F1 IN SCHOOLS™ Costa Rica, 2024
Development Class

DESIGN & ENGINEERING

NINTAI NEXUS

PORTFOLIO

in Schools
STEM Challenge

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LET'S RACE!

INTRO

NINTAI NEXUS™ Introduces you our design and engineering portfolio, where innovation meets ambition, and dreams take flight. Here, we embark on an exhilarating journey to craft the next generation of aerodynamic excellence embodied in our car NN24.

RESEARCH

FRICTION

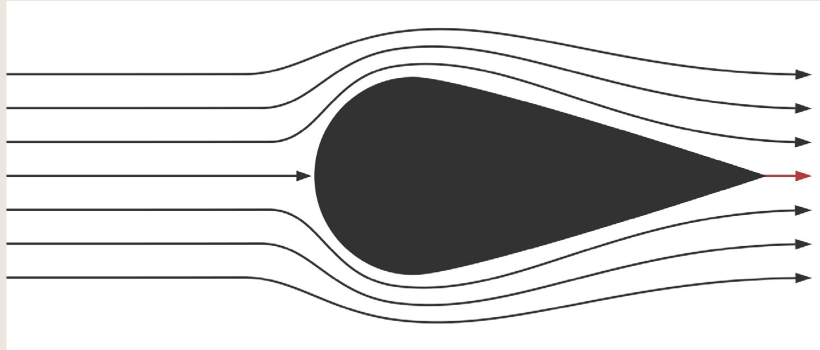
Defined as the force that resists the sliding or rolling of one solid object over another. Frictional forces, a lot of times are beneficial, but they also present a great measure of opposition to motion, for example, about 20% of the engine power of a car is consumed in overcoming frictional forces in the moving parts. When the team needed to select materials, low coefficients of friction materials where implemented, such as a composite blend of nylon and carbon fibers, reducing energy loss and improving overall efficiency, allowing our car to accelerate more quickly and maintain higher speeds on the track.

INNERTIA

It is the property of a body of which it opposes any agency that attempts to put it in motion, or if it is moving, to change the magnitude or direction of its velocity. It is important to clarify that a moving body keeps moving not because of its inertia, but only because of the absence of a force to slow it down, change its course, or speed it up. By strategically positioning mass and optimizing the car's weight distribution, the car's agility and responsiveness will enhance.

TEARDROP SHAPE

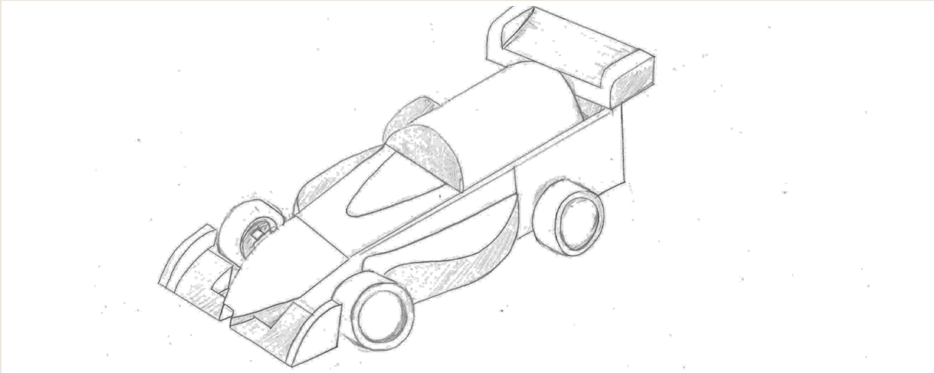
It is a shape characterized by a pointed section that gradually tapers towards the rear, resembling the shape of a teardrop. This shape enhances the aerodynamic performance of the car significantly and minimizes air resistance or drag as the car moves through the atmosphere, which results in less energy being expended to propel the car forward enabling higher speeds and improved efficiency. Additionally, the teardrop shape promotes the generation of downforce, which is crucial for maximizing traction and stability, during high-speed cornering.

