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3D REPREZENTATION IN INVENTOR AND FINIT ELEMENT ANALYSIS OF A BICYCLE

Abstract: *The bike is a great way to travel from one point to another, given the possibility of a higher mobility on smaller distances, providing a healthy style of living, travel and sports. The best choice for town is a mountain-bike due to suspension front and rear, optionally offering a better stability and extra comfort.*

Key words*: CAD, Inventor, Ansys, bicycle frame, finite element analysis, Keyshot5.*

INTRODUCTION

Around the 20th century, bicycles reduced crowding in large cities, allowing workers and citizens to commute from the suburbs to work. They also reduced dependence on horses and cars. Bicycles allow people to travel for leisure, because they are three times more energy efficient in relation to other means of transportation in a city.

This research work defines and presents a graphical model and a finite element analysis of a customized bicycle, using Inventor software, taking as a reference a real bike.

To define all the steps necessary to achieve 3D frame along with all the other ingredients for a better understanding of how it works, presenting techniques and how they were made.

The most common design for a bicycle frame is the "safety bicycle" (bicycle, called in this way because, after the years 1880, bicycles totally have changed the design, the front wheel and the rear one have become equal in size and shape to a symmetric caught) [1], [2]. The frame is made up of two triangles, a main triangle front and posterior triangle.

This is known as the diamond frame [3], [4]. Frames are required to be strong, stiff and light and for doing so, it combines various shapes and materials [5].

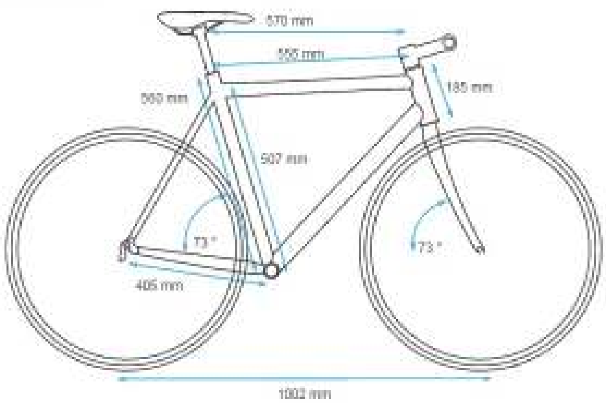


Fig. 1 2D bicycle model DHS-Bike [1], [6].

The bike has been customized after being measured, and was transposed in a real model, compared to the one at which it was left, Figure 1.

2. MODELING OF THE MOUNTAIN-BIKE

To represent in the INVENTOR software [11] the bicycle frame mountain bike, some measurements were made on a real model DHS-StreetRage BIKE, and accomplished a 2D model (wireframe) in order to facilitate the process of achieving the necessary parts and assembly as well as easier within the software. Results obtained after measurements are presented in the scheme shown in Figure 2, branch *2D Sketch*.

Achievement outline was followed by 3D representation of the parts to be assembled and the superimposed outline obtained previously.

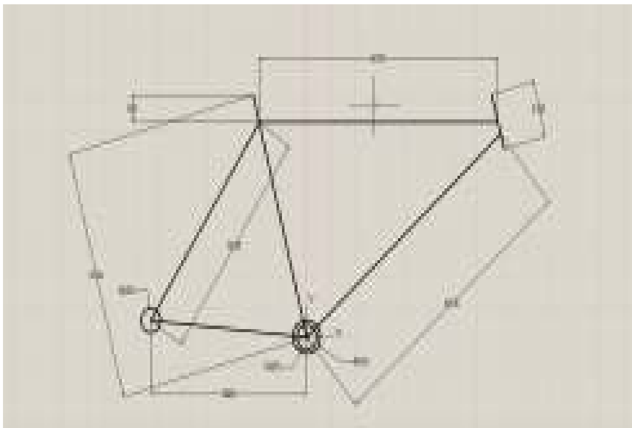


Fig 2 The outline of the frame after the measurement.

