equation of motion Cauchy develop the beginning

$$\boldsymbol{\nabla} * \boldsymbol{T} + \rho\left(\boldsymbol{f} - \dot{\boldsymbol{V}}\right) = 0$$

Substituting the constitutive equation

$$\boldsymbol{\nabla} * (\left(-P + \lambda_v + (\boldsymbol{\nabla} * \boldsymbol{V})\right)\boldsymbol{1} + 2\mu_v\boldsymbol{D}) + \rho\left(\boldsymbol{f} - \dot{\boldsymbol{V}}\right) = 0$$

It is obtained by developing and simplifying.

$$(-\boldsymbol{\nabla P}) + (\boldsymbol{\nabla V})\boldsymbol{\nabla}\lambda_v + 2\boldsymbol{\nabla}\mu_v * \boldsymbol{D} + (\lambda_v + \mu_v)\boldsymbol{\nabla}(\boldsymbol{\nabla V}) + \mu_v\nabla^2\boldsymbol{V} = \nabla * \boldsymbol{T}$$

And again Cauchy

$$\boldsymbol{\nabla} * \boldsymbol{T} = -\rho\left(\boldsymbol{f} - \dot{\boldsymbol{V}}\right)$$

$$\boldsymbol{\nabla} * \boldsymbol{T} + \rho\boldsymbol{f} = \rho(\frac{\partial \boldsymbol{V}}{\partial t} + \boldsymbol{V} * \boldsymbol{\nabla V})$$

Knowing λ_v and ρ and depends μ_v ɵ, higher viscosities are changes due to temperature so that they can approach and μ_v λ_v are functions of temperature only, now considering the interstitial fluid will say a temperature constant or you can approximate constant equation would look like:

$$\rho\left(\frac{\partial \boldsymbol{V}}{\partial t}+\boldsymbol{V}*\nabla\boldsymbol{V}\right)=(-\nabla\boldsymbol{P})+\ \rho\boldsymbol{f}+(\lambda_{\nu}+\mu_{\nu})\nabla(\nabla*\boldsymbol{V})+\mu_{\nu}\nabla^2\boldsymbol{V}$$

Because consider constant ɵ interstitial fluid and therefore are μ_v λ_v and constant.

Now performing the consideration that the interstitial fluid is almost incompressible, you get to the Navier-Stokes equation for incompressible and isothermal fluids.

$$\rho\left(\frac{\partial \boldsymbol{V}}{\partial t}+\boldsymbol{V}*\nabla\boldsymbol{V}\right)=(-\nabla\boldsymbol{P})+\ \rho\boldsymbol{f}+\mu_{\nu}\nabla^2\boldsymbol{V}$$

Whereas free surfaces, no significant changes in pressure or height, so I can despise the body forces and consider constant rf = ρg term where g is the gravitational acceleration constant and I can see it in the end ∇P as ∇ (P + ρg * z).

The next step is to proceed with the dimensionless equation, for the Reynolds number and to assess what terms are heavier ie which ones most affect behavior modeling approach interstitial fluid, and make simplifications related but consider that start with a linear approximation take place, so that the inertial term disappear, the same Reynolds number of the fluid and likewise eliminate Article -Yao supported, W., Shen, Z., & Ding, G. (2013). Simulation of Interstitial Fluid Flow in ligaments: Comparison Among Stokes, Darcy and Brinkman Models.International Journal of Biological Sciences, 9 (10), 1050-1056. doi: 10.7150 / ijbs.7242-. Re speaks for a small interstitial fluid so the inertial part is neglected, as had been anticipated.

$$\left(\frac{\partial \boldsymbol{V}}{\partial t}+\boldsymbol{V}*\nabla\boldsymbol{V}\right)=(-\nabla\boldsymbol{P})+\frac{1}{Re}\nabla^2\boldsymbol{V}$$

Where Re is the Reynolds that is defined as Re = ρUL/μ_v where U is the characteristic velocity and L number feature length that this case would be the length of our container. Likewise considered that the interstitial fluid is virtually incompressible fluid, based on his great composition of water, so that the equation is of the following form.

$$0 = (-\nabla \boldsymbol{P}) + \frac{1}{Re}\nabla^2 \boldsymbol{V}$$

Due to the porous medium in the interstitial fluid flow is required for the application of the law of Darcy. .$_{(1)}$

$$U = K_C((P_i - P_{con}) - (\pi_i - \pi_{con}))$$

Where K_C is the coefficient of permeability in this case in particular of container material, P_{con} is the hydrostatic pressure due to the environment in which are found the bacteria inside the container, $P_i$is pressure hydrostatic interstitial fluid on the capillary walls of the container π_{Con} is the osmotic pressure in the middle inside the container and π_i is the osmotic pressure in the interstitial fluid.

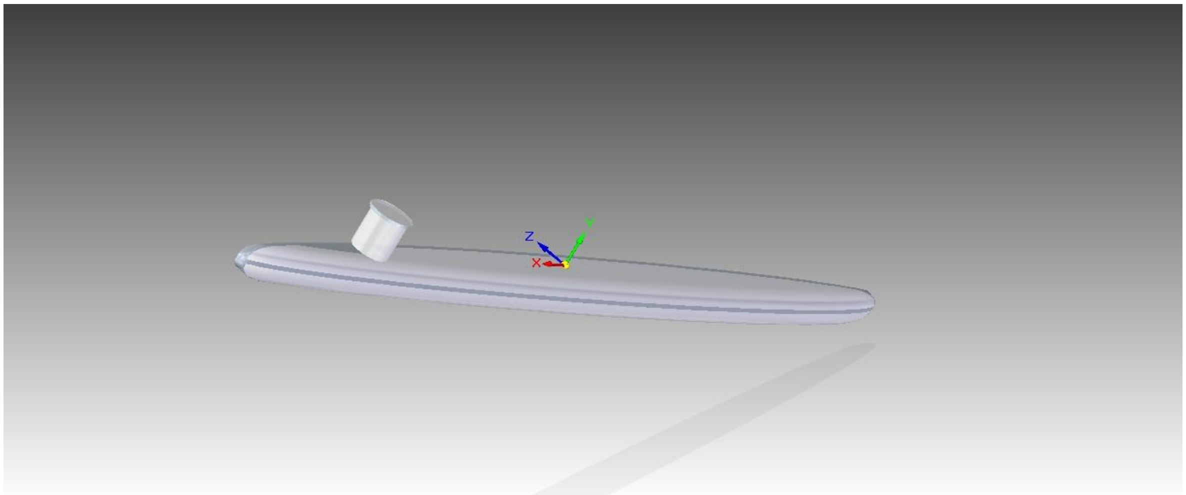
The definition of Reynolds number, we can observe that this dimensionlesss served to see that element have higher and lower weight in the equation of Stokes and due to this analysis Gets a number of Reynolds low viscosity are of very little value and for that very reason was the simplification of not considering the Stokes equation based on inertial , along these same lines, flow of fluid with low Reynolds number that pass through a porous material such as our container, approaching through the Brinkman equation and k_m which is the hydraulic permeability of the material of which it is made the container, in this case set out to design the container of a porous polymer which are facts sub dermal hormonal, implants by k_m would be given by the characteristics of the polymer. The dimensionless Brinkman is given in the following way.

$$K = \frac{k_m}{D^2}$$

Where D would be the diameter of the pores of the material and to replace the Brinkman equation.

$$0 = (-\nabla \boldsymbol{P}) + \frac{1}{Re}\nabla^2 \boldsymbol{V} - \frac{1}{Re * K}\boldsymbol{V}$$

This would be the final differential equation which would approximate the behavior of the fluid interstitial on our container and dare it, it was not possible to solve it since the value of the characteristic speed not able to get it requiring a substitution into the equation the law of Darcy in a data which is P_{con} since this depends on the volume and type of medium where enter the bacteria inside the container and due to lack of time is unable to obtain the data and therefore the equation was not resolved and proceeded to the simulation of fluid, however following places the type of geometry that would have the subdermic container.



Communication module (externally internal).

Initial considerations.

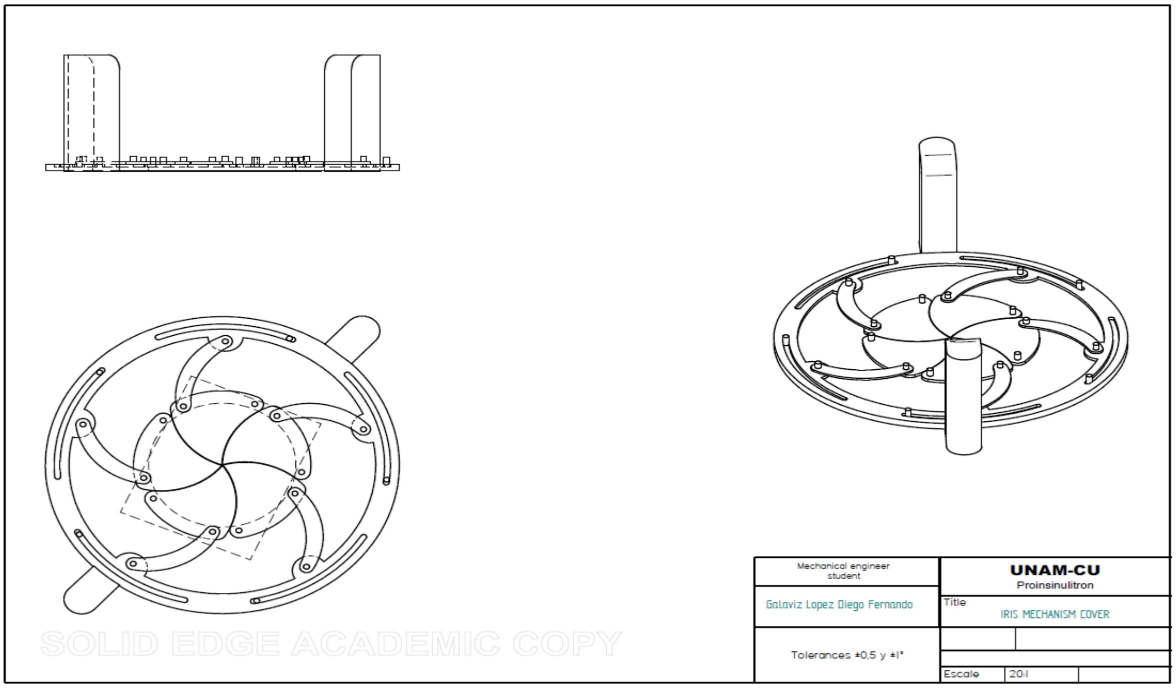
This module is in charge of connecting the inner container in which the bacteria are housed with the surface layer of the skin para that they can be removed and changed easily and in order to maintain the health of the patient avoiding infections. Relating This module, with a device widely used at present, would be the catheter, where one of the main drawbacks is the increased chance of infection is why in design our IT WAS A parameter of paramount importance, which the solution we propose for was the use of gate key UN System User cabbage sure to keep avoiding contact of the " New Generation catheter " as we call it, scammers Middle reducing the chance of infection.

Consists of three parts the first is a small conduit communicating order of millimeters container bacteria within the interstitial fluid with the outer layer of skin where the gate which serves as a seal is located and is required to open the use of a special "key" that is located in the external module and is easy to use.

In terms of materials, the dishes based fixed and would be composed entirely of stainless steel X15Cr13 is intermediate and in terms of internal and external links would be made of EPP -PEEK by Ketron[1] LSG is a polymer with high impact strength, biocompatible, high corrosion resistance and is backed by the FDA.