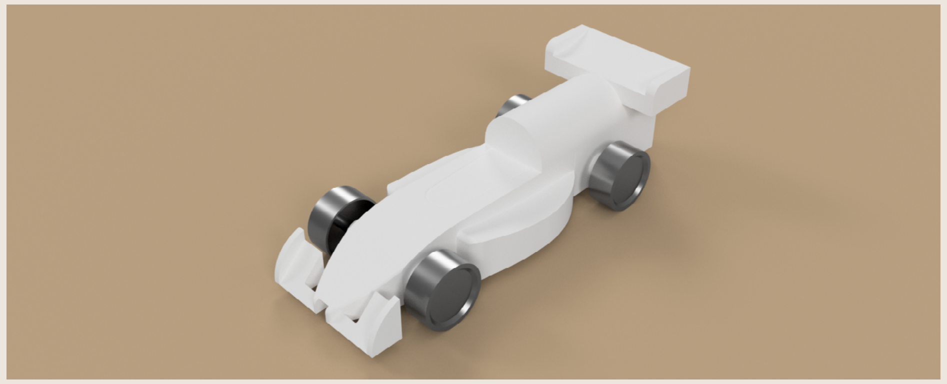


IDEAS & SKETCHES

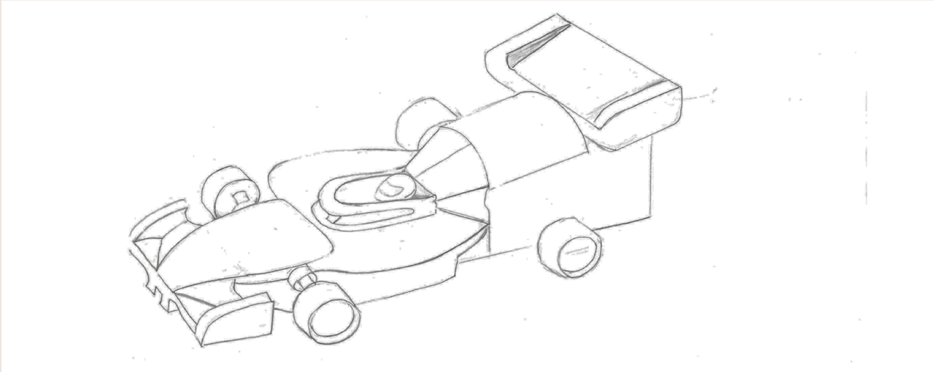
FIRST IDEAS

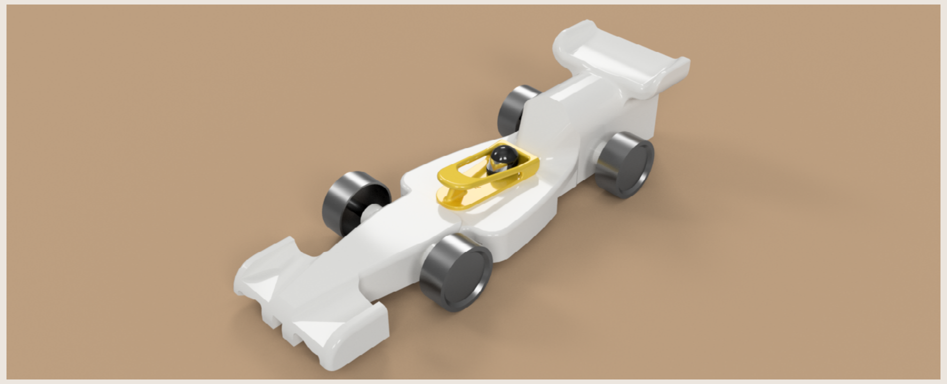
The initial design was quite simple, operating at more basic levels than what is truly demanded of us. Nevertheless, it included components that were later eliminated. Even though we understood It would not be the final 3D model, it worked as a foundation for creating subsequent designs.



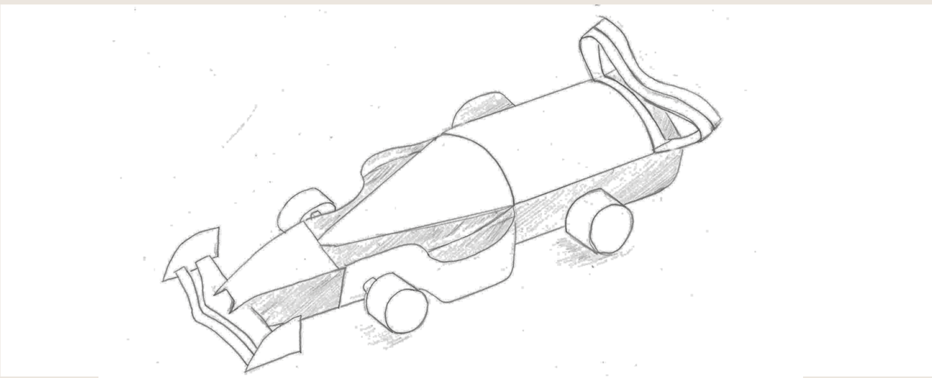


Render #2. The second design has an increased complexity. The body of the car is lower than the first one, and its design incorporates more advanced functions.





Render #3. After the design of the first two cars, the team was informed about various changes. The third design was the final one, where carbon fiber wings were implemented, and the use of the halo in the body was eliminated.