Graphical representation starts with specifying the way in which it was constructed tyre and rim [7], using branch *2D Sketch*.

For representation, we achieved a profile sketch of the room. Using the *Revolve* command, through rotation with 360 degree of the profile-outline around the axis system, results the 3D model of rim, Figure 3. Analogy has been made for the realization of the rim, pressure valve, bolts and other pieces with a symmetrical geometry**.** An obstacle has appeared on rolling radii, because drawing using the *3D Sketch* command, working simultaneously in all 3 planes of drawing to a model just to a given angle between the blocks and the rim.

From a technical standpoint, a bicycle type mountain consists of a frame made of steel/aluminium, a suspension fork for reduction of the impact [8], a gear box of gears and chain, from chainmail and making bolts between the sheets and transmission gears, wheels for land movement, transposing the brakes (with derailleurs or disc), together with the hub of the crank arm crank and pedal, fork, bearings, studs, screws, Figure 4.

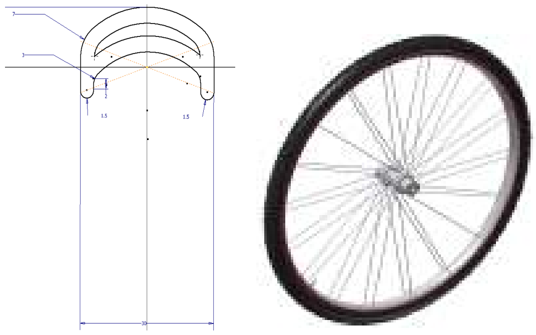


Fig. 3 Sketch the profile of the rim, and 3D model of wheel.

Fig. 4 Parts of the bicycle [9]: 1-handlebar pads; 2-handlebar; 3-fastening clamp; 4-frame; 5-saddle; 6-tyre; 7-rim; 8-wheel sprockets billet and; 9-chainrings; 10-block crank and sheets; 11-crank arm; 12-pedal; 13-suspension fork; 14-upper fork; 15-set bearings; 16-brake.

Modeling framework has been constructed at the same time in *2D Sketch,* in which they were defined more straight and flat for the progressive achievement of the frame using the command *Revolve.*

The 3D model of the front triangle has been made with circular tubes having sections in order to achieve this when assembling bumpers will use the *Extrude* command, section *Cut.*

For the posterior triangle it was drawing a path using the *2D Sketch* command followed by a sketch in the end of the route, with the *Sweep* command and the command of *Mirror* to replica the arm and on the opposite side of the transverse plane.

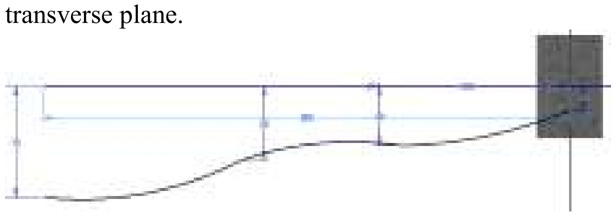


Fig. 5 Posterior triangle section.

In order to obtain the 3D model of the crank arm were made a series of drawings containing circles and squares, using the *Extrude* cylinders have been obtained with a rectangular section inside.

After drawing a line which represents the length of the pedal, along it will be draw three irregular shapes, using the *Loft* command, Figure 6.

Towards the end you will use the command *Thread* by entering a threaded hole.

Fig. 6 Aluminium alloy Hard Tail (HT) frame bike.