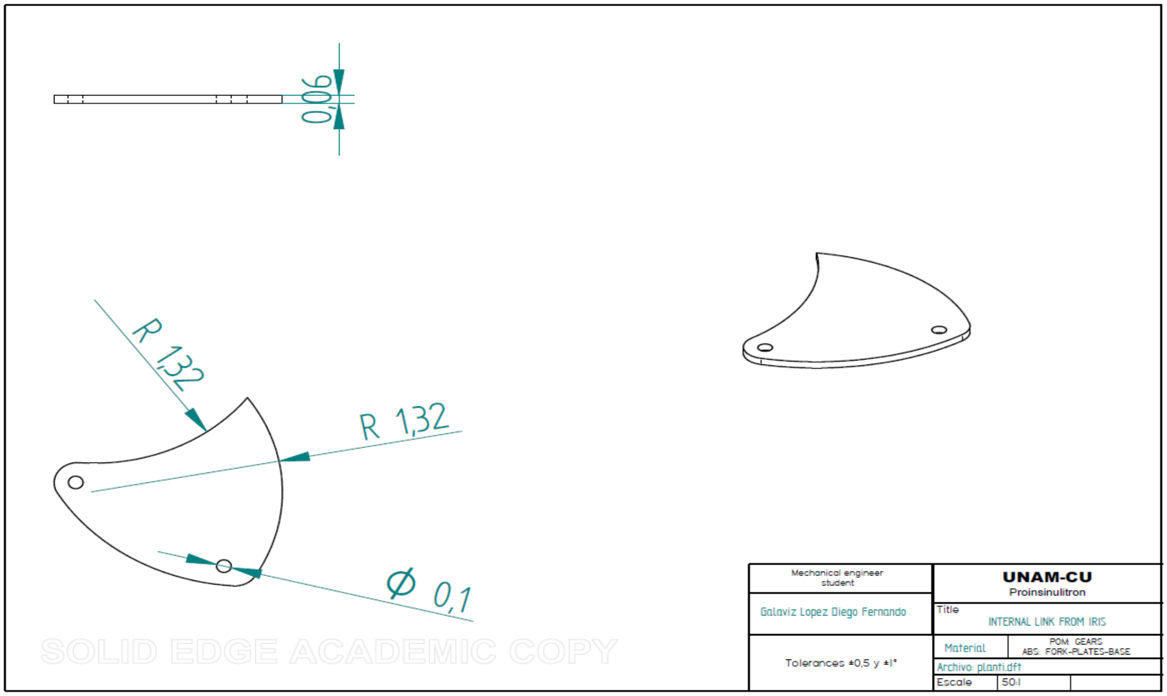
Parts of the iris gate.

Iris.

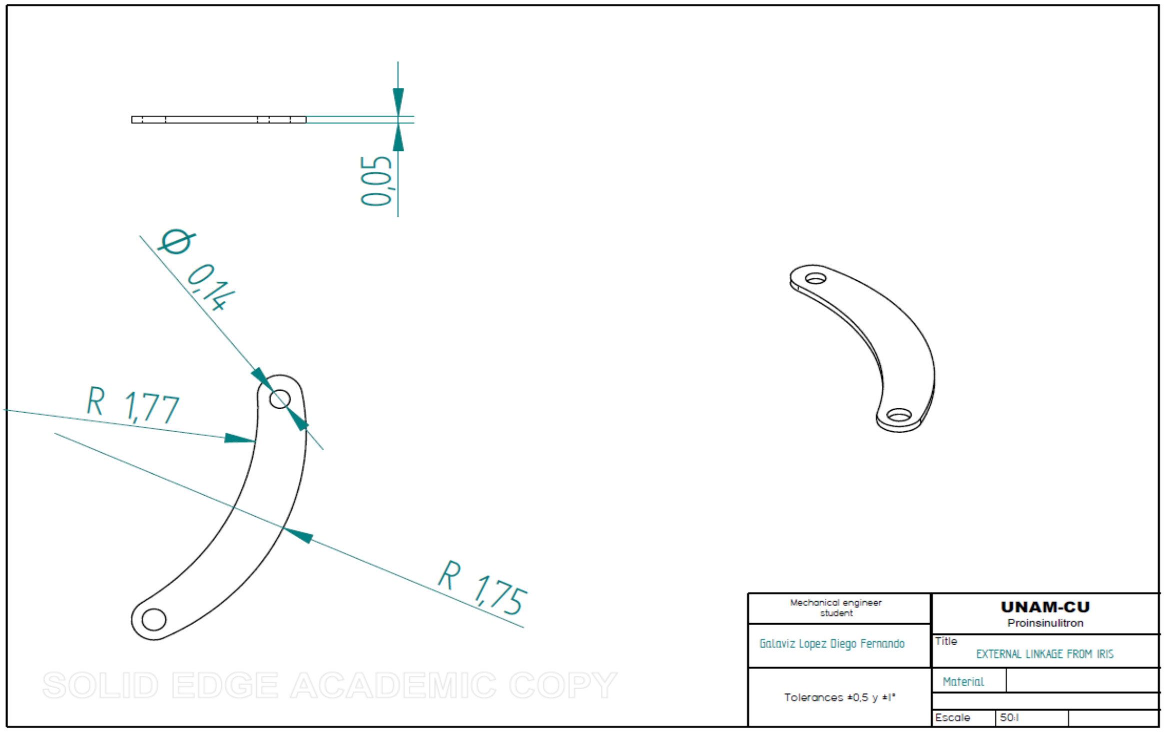


Link internal opening.

[1] Material data base .Matweb. (2015). DataSheet Quadrant Epp Ketron. 20 July 2015, de Matweb Web site: http://www.matweb.com/search/datasheet.aspx?MatGUID=76851b692e094aa59a0469d76aacef6a

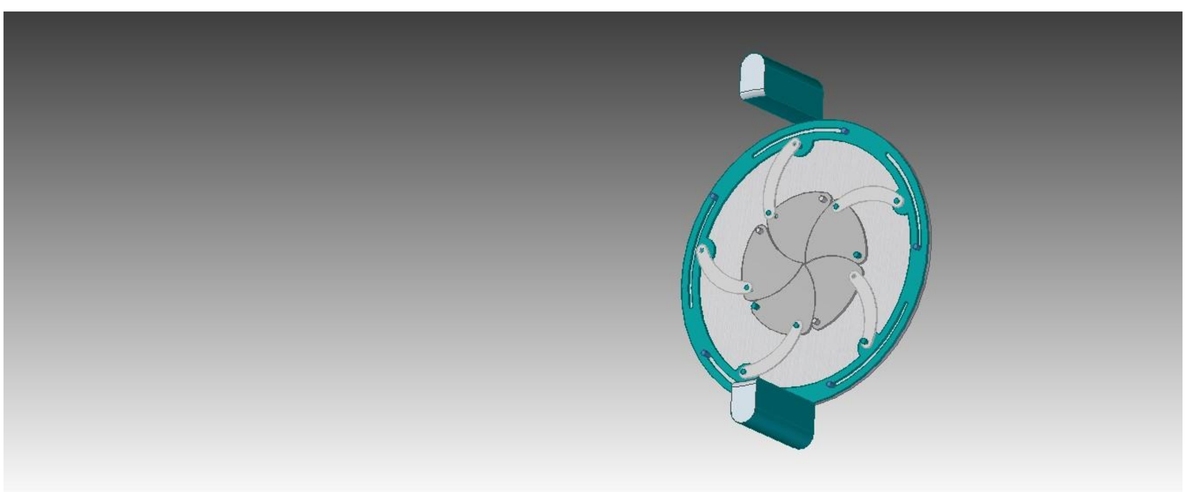


Link from opening



Simulation of kinematic and dynamic of iris.

Iris Complete.

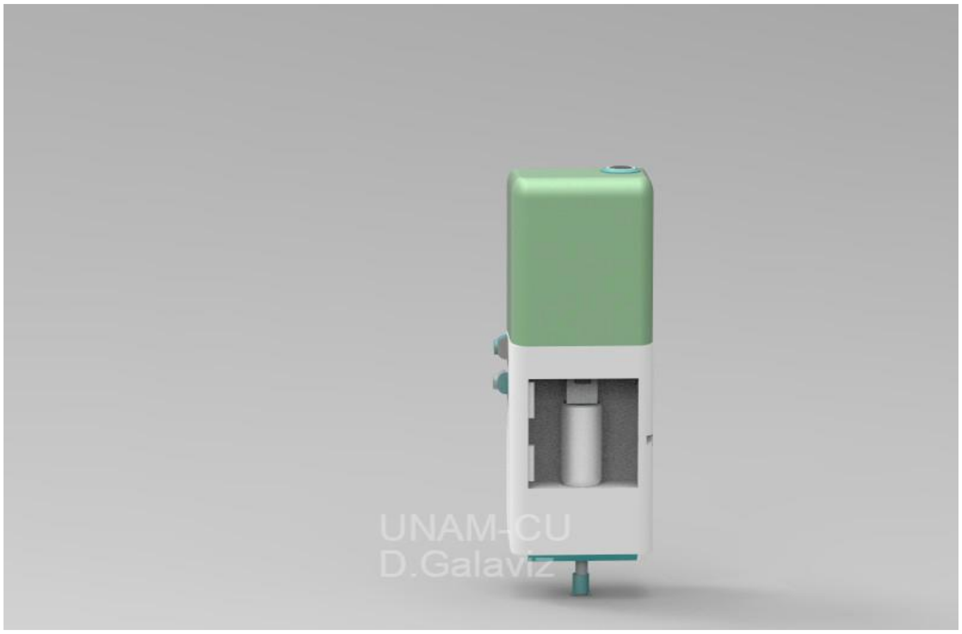


Module removal and replacement of bacteria.

Initial considerations.

Based on the objectives outlined at the beginning is the design of an internal container that provides a better quality of life for the patient, but to do this was taken into account that although the bacteria can measure the level of glucose and produce insulin, the spend time performance bacteria come down due to various factors, so it was important to design a form of extraction and change of bacteria without falling into a complex device, because what is sought is that virtually any user it can use and likewise trying to keep costs down by reducing the number of parts and electronic control.

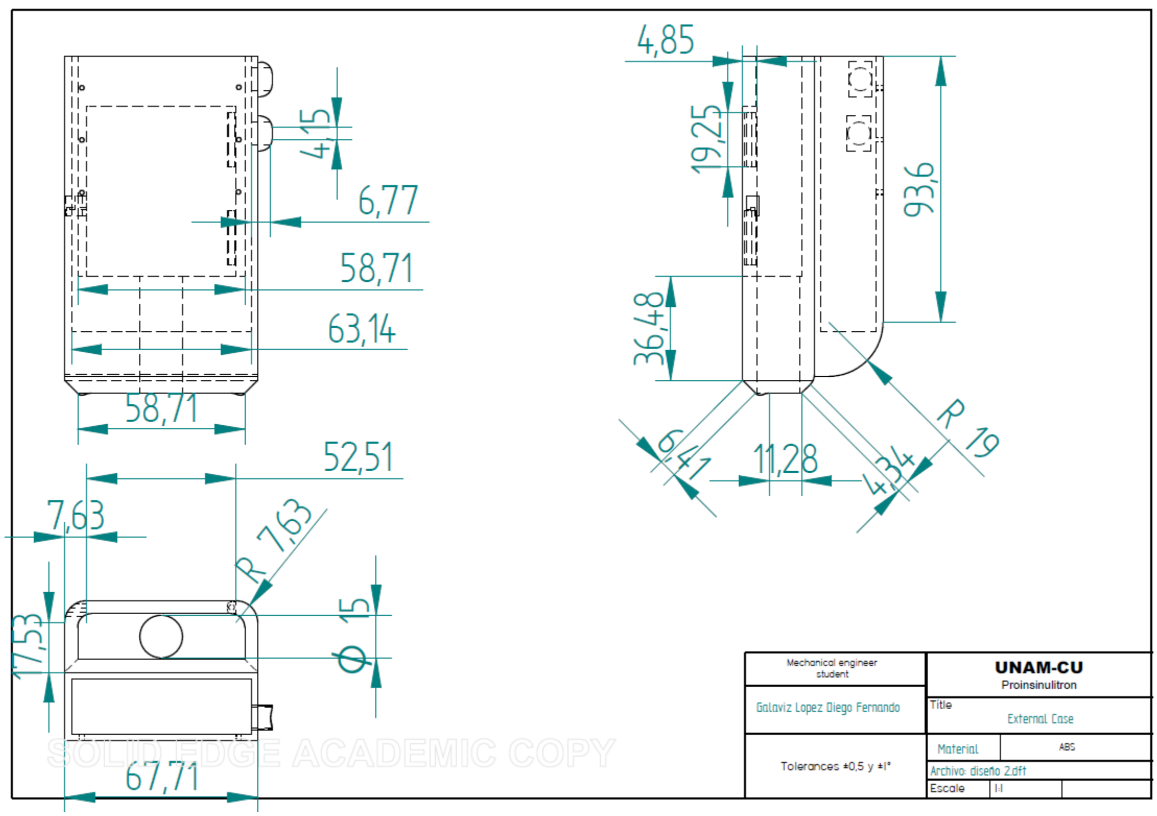
Following these considerations pose the area of engineering design an automatic "syringe" needle, with the main problem the size and control, for it using a mechanism that has only one electrical part was used and that the control of extraction and injection dare an entirely mechanical mechanism are made. For the design considerations in mechanical engineering sought out the external device ergonomic and user friendly as explained above.