THE BLOCK KITS

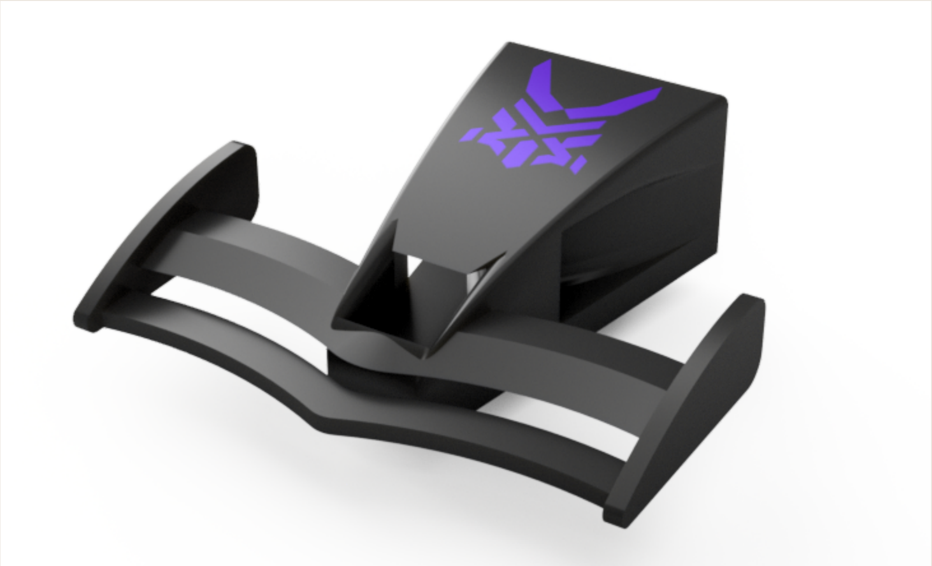
The blocks are standardized components provided by the organization to teams participating in the competition, serving as the foundational building blocks for manufacturing the car. In our case at the development class, our block shapes differed slightly from the standard F1 in Schools blocks provided by the organization. Rather than premachined shapes representing specific components of an F1 car, our blocks were rectangular in shape with no predefined contours. This allowed us greater flexibility and creativity in designing and sculpting the NN24.

NN24

To create the design of the car, there was a previous investigation about Adrian Newey's assorted designs. Starting with March 881, known for its aerodynamic prowess, was one of our principal inspirations, leading us to the final body of the car. Both front and rear wings are active components, thanks to our material selection, using a composite blend of nylon and carbon fiber that contributes with flexibility. This strategic choice transforms traditionally static wings into dynamic, making the components capable of adapting to real-time aerodynamic demands, optimizing aerodynamic efficiency and downforce generation.

FRONT WING

The front wing design was greatly influenced by Red Bull Racing, because of its distinctive characteristics just as stability, agility, and aerodynamic efficiency. This front wing will enable precise aerodynamic manipulation to optimize performance. Additionally, it has a hole at the front that exits through the sides of the wing in a "V" shape, with the aim of redirecting the air towards the tires.



REAR WING

The rear wing was inspired by the F2 latest design, which is designed to balance aerodynamic efficiency with downforce generation, enhancing straight line speed. Our rear wing features a headband that allows it to be attached to a channel located in the body of the car.

FINAL DESIGN

The final design incorporates several modifications based on earlier iterations, aimed at optimizing performance and efficiency, while implementing unique characteristics. The car incorporates a loft where the halo structure would traditionally be situated. As well, the design utilizes separate wings crafted from lightweight composite blend of nylon and carbon fiber, elevating the car's agility and responsiveness, giving us a competitive edge in the competition.

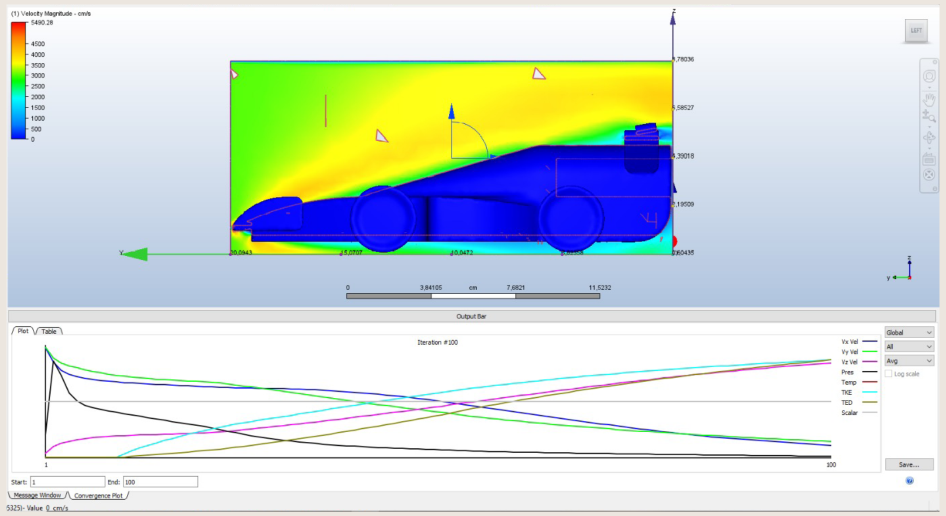
PAINT SELECTION IN DESIGN

Using spray paint in purple, black, and white, the NN24 undergoes a transformation to enhance its appearance and performance on the track. The spray paint adheres seamlessly to the car's body, forming a durable and visually appealing coating. Beginning with the application of purple, the car takes on a captivating shade that adds depth and allure to its design. As the black paint is skillfully applied, it accentuates the car's sleek lines, contributing to its aerodynamic profile. Finally, the addition of white paint serves to highlight intricate details, such as sponsor logos and the name time, ensuring clarity and precision in every movement. Through this careful painting process, the NN24 not only achieves a striking visual aesthetic but also gains resilience to withstand the demanding challenges of F1 in Schools competitions.