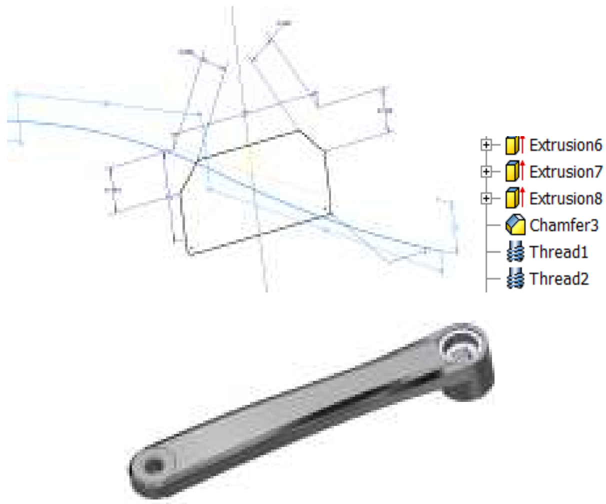


Fig. 7 Arm crank left.

The 3D representation of the other landmarks such as the gear pinion and format chainrings is based upon a sketch later transformed by *Extrude* into a disc, its surface when designing a profile for the teeth of the wheel. To carve and to multiply the model the *Cut* and *Circular Pattern* command are used, Figure 8.

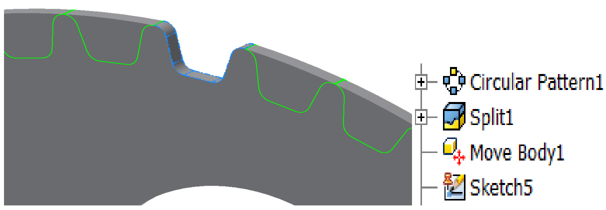


Fig. 8 Sheet cutting teeth.

The same commands will apply to orders and for the realization of bicycle sprockets. The gear consists of three chainrings, Figure 9, normally the city bikes come equipped with just a single chainring and seven sprockets, offering speeds decreasing power divider.

Each chainring has a user's Guide: for mountainous terrain (sloped, bumpy), city-tour (walking daily through the town), declined.

Fig. 9 Hook worksheets.

Different from the square-shaped arm, chainring and pedal assembly in the axial hub, sprockets are mounted separately in the axis of the wheel with the right head, Figure 10.

Fig. 10 Hook pins.

It shapes the crank hub with bearings, and it assembles in its housing framework, functional to ensure proper seating without interruptions, leaps or blockages. The next step is to describe a new sketch, using the *2D Sketch* command. After this, using the *Extrude* command the sketch is transposed in 3D model and the edges are rounded using the *Chamfer* and *Fillet* commands, Figure 11.

Fig. 11 Block frame bearings.

An important part of the motion system of bicycle brake lever is in conjunction with skids, a handle for brake-front and one for rear-brake.

Modeling begins with model *2D Sketch* for each component in part because the brake handle summarizes several pieces. The process is followed by a command to *Extrude*, handle, plastic casing, screws, and finally using *Assemble* module and command of it, *Constrain*, it was coerced, Figure 12.

Fig. 12 Right Brake handle.

Modeling of fork bicycle started with the top commands of type *Circle*, after which commands were used 3D *Extrude* and *Subtract* for the achievement of superior and inferior fork model.

Then be used editing commands *Fillet* and *Chamfer* to trim model.

At the bottom of the fork will use the same commands as in the upper part, following the commands *Mirror* and *Pattern* for carrying out mounting the brake holes, Figure 13.

Fig. 13 Bill of material fork upper-lower fork.

The model was imported in STP format and load into a program of rendering, photo and video editing *Keyshot5*.

We apply effects and scenarios-type *Environment, Lighting, Shadows,* and *Color* to bring the modelled bicycle as close to a real environment, Figure 14.

Fig. 14 Model rendered with KeyShot Rendering 5.

3. OPTIMIZATION OF BICYCLE FRAME/ MODELING IN ANSYS WORKBENCH

ANSYS Mechanical is a finite element analysis tool for structural analysis, including linear dynamic studies , nonlinear and static.

Finite element simulation offers various ways to test the model behaviour for different axial forces, shear, bending moments or torsion and support models, CAD programs by imports simple in different formats and a variety of equations for a wide range of issues mechanical design.