Parts of the external device.

Case.

It was designed with ergonomic dimensions of a material resistant to impact and flexible so, that it was an economic manufacturing series. The following specifications of the dimensions of the case some part of the external device used to extract and change the bacteria.



For the selection of the material as mentioned before certain criteria are followed, a polymer ABS because of its good dimensional stability, acceptable hardness for the application (Rockwell hardness) between 90 and 119 and the value of its tensile strength was selected which on average is between 20 and 73 [MPa] and shows good adaptation to forming processes such as extrusion and stamping .

Once you specify this information we proceeded to analyze the behavior of the material before charges could suffer, he said analysis is approached by mechanics of materials to further develop and simulate the model using FEA (Finit Analisys Element) through Inventor 2014 Autodesk software. As for the value of the loads we rely on published data on biomechanics Article XV International Congress of ergonomics.

AUTODESK

Analyzed File:	carcasa.ipt
Autodesk Inventor Version:	2014 (Build 180170000, 170)
Creation Date:	06/09/2015, 06:04 p.m.
Simulation Author:	Diego Fernando Galaviz
Summary:	

Project Info (iProperties)

Physical

Material	PC/ABS Plastic

Note: Physical values could be different from Physical values used by FEA reported below.

carcasa

General objective and settings:

Design Objective	Single Point
Simulation Type	Static Analysis
Last Modification Date	22/07/2015, 03:07 p.m.
Detect and Eliminate Rigid Body Modes	No

Mesh settings:

Avg. Element Size (fraction of model diameter)	0.1
Min. Element Size (fraction of avg. size)	0.2
Grading Factor	1.5
Max. Turn Angle	60 deg
Create Curved Mesh Elements	Yes

Material(s)

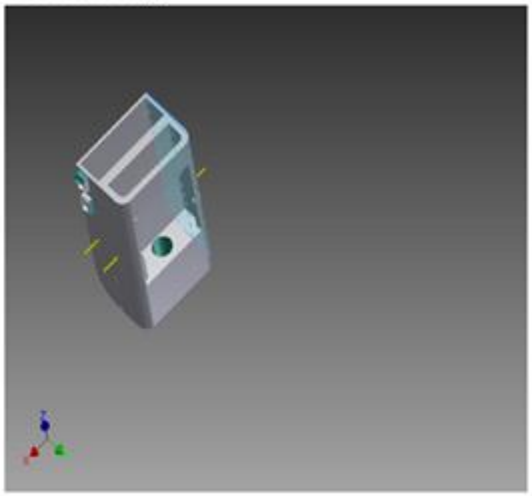
Name	PC/ABS Plastic	
General	Mass Density	0.357273 g/cm^3
	Yield Strength	54.4 MPa
	Ultimate Tensile Strength	54.1 MPa
Stress	Young's Modulus	2.78 GPa
	Poisson's Ratio	0.4 ul
	Shear Modulus	0.992857 GPa
Part Name(s)	carcasa.ipt	

Operating conditions

Fuerza:1

Load Type	Force
Magnitude	690.000 N
Vector X	690.000 N
Vector Y	0.000 N
Vector Z	0.000 N

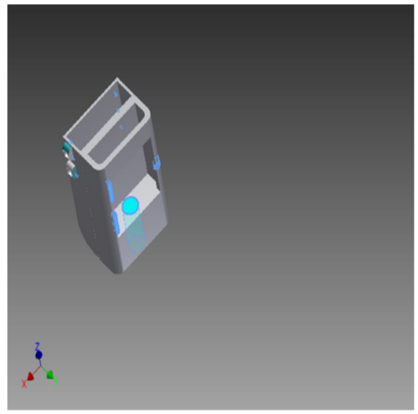
⊟ Selected Face(s)



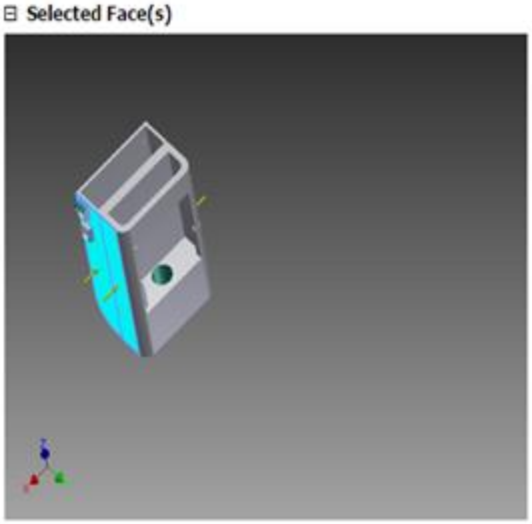
Fuerza:2

Load Type	Force
Magnitude	690.000 N
Vector X	-690.000 N
Vector Y	0.000 N
Vector Z	0.000 N

⊟ Selected Face(s)



⊟ Selected Face(s)



⊟ Results

⊟ Reaction Force and Moment on Constraints

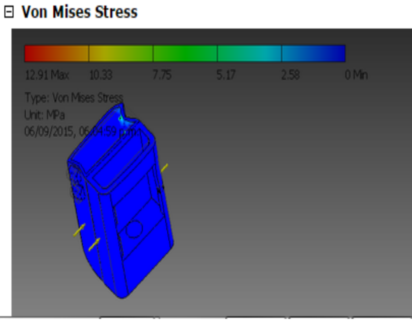
Constraint Name	Reaction Force		Reaction Moment	
	Magnitude	Component (X,Y,Z)	Magnitude	Component (X,Y,Z)
Restricción fija:1	0 N	0 N	1.25753 N m	0 N m
		0 N		-1.19036 N m
		0 N		-0.405475 N m

⊟ Result Summary

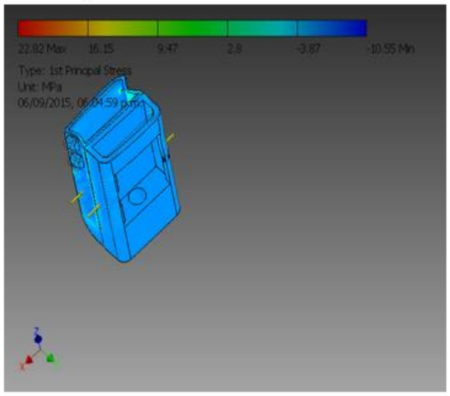
Name	Minimum	Maximum
Volume	162476 mm^3	
Mass	0.0580483 kg	
Von Mises Stress	0.000204927 MPa	12.914 MPa
1st Principal Stress	-10.5463 MPa	22.8207 MPa
3rd Principal Stress	-22.9007 MPa	10.5448 MPa
Displacement	0 mm	0.0521711 mm
Safety Factor	4.21248 ul	15 ul

⊟ Figures

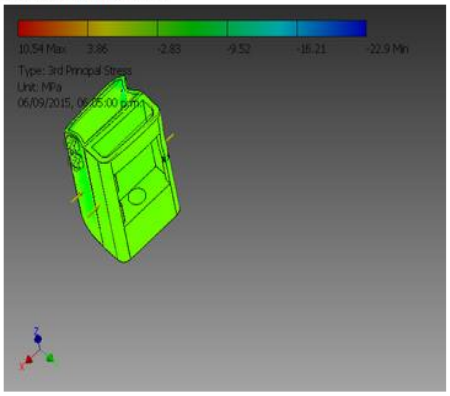
⊟ Von Mises Stress



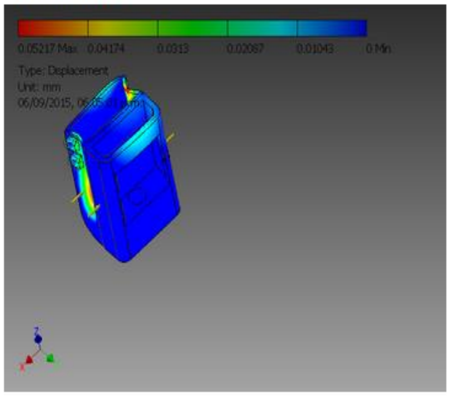
⊟ **1st Principal Stress**



⊟ **3rd Principal Stress**



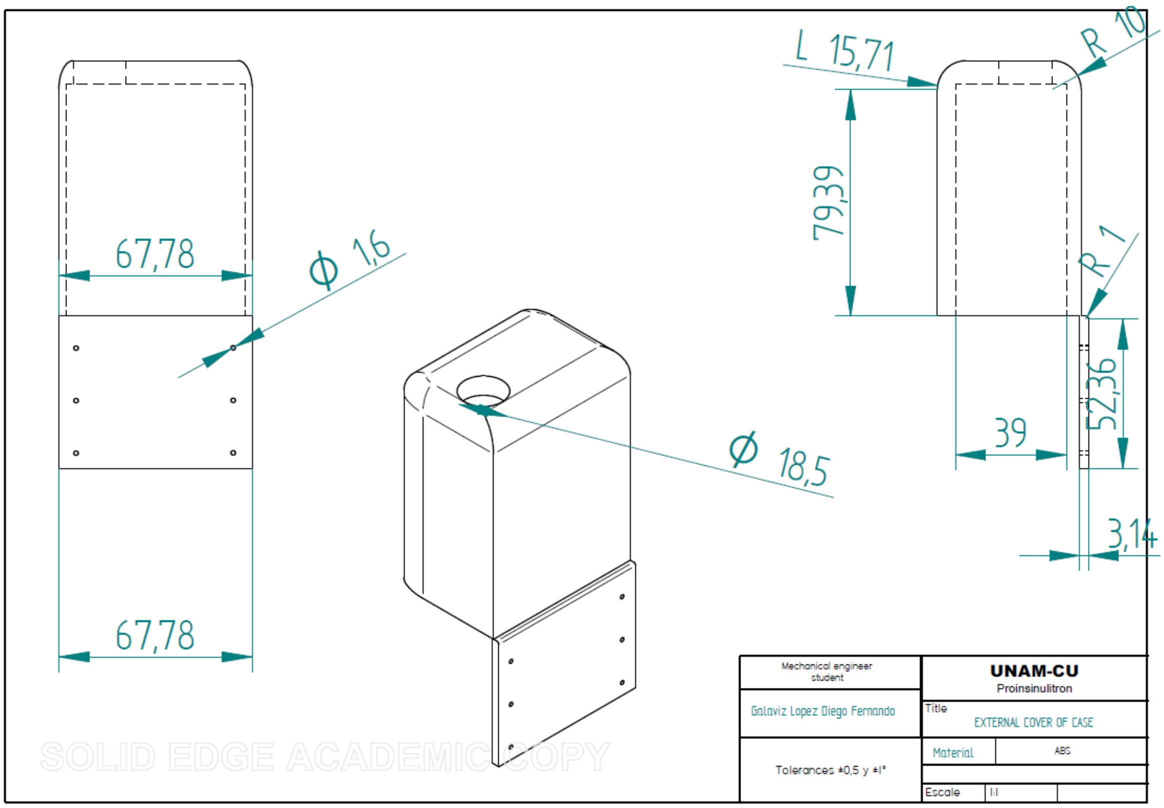
⊟ **Displacement**



By observing the results of the simulation results are obtained according to the first estimates would generate a bending moment on the side face because the wall thickness is small and acts as a stress concentrator , but this will be counteracted because in that area eccentric gear mechanism is screwed engine as providing greater rigidity.

Housing cover .

Basically the same above criteria with the additional consideration to be a little high thus optimizing space for eccentric gear mechanism , just as it was proposed to use ABS polymer followed.