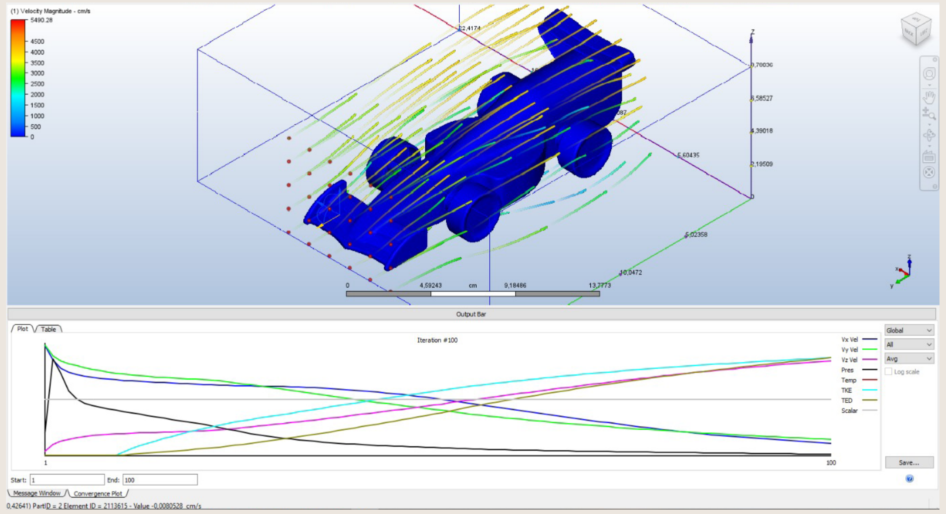
TESTING CFD

During the design phase of the car, we heavily relied on Computational Fluid Dynamics (CFD) testing and analysis to assess its aerodynamic performance. This program emerged as the primary method for evaluating components due to its effectiveness in simulating airflow behaviors.

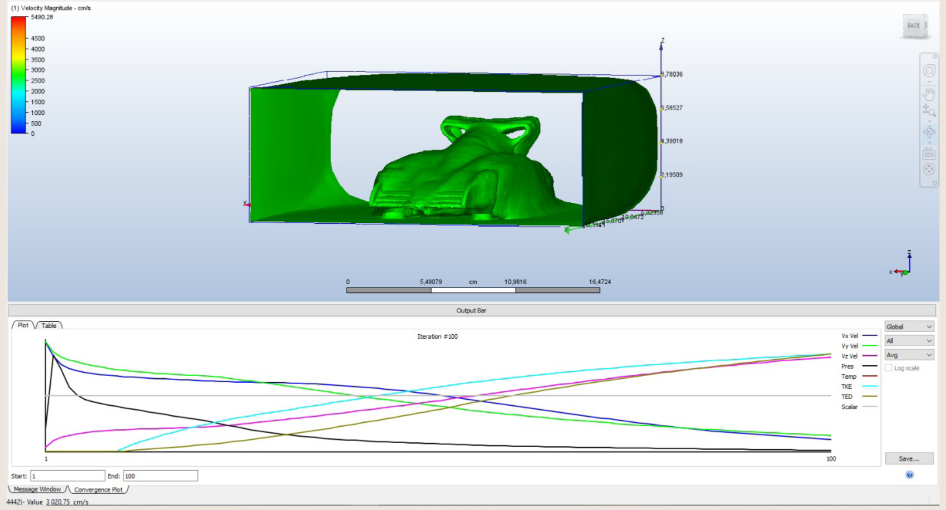
CUTTING PLANE



FLOW



SURFACE



Drag force in x direction: 0.019, Newton
Total area: 534.863cm2

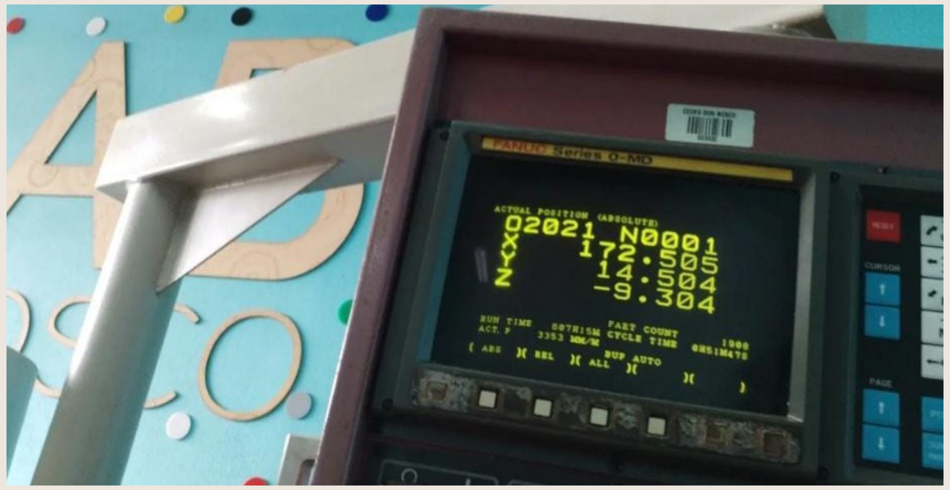
Velocity of air: 18.5m/s
Density of air: 1.2kg/m3

CAM / CNC

CNC (Computer-Aided Manufacturing) and CNC (Computer Numerical Control) are different technologies that are related. CAM implies the use of softwares to control all the steps related to the manufacturing process; it allows the automation and optimization of these processes by giving the instructions, coming from the design specifications, to the machines. The CNC refers to the automation of the tools and the processes of a machine through computer control. These machines have the possibility to perform precise movements based on the instructions provided by the CAM software.