Fig. 15 Hard Tail (HT) frame meshing in ANSYS Workbench using the function Design Modeler.

In the Ansys Workbench, after defining the geometry has been entered in the *Modeler Design* as the model to be meshed with the *Meshing* and model was loaded/linked corresponding to a finite element analysis.

The mesh of the model was done with a finer web than the default program does, because at the time used General mesh, the material defects in the structure of the model, resulting in errors of more than 25% of the surface mesh, these errors aren't allowed in the final.

Properties of Outline Row 4: Structural Steel

	A	B	C
1	Property	Value	Unit
2	Density	7850	kg m^-3
3	Isotropic Secant Coefficient of Thermal Expansion		
6	Isotropic Elasticity		
7	Derive from	Young's Mod...	
8	Young's Modulus	2E+11	Pa
9	Poisson's Ratio	0.3	
10	Bulk Modulus	1.6667E+11	Pa
11	Shear Modulus	7.6923E+10	Pa
12	Field Variables		
13	Temperature	Yes	
14	Shear Angle	No	
15	Degradation Factor	No	
16	Alternating Stress Mean Stress	Tabular	
20	Strain-Life Parameters		
28	Tensile Yield Strength	2.5E+08	Pa
29	Compressive Yield Strength	2.5E+08	Pa
30	Tensile Ultimate Strength	4.6E+08	Pa

Fig. 16 Material properties.

Fig. 17 The application of forces and boundaries.

The forces were applied to the outer surface of the bumper support frame at the point C (representing the weight of a cyclist $G_b = 120$ kg) on the inner surface of the joints in the front forks with oblique in section D (representing the rider's pedalling force. $FP = G_b/4$).

Bonds were chosen on surfaces as simple movement supports preventing the axis OY at the point A, representing the support fork and in point (B) representing the forks for wheel, Figure 17.

The tensions that resulted from the review are relatively small, since the model is oversized, the next step being the introduction of all the variables (the sections on the front bumpers, and the rear section of the ring for the introduction of the bicycle crank mechanism) in the *Response Surface Optimization* to find the indicated values of weight/approximate voltage section for a set value $\sigma = 1.2 \cdot 10^8$ N/m^2.

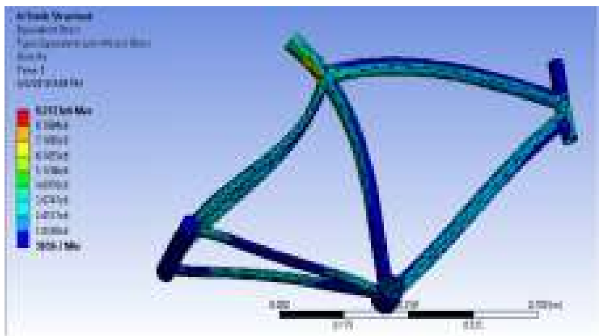


Fig. 18 Von-Mises stresses results.

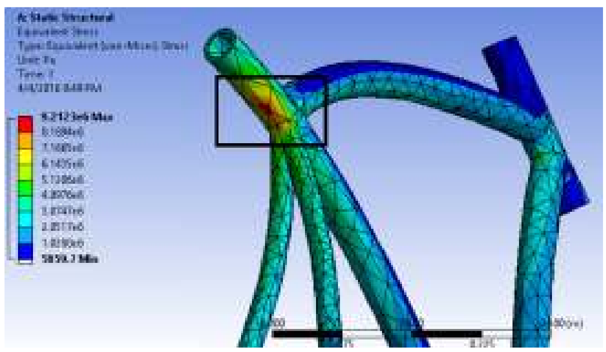


Fig. 19 The maximum tension point.

In the *Model Geometry*, it was calculated and the distorted structure of bars and identified where the vertices twisted reaches its maximum, i.e. merging between the frame and the saddle the cyclist.