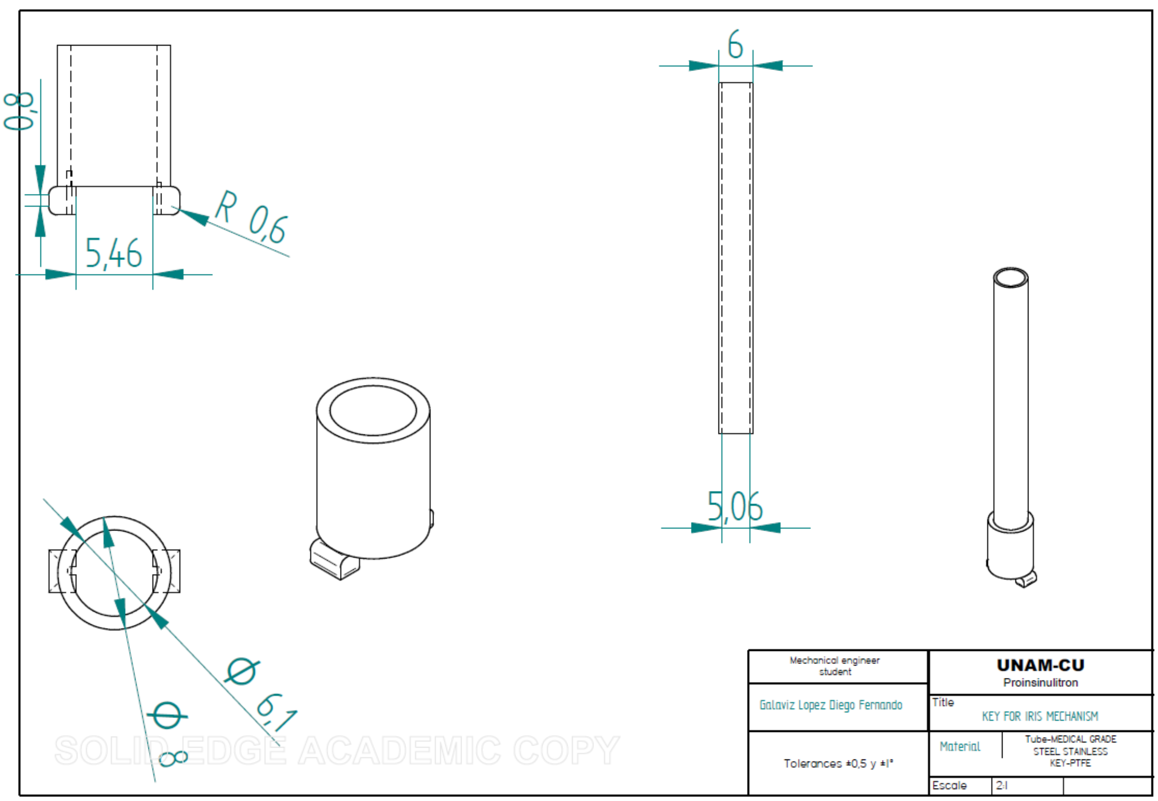
By FEA analyzing I will put as cargo the theoretical weight of the entire device simulating the behavior that would occur in the screws on the cover , if the user only charge the device in this way, with the previous analysis expected value of forces cutting the screws is why I put a couple more at the end of the cap, to distribute shear .

Supply pipe , and iris wrench.

It consists of parts so first is the tube which will be sucked down or the medium containing the bacteria, and the key that opens the iris and forms an airtight connection therewith.

If the tube was selected as stainless steel medical grade material , specifically X15Cr13 stainless steel used in medical instruments .

For the key was chosen as a material PTFE resin because of its wide use in medical applications due to its corrosion resistance , biocompatibility and resistance , just as it is approved by the FDA for use in medical items such as polymer engineering.



Stress Analysis Report KEY

Analyzed File:	tubollave.iam
Autodesk Inventor Version:	2014 (Build 180170000, 170)
Creation Date:	06/09/2015, 06:29 p.m.
Simulation Author:	GALAVIZ LOPEZ DIEGO FERNANDO

⊟ Project Info (iProperties)

⊟ Summary

Author	CASA

⊟ Project

Designer	CASA
Cost	$0.00
Date Created	06/09/2015

⊟ Status

Design Status	WorkInProgress

⊟ Physical

Mass	0.00450751 kg
Area	0.00270439 m^2
Volume	0.000000735777 m^3
Center of Gravity	x=0.000000166718 m y=0.00000133227 m z=0.0285926 m

Note: Physical values could be different from Physical values used by FEA reported below.

⊟ Simulation:1

General objective and settings:

Design Objective	Single Point
Simulation Type	Static Analysis
Last Modification Date	06/09/2015, 06:26 p.m.
Detect and Eliminate Rigid Body Modes	No
Separate Stresses Across Contact Surfaces	No
Motion Loads Analysis	No

Mesh settings:

Avg. Element Size (fraction of model diameter)	0.1
Min. Element Size (fraction of avg. size)	0.2
Grading Factor	1.5
Max. Turn Angle	60 deg
Create Curved Mesh Elements	No
Use part based measure for Assembly mesh	Yes

⊟ Material(s)

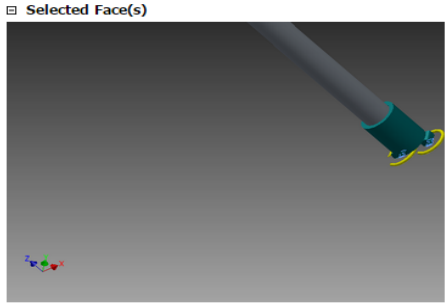
Name	Polytetrafluoroethylene	
General	Mass Density	2.02 g/cm^3
	Yield Strength	20.7 MPa
	Ultimate Tensile Strength	22.4 MPa
Stress	Young's Modulus	0.583 GPa
	Poisson's Ratio	0.45 ul
	Shear Modulus	0.201034 GPa
Part Name(s)	llavediseño2.ipt	
Name	Stainless Steel AISI 304	
General	Mass Density	8 g/cm^3
	Yield Strength	215 MPa
	Ultimate Tensile Strength	505 MPa
Stress	Young's Modulus	195 GPa
	Poisson's Ratio	0.29 ul
	Shear Modulus	75.5814 GPa
Part Name(s)	tubodiseño 2.ipt	

⊟ Operating conditions

⊟ Moment:1

Load Type	Moment
Magnitude	24.000 N m
Vector X	0.000 N m
Vector Y	0.000 N m

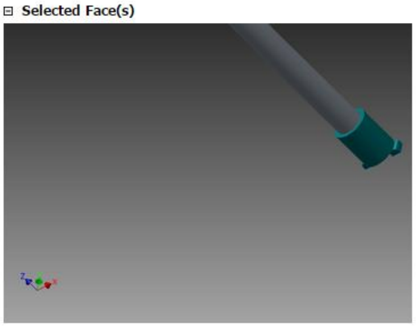
⊟ Selected Face(s)



⊟ Frictionless Constraint:1

Constraint Type	Frictionless Constraint

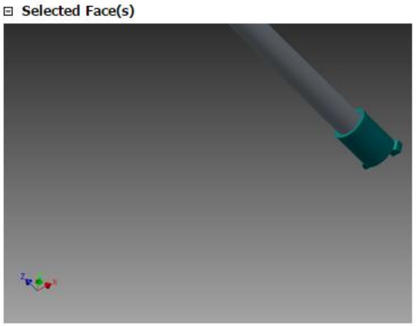
⊟ Selected Face(s)



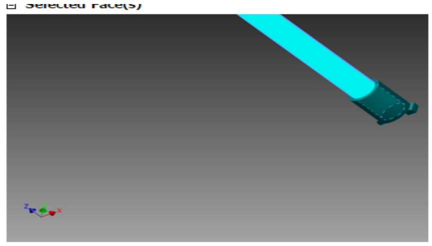
⊟ Fixed Constraint:1

Constraint Type	Fixed Constraint

⊟ Selected Face(s)



⊟ Selected Face(s)



⊟ Fixed Constraint:3

Constraint Type	Fixed Constraint

⊟ Selected Face(s)

⊟ Results

⊟ Reaction Force and Moment on Constraints

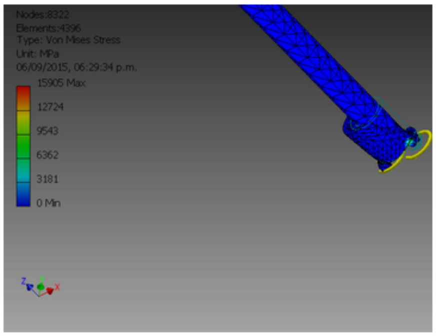
Constraint Name	Reaction Force		Reaction Moment	
	Magnitude	Component (X,Y,Z)	Magnitude	Component (X,Y,Z)
Frictionless Constraint:1	0 N	0 N	0 N m	0 N m
		0 N		0 N m
		0 N		0 N m
Fixed Constraint:1	0 N	0 N	0 N m	0 N m
		0 N		0 N m
		0 N		0 N m
Fixed Constraint:2	0 N	0 N	0 N m	0 N m
		0 N		0 N m
		0 N		0 N m
Fixed Constraint:3	0 N	0 N	24.144 N m	0 N m
		0 N		0 N m
		0 N		-24.144 N m

Result Summary

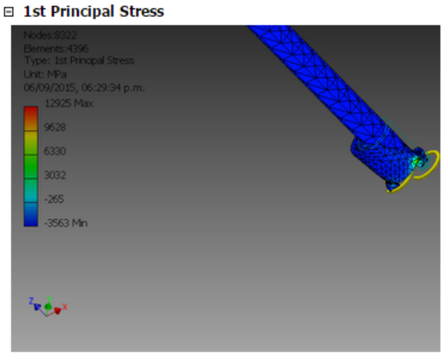
Name	Minimum	Maximum
Volume	735.777 mm^3	
Mass	0.00450751 kg	
Von Mises Stress	0 MPa	15905.3 MPa
1st Principal Stress	-3562.85 MPa	12925.1 MPa
3rd Principal Stress	-15610.2 MPa	2608.02 MPa
Displacement	0 mm	161.042 mm
Safety Factor	0.00130145 ul	15 ul