CAM / CNC TECHNIQUES

The CAM/ CNC machines and technologies use different techniques depending on the expected result and the work that is being performed. When a CAM/CNC process is going to be carried out, it is important the Integration of CAD/CAM since it fulfills an important function by allowing the transfer of design data to the manufacturing processes. Once you have the necessary data, with the CAM software of Fusion 360 it is possible to produce a toolpath that specifies the movements and the tool's trajectory, by optimizing the toolpaths it is possible to minimize the machining time and inspect the possible mistakes in the CNC programming code. For this specific part you need to set up the workpiece according to the axes and their origin in the piece, so that the toolpath is precise with the necessary operations.



It is important to select the right tools depending on the job you are developing and the operations that the manufacturing process requires, because this also affects the cutting and spindle speeds included in the CNC programs.

Before executing the configuration made with the CAM software and developed in a code, it is necessary to simulate and verify the effectiveness of the configuration. This allow us to visualize the entire machining process from a computer in the same way as it would be if we did it on a machine. That way it is possible to identify potential issues such as tool collisions and resolve those issues before running it on the workpiece. All these processes are necesary to achive and improve the productivity, effectiveness and accuracy of the manufacturing process.

MANUFACTURING PROCESS

For the manufacturing process of the NN24 a Johnford CNC machine with 3 axes and a FANUC controller was used. The programs were developed in the CAM software of Fusion 360 and went through a process of analysis to determine and inspect the operations with the simulation of the programs. The program is based in different manufacturing strategies such as drilling, roughing and finishing, meaning that the program is divided in three different parts. For the implementention of the programs in the CNC machine, it is neccesary to have a tool library with the technical specifications, and the details of the program and operations. The following images correspond to the Setup of the programs used in the manufacture of the NN24, specifying the tools and speeds.

SOFTWARE SETUP

SETUP 1

In the first setup, the program worked with 3 different tools: a 6mm diameter drill bit for drilling, a flat-end mill with a diameter of 12.7mm for adaptive roughing, and a ball-end mill with a diameter of 4.76mm for the final finishing of the operation. This was done at spindle speeds of 5000rpm, 2500rpm, and 6684rpm, resulting in an operation time of approximately 1 hour and 13 minutes, plus tool change time.

Configuración

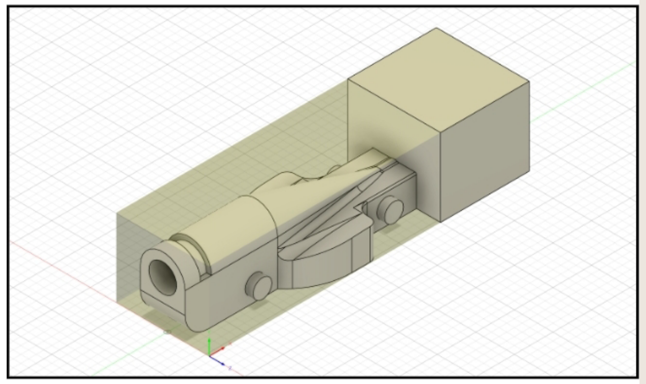
Plano de trabajo: #0

Material:
DX: 207.5mm
DY: 50.4mm
DZ: 60.2mm

Pieza:
DX: 207.5mm
DY: 50.4mm
DZ: 60.2mm

Stock Lower in WCS #0:
X: 0mm
Y: 0mm
Z: -60.2mm

Stock Upper in WCS #0:
X: 207.5mm
Y: 50.4mm
Z: 0mm



Total

Number Of Operations: 3
Number Of Tools: 3
Herramientas: **T1 T2 T5**
Maximum Z: 15mm
Minimum Z: -55.6mm
Maximum Feedrate: 1000mm/min
Velocidad máxima de husillo: 6684rpm
Cutting Distance: 70922.36mm
Distancia rápida: 5566.3mm
Estimated Cycle Time: 1h:13m:13s

Herramientas

T1 D1 L1	
Tipo: taladrar	Minimum Z: -55.6mm
Diámetro: 6mm	Maximum Feed: 1000mm/min
Ángulo de la punta: 118°	Velocidad máxima de husillo: 5000rpm
Longitud: 100mm	Cutting Distance: 100mm
Flutes: 2	Distancia rápida: 247.7mm
Descripción: Broca Diámetro 6	Estimated Cycle Time: 9s (0.2%)
T2 D2 L2	
Tipo: fresa con punta plana	Minimum Z: -29.7mm
Diámetro: 12.7mm	Maximum Feed: 1000mm/min
Longitud: 57mm	Velocidad máxima de husillo: 2500rpm
Flutes: 4	Cutting Distance: 4974.28mm
Descripción: Fresa punta plana 1/2x1/2	Distancia rápida: 4844.98mm
Proveedor: Tooltech	Estimated Cycle Time: 6m:16s (8.6%)
T5 D5 L5	
Tipo: fresa con punta de bola	Minimum Z: -30.65mm
Diámetro: 4.76mm	Maximum Feed: 1000mm/min
Radio de esquina: 2.38mm	Velocidad máxima de husillo: 6684rpm
Longitud: 41mm	Cutting Distance: 65848.08mm
Flutes: 3	Distancia rápida: 473.62mm
Descripción: Fresa punta de bola 3/16 x 3/16	Estimated Cycle Time: 1h:6m:3s (90.2%)