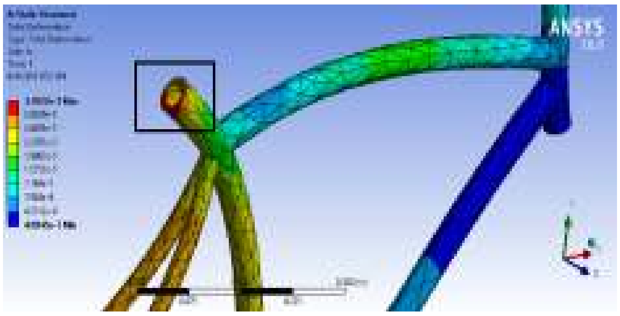
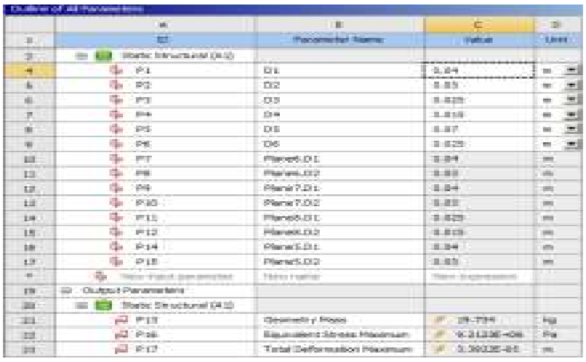


Fig. 20 Maximum point of deformed shape.

For calculating optimization through module *Design of Experiments*, I followed the introduction of transverse sections of the bumpers, in total six types of sections, as variable parameters, receiving between a lower and an upper limit, the remaining parameters as a function of the six mentioned in figure 21.



	A	B	C	D
1	ID	Parameter Name	Value	Unit
3	Static Structural (A1)			
4	P1	D1	0.04	m
5	P2	D2	0.03	m
6	P3	D3	0.025	m
7	P4	D4	0.018	m
8	P5	D5	0.07	m
9	P6	D6	0.025	m
10	P7	Plane6.D1	0.04	m
11	P8	Plane6.D2	0.03	m
12	P9	Plane7.D1	0.04	m
13	P10	Plane7.D2	0.03	m
14	P11	Plane8.D1	0.025	m
15	P12	Plane8.D2	0.018	m
16	P14	Plane5.D1	0.04	m
17	P15	Plane5.D2	0.03	m
*	New input parameter	New name	New expression	
19	Output Parameters			
20	Static Structural (A1)			
21	P13	Geometry Mass	19.734	kg
22	P16	Equivalent Stress Maximum	9.2123E+06	Pa
23	P17	Total Deformation Maximum	3.3903E-05	m

Fig. 21 Structure Parameters: P1/P2-section front triangle; P3/P4-posterior triangle section; P4/P5-section block crank axial; P6-thick posterior support wheel; P7/P15-proposed values depending on the early sections.

It takes into account the fact that imposing upper and lower limit values, is a necessary condition in the following calculation optimization.

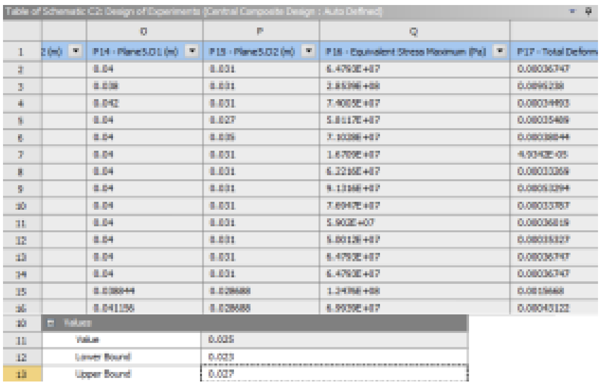


Table of Schematic C2: Design of Experiments (Central Composite Design : Auto Defined)