Figures

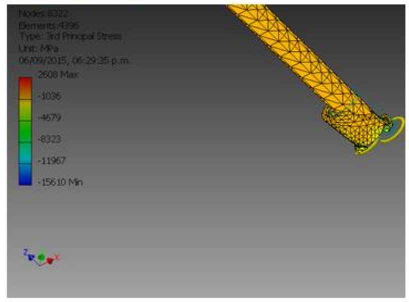
Von Mises Stress



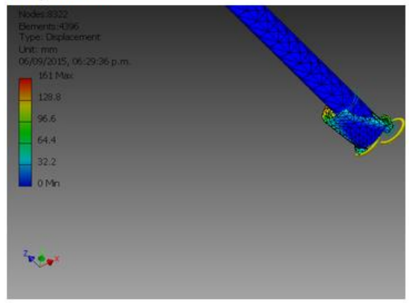
1st Principal Stress



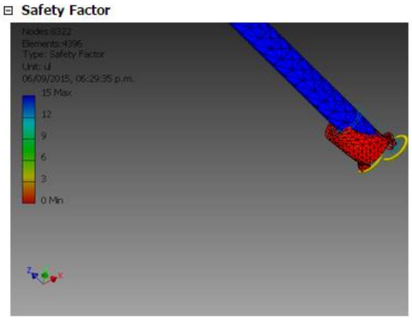
3rd Principal Stress



Displacement

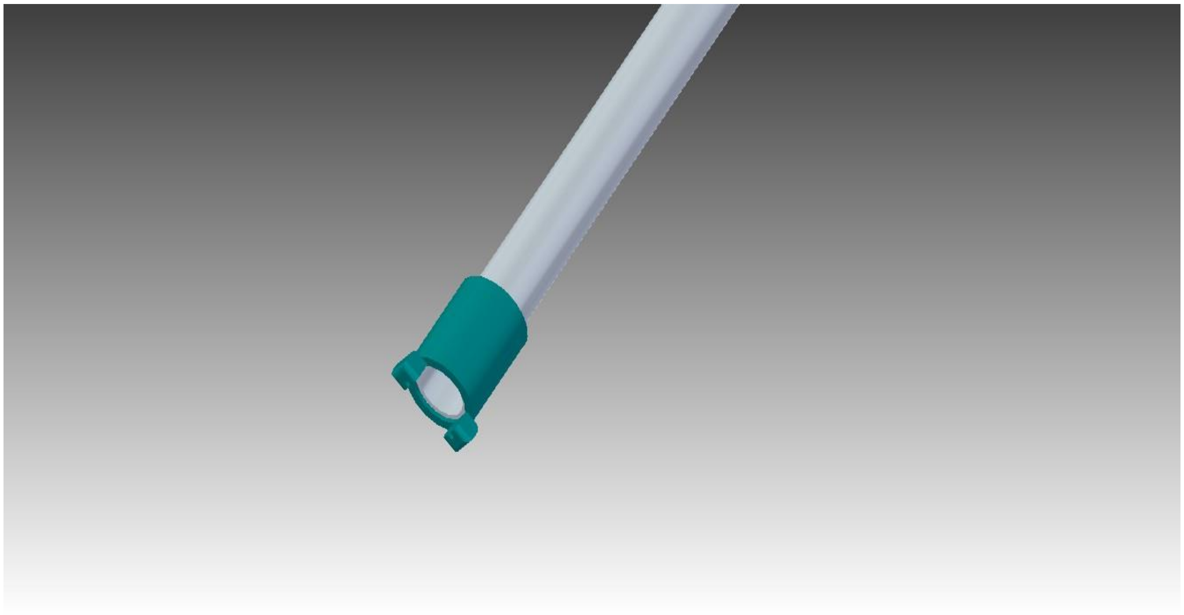


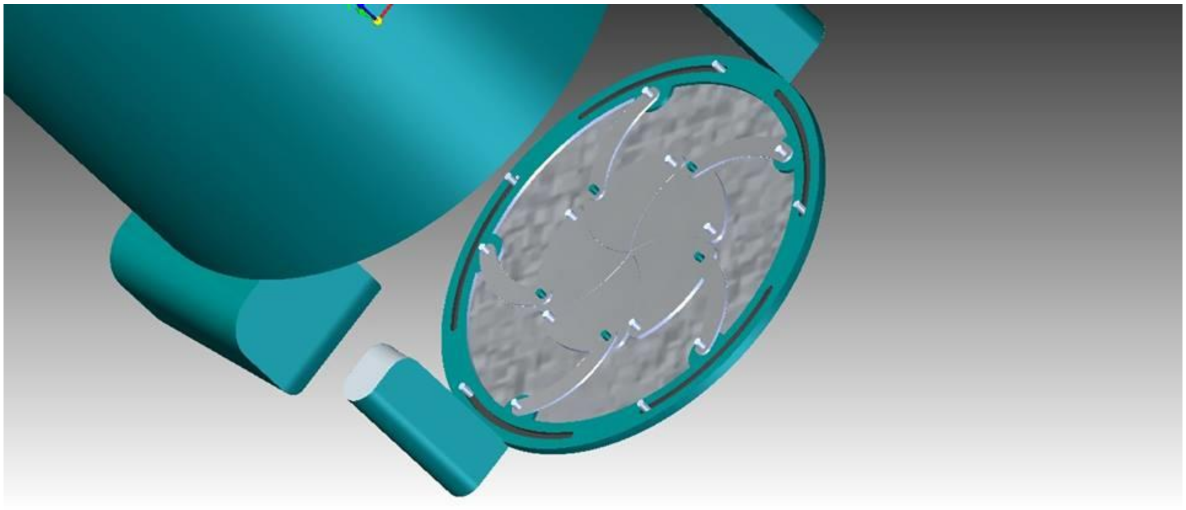
Safety Factor



Based on the analysis we can see that with the input torque causes a shear ending causing the Teflon appropriate, it should be noted that the value placed on the pair got the following article, which is the technical standard of the NASA to human, and whose figure refers to the maximum torque that a man can apply entirely hand arm and shoulder on a valve , so that our application is an excessive burden , but it serves to get data behavior of materials

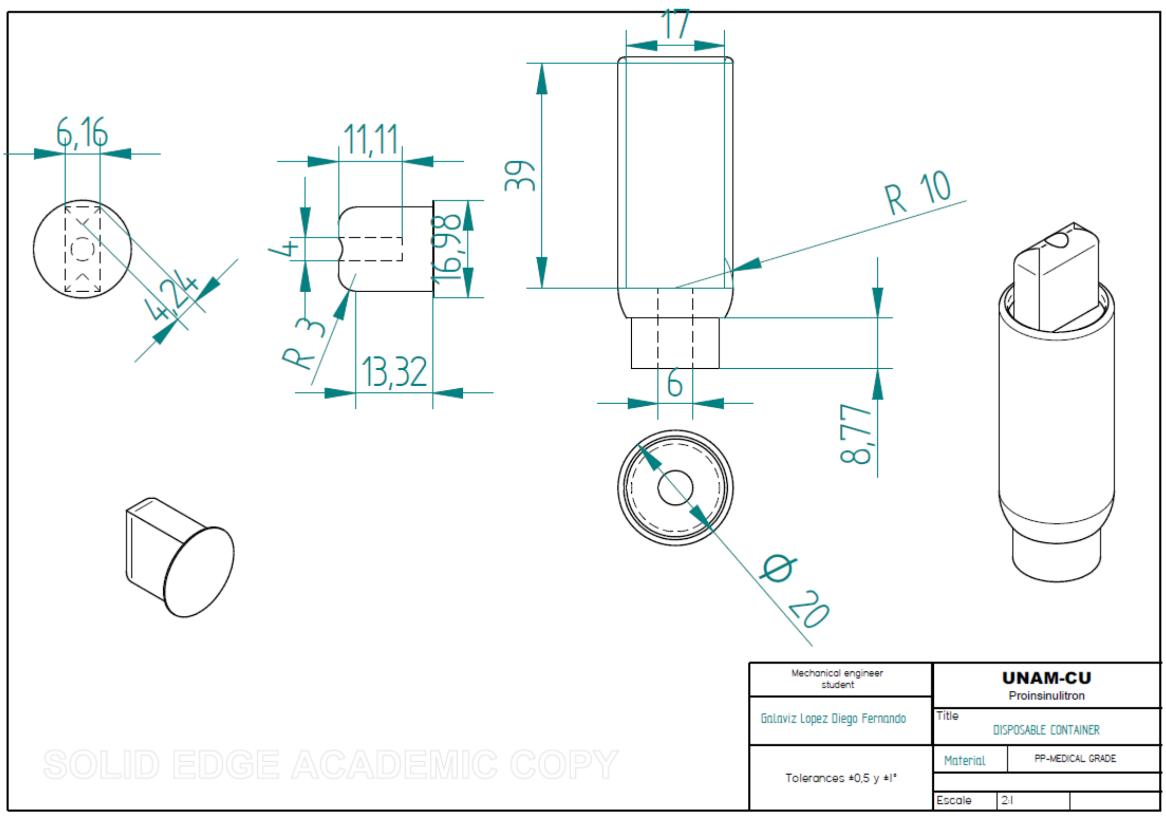
Assembly of Supply pipe, and iris wrench.



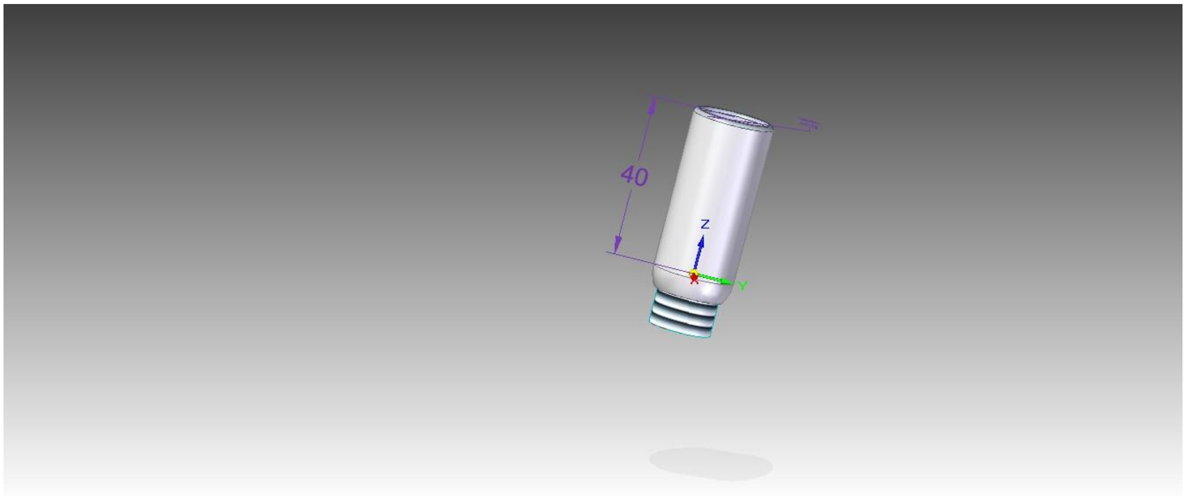


Disposable parts.

In the case of parts it was designed from a common syringe that has the dimensions required for the device and which would be manufactured in PP as commonly manufactured.In this case no stress analysis was not performed because it is considered that the opposition forces due to the viscosity of the fluid can be considered virtually null. The syringe was placed in the central part of the housing and the top plunger will circulate drilling string metric serve to join with the rear of the eccentric gear mechanism and thus prevent this from separating in time of removal or change of bacteria.

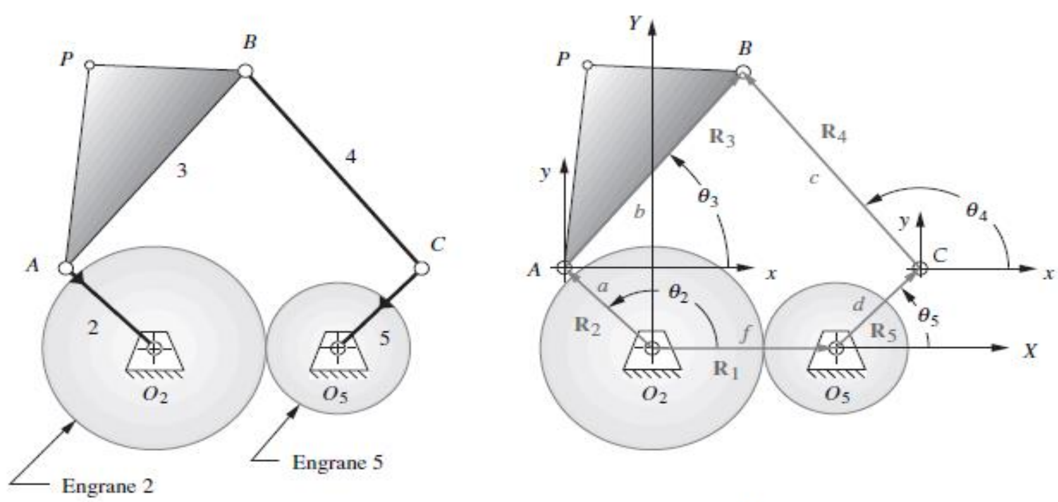


Disposable parts assembly



Eccentric gear mechanism.

It is the mechanism to serve as actuator, to transform the angular movement transnational, to thereby drive the plunger so that it is injected or extracted bacteria, this avoiding the electronic control. Based on this thought slider crank mechanism type, the "disadvantage" of these mechanisms is the space they occupy in the external device, so it chose a five-bar mechanism with gear.



[2]

Generalized equation loop mechanism gears five bars[3].