Operaciones

Operación 1/3		**T1** D1 L1
Descripción: Taladrar1	Maximum Z: 15mm	Tipo: taladrar
Estrategia: Taladrado	Minimum Z: -55.6mm	Diámetro: 6mm
Plano de trabajo: #0	Velocidad máxima de husillo: 5000rpm	Ángulo de la punta: 118°
Tolerancia: 0.01mm	Maximum Feedrate: 1000mm/min	Longitud: 100mm
	Cutting Distance: 100mm	Flutes: 2
	Distancia rápida: 247.7mm	Descripción: Broca Diámetro 6
	Estimated Cycle Time: 9s (0.2%)	
	Refrigerante: Fluido	
Operación 2/3		**T2** D2 L2
Descripción: Adaptativo2	Maximum Z: 15mm	Tipo: fresa con punta plana
Estrategia: Adaptativo	Minimum Z: -29.7mm	Diámetro: 12.7mm
Plano de trabajo: #0	Velocidad máxima de husillo: 2500rpm	Longitud: 57mm
Tolerancia: 0.1mm	Maximum Feedrate: 1000mm/min	Flutes: 4
Sobrematerial: 0.5mm	Cutting Distance: 4974.28mm	Descripción: Fresa punta plana 1/2x1/2
Reducción máxima: 25.5mm	Distancia rápida: 4844.98mm	Proveedor: Tooltech
Carga óptima: 5.08mm	Estimated Cycle Time: 6m:16s (8.6%)	
Desviación de la carga: 0.51mm	Refrigerante: Fluido	
Operación 3/3		**T5** D5 L5
Descripción: Festoneado1	Maximum Z: 15mm	Tipo: fresa con punta de bola
Estrategia: Festoneado	Minimum Z: -30.65mm	Diámetro: 4.76mm
Plano de trabajo: #0	Velocidad máxima de husillo: 6684rpm	Radio de esquina: 2.38mm
Tolerancia: 0.01mm	Maximum Feedrate: 1000mm/min	Longitud: 41mm
Sobrematerial: 0mm	Cutting Distance: 65848.08mm	Flutes: 3
Sobrepasada máxima: 0.2mm	Distancia rápida: 473.62mm	Descripción: Fresa punta de bola 3/16 x 3/16
	Estimated Cycle Time: 1h:6m:3s (90.2%)	
	Refrigerante: Desactivado	

SETUP 2

In the second setup, we worked with a 12.7mm flat-end mill for roughing and a 4.76mm ball-end mill for the final finishing in this program. The spindle operated at two different speeds, 2500 rpm and 6684 rpm. This program lasted approximately 52 minutes.

Configuración

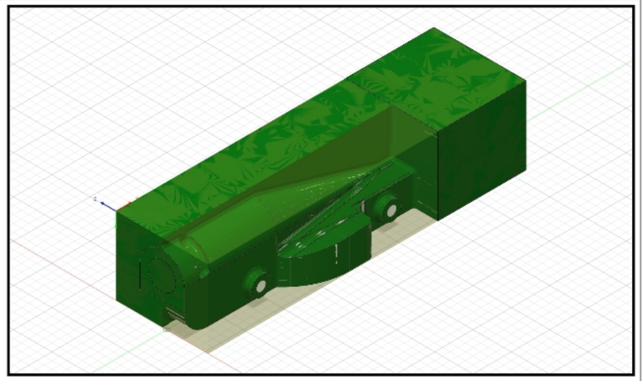
Plano de trabajo: #0

Material:
DX: 207.5mm
DY: 50.4mm
DZ: 60.2mm

Pieza:
DX: 207.5mm
DY: 50.4mm
DZ: 60.2mm

Stock Lower in WCS #0:
X: 0mm
Y: 0mm
Z: -60.2mm

Stock Upper in WCS #0:
X: 207.5mm
Y: 50.4mm
Z: 0mm



Herramientas

T2 D2 L2	
Tipo: fresa con punta plana	Minimum Z: -34.2mm
Diámetro: 12.7mm	Maximum Feed: 1000mm/min
Longitud: 57mm	Velocidad máxima de husillo: 2500rpm
Flutes: 4	Cutting Distance: 4980.56mm
Descripción: Fresa punta plana 1/2x1/2	Distancia rápida: 5699.58mm
Proveedor: Tooltech	Estimated Cycle Time: 6m:21s (12.1%)
T5 D5 L5	
Tipo: fresa con punta de bola	Minimum Z: -30.92mm
Diámetro: 4.76mm	Maximum Feed: 1000mm/min
Radio de esquina: 2.38mm	Velocidad máxima de husillo: 6684rpm
Longitud: 41mm	Cutting Distance: 45268.97mm
Flutes: 3	Distancia rápida: 558.01mm
Descripción: Fresa punta de bola 3/16 x 3/16	Estimated Cycle Time: 45m:29s (86.9%)