		O	P	Q	
1	2 (m)	P14 - Plane5.D1 (m)	P15 - Plane5.D2 (m)	P16 - Equivalent Stress Maximum (Pa)	P17 - Total Deform
2		0.04	0.031	6.4793E+07	0.00036747
3		0.038	0.031	2.8539E+08	0.0095238
4		0.042	0.031	7.4005E+07	0.00034493
5		0.04	0.027	5.8117E+07	0.00035409
6		0.04	0.035	7.1028E+07	0.00038844
7		0.04	0.031	1.6709E+07	4.9342E-05
8		0.04	0.031	6.2216E+07	0.00033369
9		0.04	0.031	9.1316E+07	0.00053294
10		0.04	0.031	7.6947E+07	0.00033787
11		0.04	0.031	5.902E+07	0.00036819
12		0.04	0.031	5.0012E+07	0.00035327
13		0.04	0.031	6.4793E+07	0.00036747
14		0.04	0.031	6.4793E+07	0.00036747
15		0.038844	0.028688	1.2476E+08	0.0015668
16		0.041156	0.028688	6.9939E+07	0.00043122

10	Values	
11	Value	0.025
12	Lower Bound	0.023
13	Upper Bound	0.027

Fig. 22 Calculation parameters.

As it has been from the beginning, oversize and the tensions resulting from the calculation were way too small, it was desirable that worksite the actual model. As output parameters we used the total mass of the frame, its volume, maximum tension and maximum allowable deformation, depending on which, towards the optimization end the final values of parameters will be calculated and eventually changed.

Fig. 23 Bicycle frame optimization.

The model has been optimized, keeping the dimensions of length of a hand, this being a condition home in designing and optimizing its framework, on the other hand, the sections have become smaller, the weight of the model the same, and the tensions occurring over the bezel does not exceed the allowable stresses imposed, approaching the proposed allowable tension.

Framework optimization of the total weight of the watched the system and checking the maximum permissible tension thereof so as to comply with the rules imposed upon him, after the calculation came out three results, the best result being the *candidate point 3* weighing G = 12.773 kg and $\sigma = 0.327 \cdot 10^8$ N/m^2 values appear in the border present in figure 22.

Values have been replaced in the initial project, with tensions and deformities in figures 23 and 24.

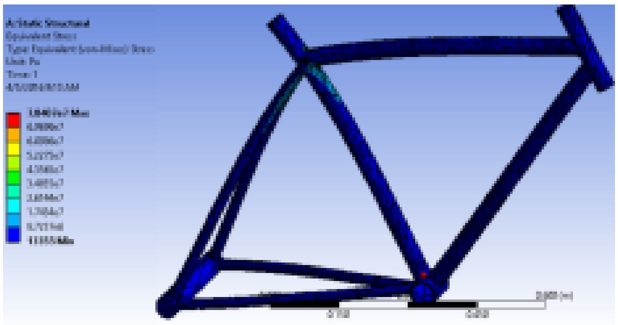


Fig. 24 Von-Mises tension after optimization.

Fig. 25 Deformed shape after optimization.

4. CONCLUSIONS

Considering the alarming pace of increase of pollution and congestion in the urban context, it is difficult to increase the number of vehicles on a daily basis, in exchange for an ecological alternative to choose. Mountain bike frame, also called Hard Tail (HT), has a simpler, without the complicated systems of joints of another model, yet more complicated Full Suspension than models of city bikes, which makes them more reliable in time and cheaper as maintenance (from one frame only replaceable component is HT ear from the shifter) [10].

Framework of HT offers a fixed geometry, which makes the body position and certain distances, such as a chain or line distance from spindle to up his pedals don't change, so there are no influences on pedalling system.

The biggest disadvantage of frames is, of course, HT that all shocks produced by shifting the rear wheel over bumps and obstacles are submitted by rider's almost entirely. This is not only inconvenient but produces strong shocks on the skeletal system and, at high speeds at different levels can lead to sideslip of the rear part of the bicycle.

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