---

[2] Imagen tomada de Robert L.Norton.(2009). Diseño de Maquinaria. México: McGraw Hill. PP 172.Figura 4-11

$$L2 + L3 - L4 - L5 - L1 = 0$$

The analysis is preferred to carry out complex numbers so the expression is replaced in the way:

$$ae^{i\theta_2} + be^{i\theta_3} - ce^{i\theta_4} - de^{i\theta_5} - fe^{i\theta_1} = 0$$

Being complex numbers , which are widely used in the study of kinematics and mechanisms due to isomorphism found with respect to the vectors , presenting the advantage that they can be write shortest way and operation division if defined for complex numbers knowing this equation can be decomposed into two loop equations, the real and imaginary part and thus could solve two unknowns , however the only data we have are the angle of the link 2 will be the input variable , the link length 1 and the angle that are constants as they are fixed , so a method not supported equations would because they are more unknowns than equations , but because it is a system with a kinematic pair higher order are gears , they have a relationship is given by the following expression for this particular case .

$$\theta_5 = \lambda * \theta_2 + \varphi$$

Where λ is the gear ratio and φ is the phase angle and parameters are given by us at the time of design

This expression can reduce the number of unknowns to have an analytical solution to the system

$$ae^{i\theta_2} + be^{i\theta_3} - ce^{i\theta_4} - de^{i(\lambda*\theta_2+\varphi)} - fe^{i\theta_1} = 0$$

Separating into its real and imaginary parts.

$$\begin{cases} a * \cos\theta_2 + b * \cos\theta_3 - c * \cos\theta_4 - d\cos(\lambda * \theta_2 + \varphi) - f * \cos\theta_1 \\ a * \sin\theta_2 + b * \sin\theta_3 - c * \sin\theta_4 - d\sin(\lambda * \theta_2 + \varphi) - f * \sin\theta_1 \end{cases}$$

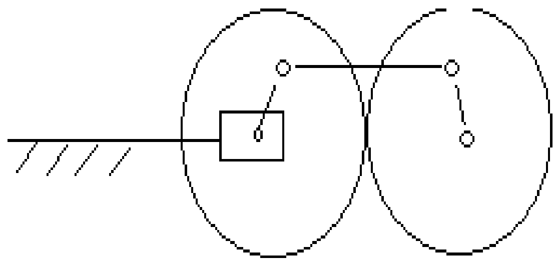
Thus it would proceed algebraically to solve the giving as parameter or degree of freedom to θ_2 for Δθ and define the position of each link of the mechanism system. After much research it was found that the mechanism of 5 bars geared to be more suited to our need because of their type of investment regarding the general mechanism of 5 bars engaged, it is a mechanism designed by Dr. engineering

---

[3] Robert L.Norton. (2009). Diseño de Maquinaria. México: McGraw Hill. PP 172, 173,174.

Nguyen Duc Thang[4] , the which as already mentioned is an investment geared 5-bar mechanism and amended the measures necessary for this project and each piece was designed in CAD software .

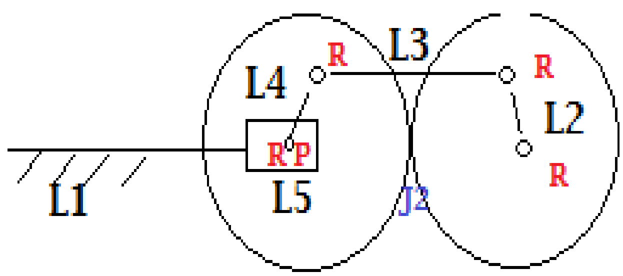
Representation of skeleton



Applying equation Grubler - Kutzbach .

$$3 * (n - 1) + 2 * J_1 + 1 * J_2$$

Where J_1 is defined as kinematic pairs lower order and $J_2$are the kinematic pairs of higher order.



Replace.

$$SDF = 3 * (5 - 1) - 2 * 5 - 1 * 1$$

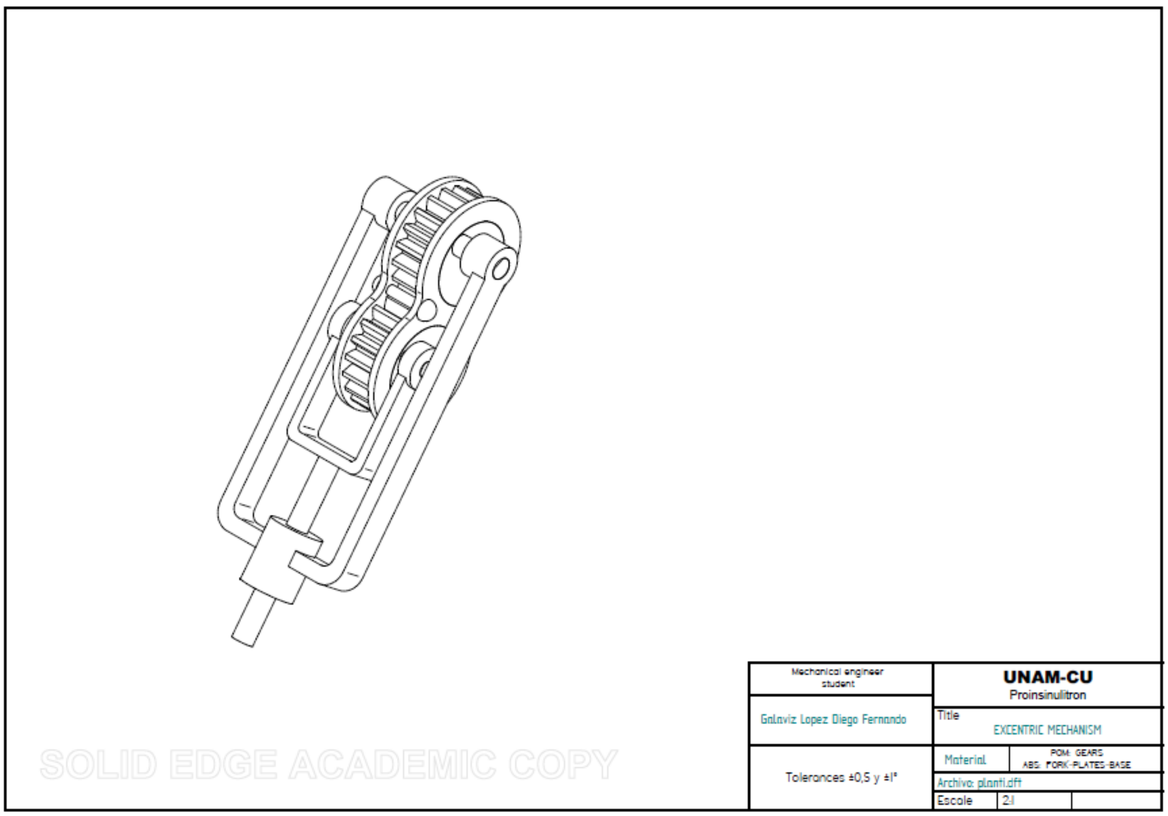
$$Single\ Degree\ of\ Freedom = 1$$

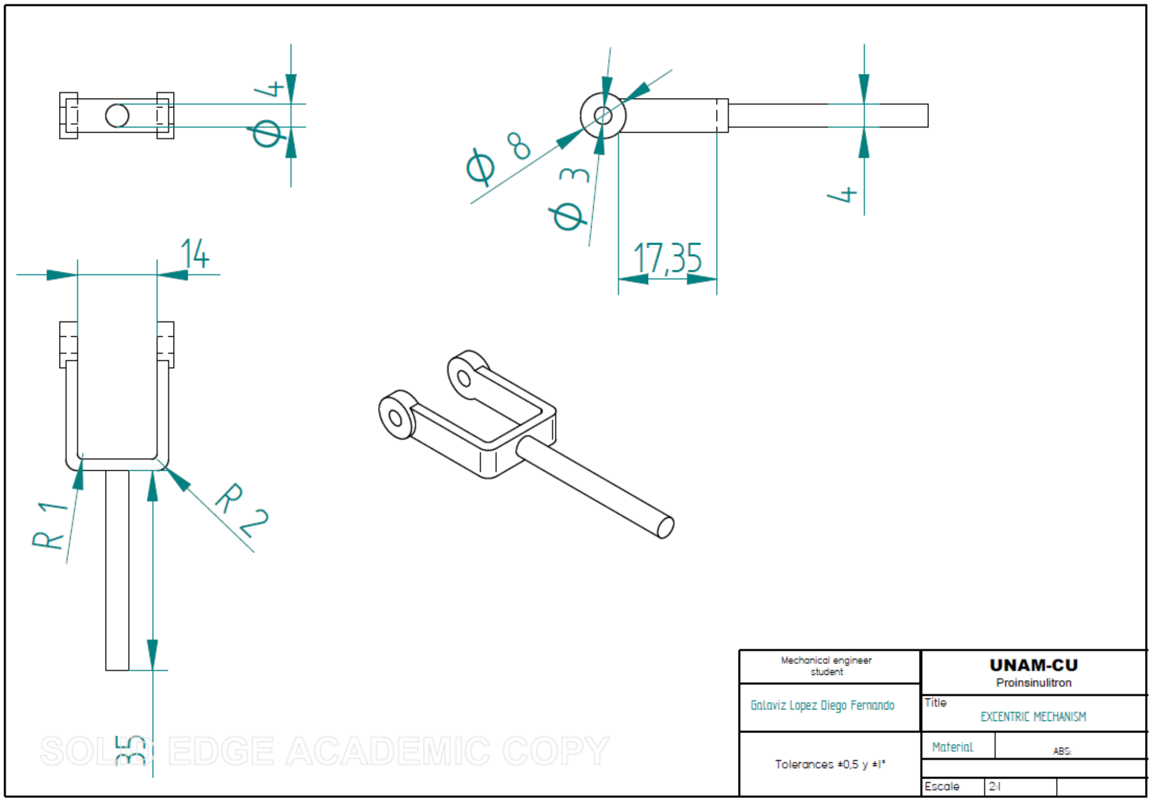
Therefore it is a desmodromic mechanism ,ie from a single parameter will be defined the movement mechanism , which singly could be stated as the number of actuators necessary for the mechanism to perform its function , in this case one

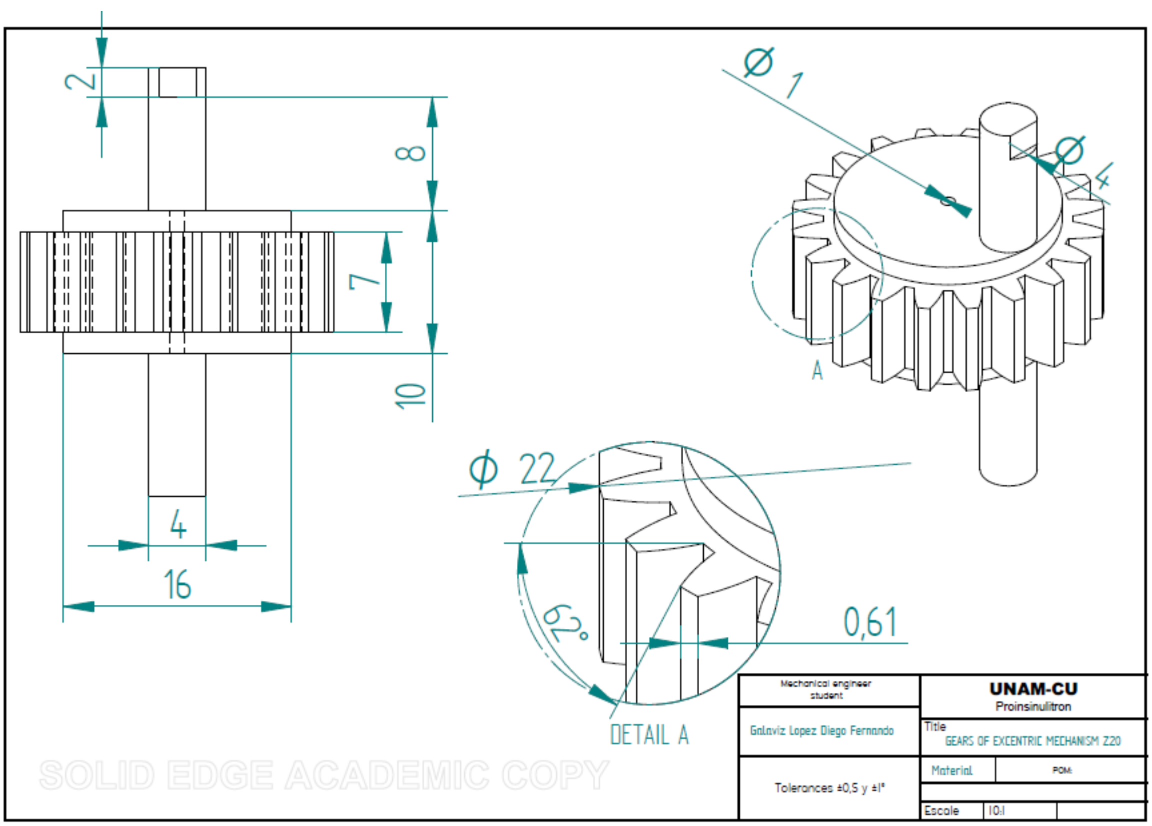
[4] Nguyen Duc Thang. (2010). Cơ cấu con trượt bánh răng lệch tâm. 2-July-2015, de Meslab Sitio web: http://meslab.org/mes/threads/20977-Co-cau-con-truot-banh-rang-lech-tam. Contact thang010146@gmail.com.