Total

Number Of Operations: 2
Number Of Tools: 2
Herramientas: **T2 T5**
Maximum Z: 15mm
Minimum Z: -34.2mm
Maximum Feedrate: 1000mm/min
Velocidad máxima de husillo: 6684rpm
Cutting Distance: 50249.53mm
Distancia rápida: 6257.59mm
Estimated Cycle Time: 52m:20s

Operaciones

Operación 1/2		**T2** D2 L2
Descripción: Adaptativo4	Maximum Z: 15mm	Tipo: fresa con punta plana
Estrategia: Adaptativo	Minimum Z: -34.2mm	Diámetro: 12.7mm
Plano de trabajo: #0	Velocidad máxima de husillo: 2500rpm	Longitud: 57mm
Tolerancia: 0.1mm	Maximum Feedrate: 1000mm/min	Flutes: 4
Sobrematerial: 0.5mm	Cutting Distance: 4980.56mm	Descripción: Fresa punta plana 1/2x1/2
Reducción máxima: 25.5mm	Distancia rápida: 5699.58mm	Proveedor: Tooltech
Carga óptima: 5.08mm	Estimated Cycle Time: 6m:21s (12.1%)	
Desviación de la carga: 0.51mm	Refrigerante: Desactivado	
Operación 2/2		**T5** D5 L5
Descripción: Festoneado1 (2)	Maximum Z: 15mm	Tipo: fresa con punta de bola
Estrategia: Festoneado	Minimum Z: -30.92mm	Diámetro: 4.76mm
Plano de trabajo: #0	Velocidad máxima de husillo: 6684rpm	Radio de esquina: 2.38mm
Tolerancia: 0.01mm	Maximum Feedrate: 1000mm/min	Longitud: 41mm
Sobrematerial: 0mm	Cutting Distance: 45268.97mm	Flutes: 3
Sobrepasada máxima: 0.2mm	Distancia rápida: 558.01mm	Descripción: Fresa punta de bola 3/16 x 3/16
	Estimated Cycle Time: 45m:29s (86.9%)	
	Refrigerante: Desactivado	

SETUP 3

In the third setup, a ball-end mill was used. Then the spindle speed was 6684 rpm, which facilitated the final finishing of the car process. It lasted approximately 1 hour.

Configuración

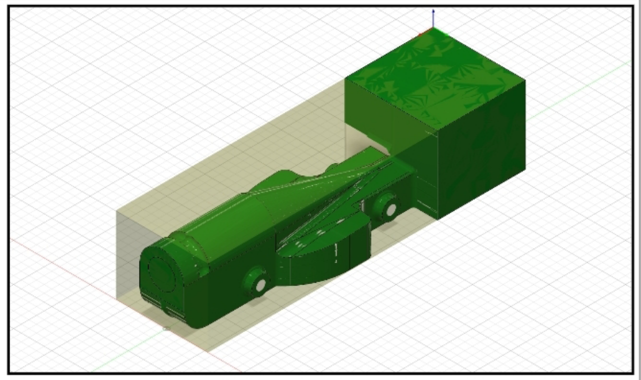
Plano de trabajo: #0

Material:
DX: 207.5mm
DY: 60.2mm
DZ: 50.4mm

Pieza:
DX: 207.5mm
DY: 60.2mm
DZ: 50.4mm

Stock Lower in WCS #0:
X: 0mm
Y: 0mm
Z: -50.4mm

Stock Upper in WCS #0:
X: 207.5mm
Y: 60.2mm
Z: 0mm



Total

Number Of Operations: 1
Number Of Tools: 1
Herramientas: **T5**
Maximum Z: 15mm
Minimum Z: -50.88mm
Maximum Feedrate: 1000mm/min
Velocidad máxima de husillo: 6684rpm
Cutting Distance: 57980.16mm
Distancia rápida: 1220.55mm
Estimated Cycle Time: 59m:6s

Herramientas

T5 D5 L5	
Tipo: fresa con punta de bola	Minimum Z: -50.88mm
Diámetro: 4.76mm	Maximum Feed: 1000mm/min
Radio de esquina: 2.38mm	Velocidad máxima de husillo: 6684rpm
Longitud: 41mm	Cutting Distance: 57980.16mm
Flutes: 3	Distancia rápida: 1220.55mm
Descripción: Fresa punta de bola 3/16 x 3/16	Estimated Cycle Time: 58m:51s