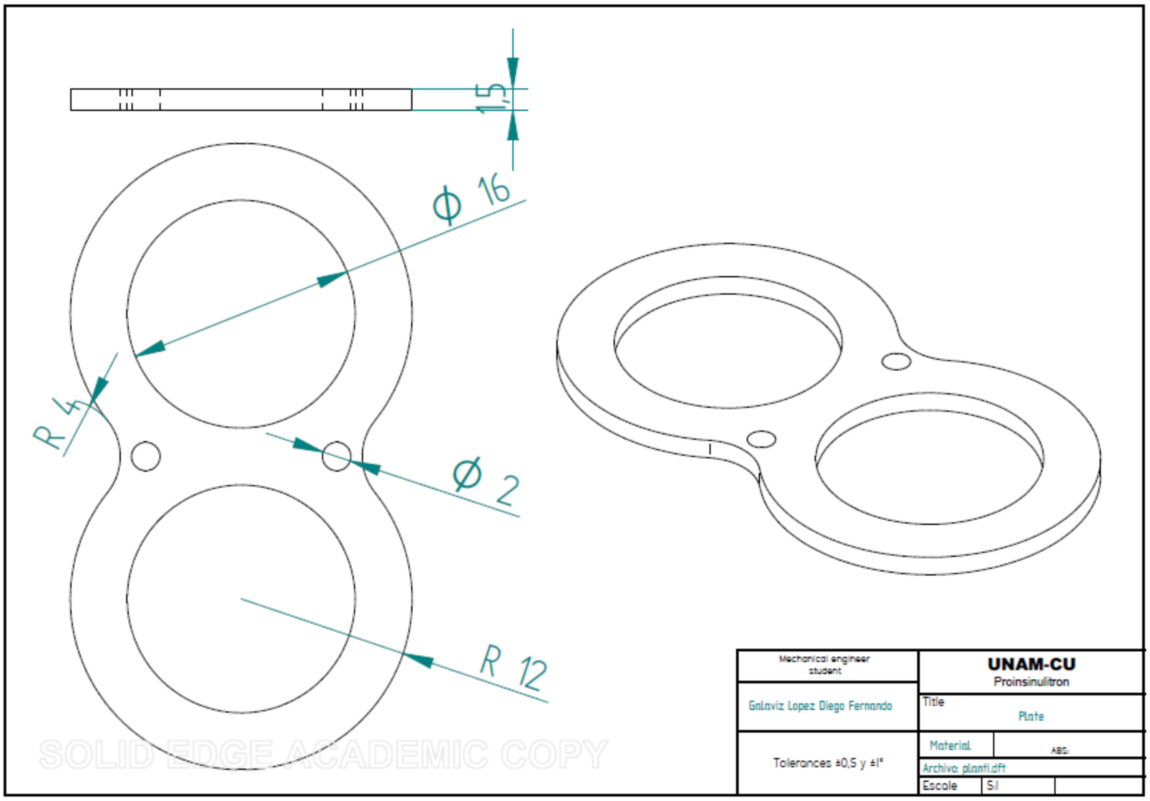
that it is in accordance with the objectives of minimizing pieces, in this case the single actuator is a micro motor that will provide the data mathematically angle θ_2.

The mechanism has two sliding spur gear teeth 20 whose axes are out of the center as well as a yoke or assembles parts and depending on motor direction it moves vertically up or down . Materials for this mechanism are basically two types polymer ABS for the frame and base and to the yoke or slide and to the gears and plates that attach acetal polymer due to its excellent wear resistance and good dimensional tolerance is a crucial aspect in the teeth of the gears.




4
Ø 4
Ø 8
Ø 3
4
17,35
14
R 1
R 2
35
Mechanical engineer student
Galaviz Lopez Diego Fernando
Tolerances ±0,5 y ±1°
UNAM-CU
Proinsinulitron
Title
EXCENTRIC MECHANISM
Material
ABS
Escale
2:1
SOLID EDGE ACADEMIC COPY


2
8
7
10
4
16
Ø 1
Ø 4
A
Ø 22
62°
0,61
DETAIL A
Mechanical engineer student
Galaviz Lopez Diego Fernando
Tolerances ±0,5 y ±1°
UNAM-CU
Proinsinulitron
Title
GEARS OF EXCENTRIC MECHANISM Z20
Material
POM
Escale
10:1
SOLID EDGE ACADEMIC COPY



For the simulation were placed pairs that correspond to the generated by a micro motor with a box of gear reducer 70:1 and which is electrical, with the objective to observe the effect of the torsion in the shafts.

Analyzed File:	Asm1.iam
Autodesk Inventor Version:	2014 (Build 180170000, 170)
Creation Date:	06/09/2015, 06:58 p.m.
Simulation Author:	GALAVIZ LOPEZ DIEGO FERNANDO
Summary:	

⊟ Project Info (iProperties)

⊟ Summary

Author	CASA

⊟ Project

Designer	CASA
Cost	$0.00
Date Created	06/09/2015

⊟ Status

Design Status	WorkInProgress

⊟ Physical

Mass	0.0157135 kg
Area	0.0117088 m^2
Volume	0.0000123197 m^3
Center of Gravity	x=-0.0482712 m y=-0.00456399 m z=0.0215604 m

Note: Physical values could be different from Physical values used by FEA reported below.

⊟ Simulation:1

General objective and settings:

Design Objective	Single Point
Simulation Type	Static Analysis
Last Modification Date	06/09/2015, 06:51 p.m.
Detect and Eliminate Rigid Body Modes	No
Separate Stresses Across Contact Surfaces	No
Motion Loads Analysis	No

Mesh settings:

Avg. Element Size (fraction of model diameter)	0.1
Min. Element Size (fraction of avg. size)	0.2
Grading Factor	1.5
Max. Turn Angle	60 deg
Create Curved Mesh Elements	No
Use part based measure for Assembly mesh	Yes

⊟ Material(s)

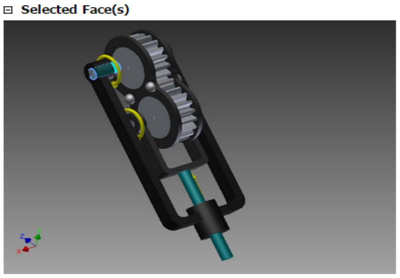
Name	ABS Plastic	
General	Mass Density	1.06 g/cm^3
	Yield Strength	20 MPa
	Ultimate Tensile Strength	29.6 MPa
Stress	Young's Modulus	2.24 GPa
	Poisson's Ratio	0.38 ul
	Shear Modulus	0.811594 GPa
Part Name(s)	Base.ipt Fork.ipt Rivet.ipt Rivet.ipt	
Name	Acetal Resin, Black	
General	Mass Density	1.425 g/cm^3
	Yield Strength	68.21 MPa
	Ultimate Tensile Strength	67.52 MPa
Stress	Young's Modulus	2.9 GPa
	Poisson's Ratio	0.39 ul
	Shear Modulus	1.04317 GPa
Part Name(s)	Z20.ipt Plate.ipt Plate.ipt Z20B.ipt	

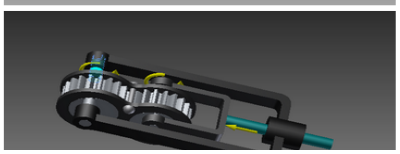
⊟ Operating conditions

⊟ Moment:1

Load Type	Moment
Magnitude	0.157 N m
Vector X	-0.157 N m
Vector Y	0.000 N m

⊟ Selected Face(s)

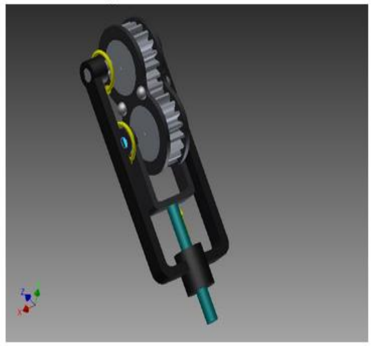


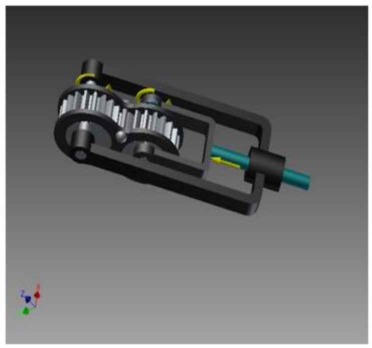


⊟ Moment:2

Load Type	Moment
Magnitude	0.157 N m
Vector X	-0.157 N m
Vector Y	-0.000 N m

⊟ Selected Face(s)





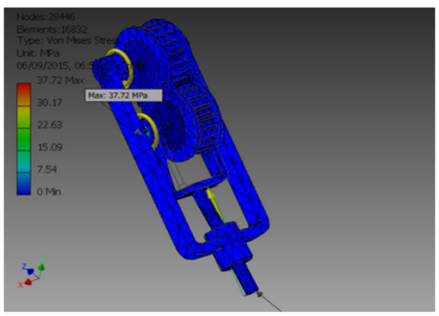
⊟ Force:1

⊟ Result Summary

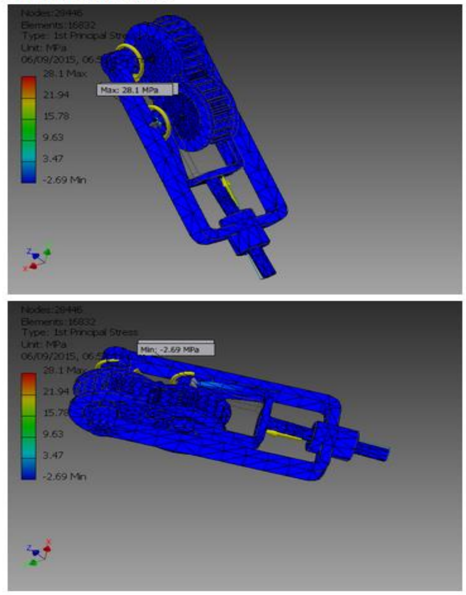
Name	Minimum	Maximum
Volume	12319.7 mm^3	
Mass	0.0157135 kg	
Von Mises Stress	0.0000143712 MPa	37.7164 MPa
1st Principal Stress	-2.68648 MPa	28.0958 MPa
3rd Principal Stress	-28.9121 MPa	3.45771 MPa
Displacement	0 mm	0.214339 mm
Safety Factor	1.03243 ul	15 ul
Stress XX	-8.18776 MPa	8.85249 MPa
Stress XY	-10.9651 MPa	11.1019 MPa
Stress XZ	-10.4418 MPa	13.8733 MPa
Stress YY	-22.8983 MPa	18.7256 MPa
Stress YZ	-14.6961 MPa	19.063 MPa
Stress ZZ	-23.9042 MPa	20.4853 MPa
X Displacement	-0.0393887 mm	0.0382462 mm
Y Displacement	-0.177016 mm	0.0607889 mm
Z Displacement	-0.0665893 mm	0.136498 mm
Equivalent Strain	0.00000000756397 ul	0.0120643 ul
1st Principal Strain	0.00000000113175 ul	0.011219 ul
3rd Principal Strain	-0.0105452 ul	0.000000244093 ul
Strain XX	-0.00128538 ul	0.00127952 ul
Strain XY	-0.00525569 ul	0.00532126 ul
Strain XZ	-0.00500488 ul	0.00664963 ul
Strain YY	-0.00825313 ul	0.00831263 ul
Strain YZ	-0.007044 ul	0.0091371 ul
Strain ZZ	-0.00871658 ul	0.00851842 ul
Contact Pressure	0 MPa	47.9011 MPa
Contact Pressure X	-6.49469 MPa	2.05586 MPa
Contact Pressure Y	-46.0733 MPa	31.9116 MPa
Contact Pressure Z	-40.5198 MPa	32.8711 MPa

⊟ Figures

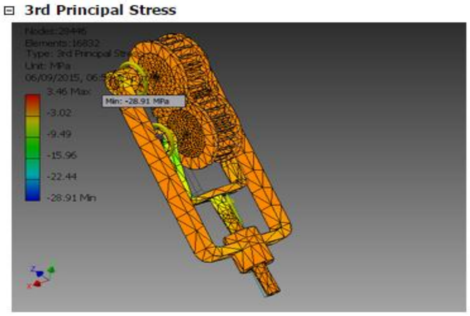
⊟ Von Mises Stress



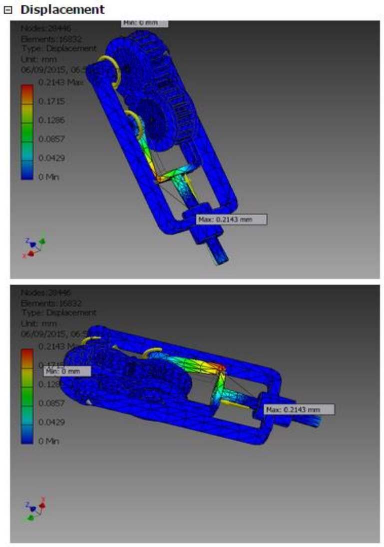
⊟ 1st Principal Stress



⊟ 3rd Principal Stress

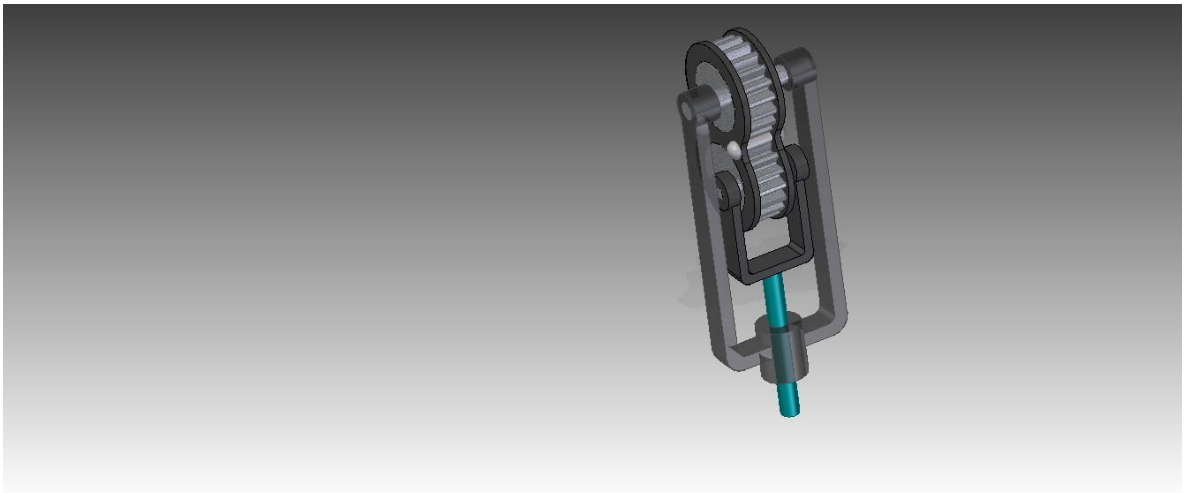


⊟ Displacement



As you can see, the torque on the input shaft to the gears receives very little effort, on the other hand the force placed on the slide causes a bending moment in the upper union, however, this load becomes excessive would be in case the user releases the device and this will impact against the ground vertically.

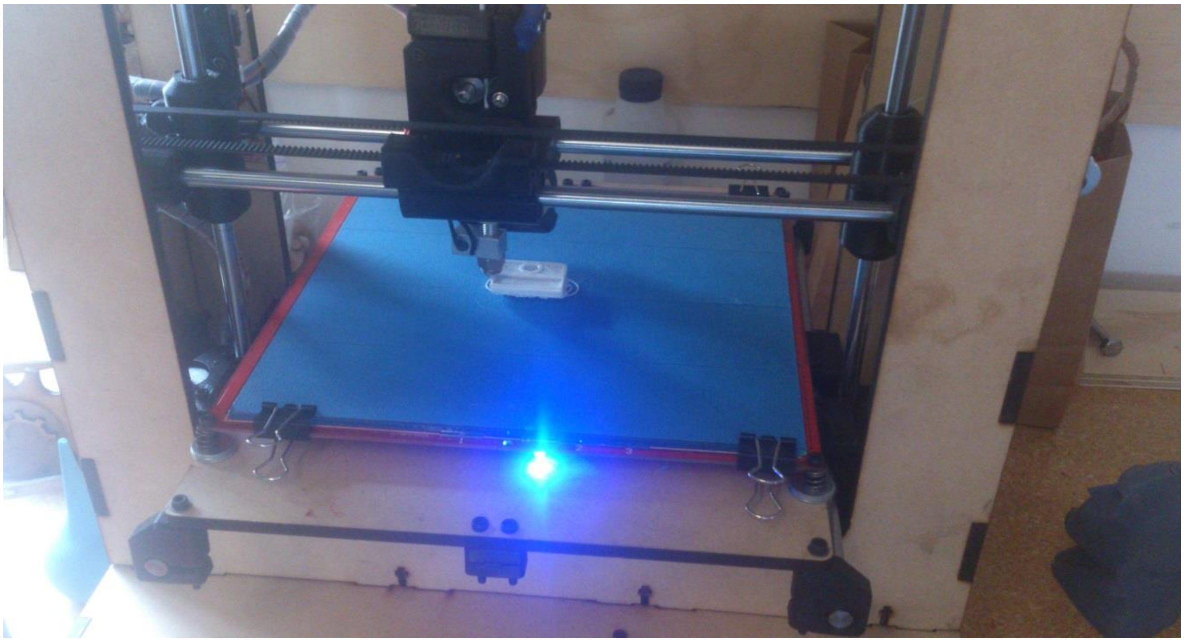
Eccentric mechanism assembly.

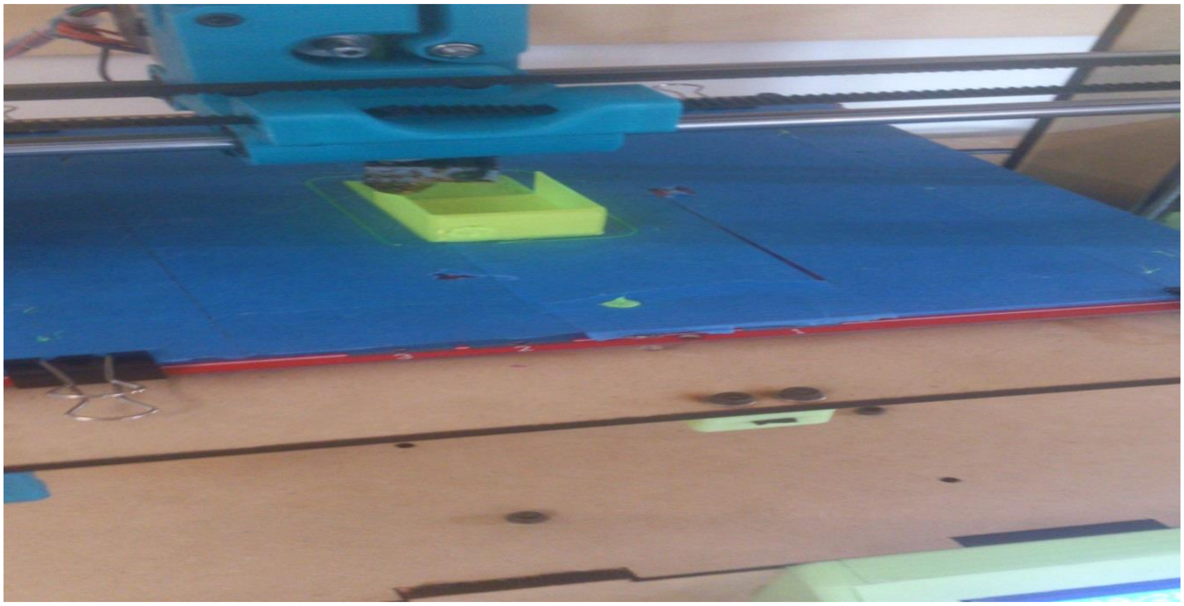


Prototype

From the original models made in CAD , we realize the construction of a prototype of the external module, through manufacturing and material 3D printing using PLA.

We should mention that due to lack of resources is not a working prototype, that is to say only Printed case, the lid and the key iris in 1: 1 scale to have the experience that would have the user to manipulate and dimensions relation to the hand.





References and sources.

Books

Mecanica del medio continuo, Notas de clase. Dr. Reyes Huesca Marco Antonio. UNAM, 2015

Mena Iniesta, B., Calculo Vectorial: grad, div, rot... y algo mas, Universidad Nacional Autónoma de México. Facultad de Ingeniería, México, 2011.

Itskov, M. (2009). Tensor Algebra and Tensor Analysis for Engineers. Germany: Springer

Keener J, Sneyd J. (2009). Mathematical physiology . New York, USA: Springer-Verlag.

Joseph Edward. Shigley - Charles R. Mischke - Richard G. Budynas - Mechanical engineering design - New York, NY - McGraw-Hill - 2004 - 7th Ed.

Kalpakjian, Serope, and Steven R. Schmid. "Tension." Manufacturing Processes for Engineering Materials. 7th ed. Vol. 2. Upper Saddle River, NJ: Pearson Education, 2014. Print.

Robert L.Norton. (2009). Diseño de Maquinaria. México: McGraw Hill. PP 172, 173,174

Web.

UNAM. (2013). Mecánica del Medio Continuo. 10 March 2015, de UNAM Web site: http://www.ptolomeo.unam.mx:8080/xmlui/bitstream/handle/132.248.52.100/2182/05Cap%C3%ADtulo1F-ene2013.pdf?sequence=10.

Instituo de Geociencias UNAM. (2009). Tensor de Esfuerzos y Esfuerzos principales. 25 March 2015, de UNAM Web site: http://www.geociencias.unam.mx/~ramon/mecsol/Tema1.pdf.

Material data base .Matweb. (2015). DataSheet Quadrant Epp Ketron. 20 July 2015, de Matweb Web site: http://www.matweb.com/search/datasheet.aspx?MatGUID=76851b692e094aa59a0469d76aacef6a.

Nguyen Duc Thang. (2010). Cơ cấu con trượt bánh răng lệch tâm. 2-July-2015, de Meslab Sitio web: http://meslab.org/mes/threads/20977-Co-cau-con-truot-banh-rang-lech-tam.

Article.

Wei Yao, Yabei Li, and Guanghong Ding, “Interstitial Fluid Flow: The Mechanical Environment of Cells and Foundation of Meridians,” Evidence-Based Complementary and Alternative Medicine, vol. 2012, Article ID 853516, 9 pages, 2012. doi:10.1155/2012/853516.

Swartz, M. A., & Fleury, M. E. (2007). Interstitial flow and its effects in soft tissues. Annu. Rev. Biomed. Eng., 9, 229-256.

Baronzio, G., Parmar, G., & Baronzio, M. (2015). Overview of Methods for Overcoming Hindrance to Drug Delivery to Tumors, with Special Attention to Tumor Interstitial Fluid. Frontiers in oncology, 5.

Lee JS, Fung YC. Stokes flow around a circular cylindrical post confined between two parallel plates. J Fluid Mech.

Software Licenses.

Autodesk Inventor Porfessiona 2014l-Student version license for Autodesk Inventor Professional 2014 - WIN 64 - ES. Serial number: 900-58262645

Solid Edge ST7 .The Solid Edge license Academic Code assigned to you for ST7 is F6D1BB290DBB.