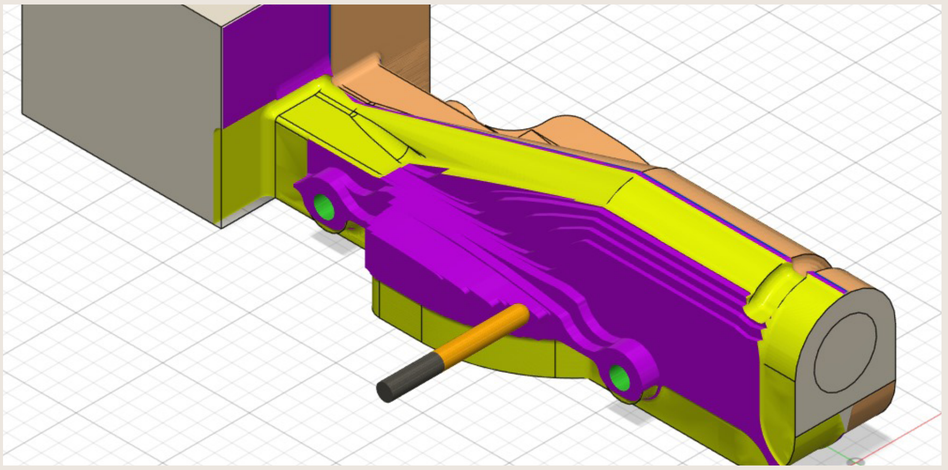
Operaciones

Operación 1/1		**T5** D5 L5
Descripción: Festoneado4	Maximum Z: 15mm	Tipo: fresa con punta de bola
Estrategia: Festoneado	Minimum Z: -50.88mm	Diámetro: 4.76mm
Plano de trabajo: #0	Velocidad máxima de husillo: 6684rpm	Radio de esquina: 2.38mm
Tolerancia: 0.01mm	Maximum Feedrate: 1000mm/min	Longitud: 41mm
Sobrematerial: 0mm	Cutting Distance: 57980.16mm	Flutes: 3
Sobrepasada máxima: 0.31mm	Distancia rápida: 1220.55mm	Descripción: Fresa punta de bola 3/16 x 3/16
	Estimated Cycle Time: 58m:51s	
	Refrigerante: Fluido	

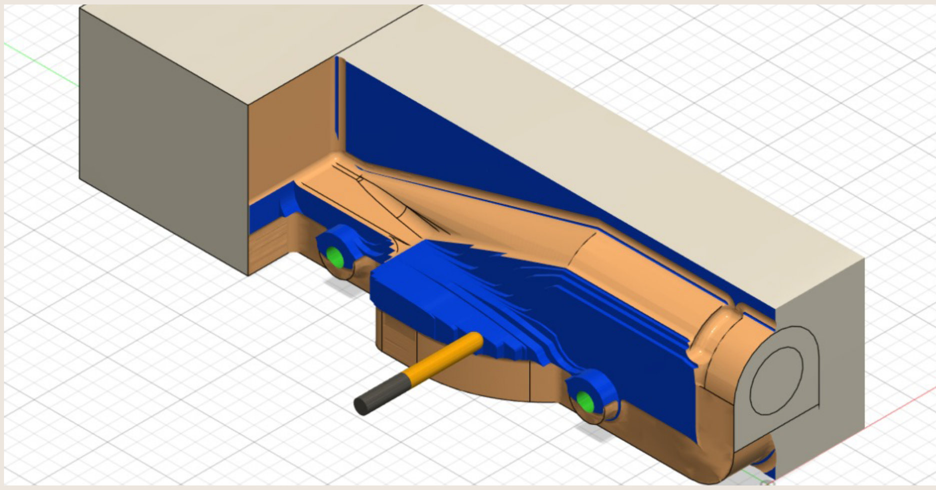
SOFTWARE'S SIMULATION

The simulation of the car's setup plays an important step in the manufacturing process, since it gives the possibility of visualizing the behavior of the program, the machine, the speeds and the tools with the workpiece, in this case, the block

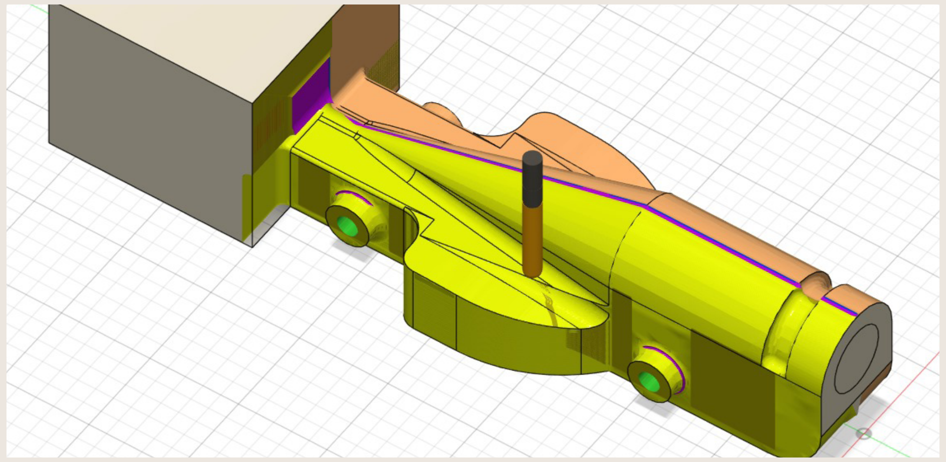
SIMULATION 1



SIMULATION 2



SIMULATION 3



With these simulations we were able to see how the design set-up would react when the car was manufactured

PREPARATION OF THE WORKPIECE

All the tools used are made of tungsten carbide, some of them were purchased specifically for the creation of the car, because some specific length dimensions were required for the finishing. For the manufacturing process, it was required to place the block in 3 different positions depending on the operation to be carried out. For this work, soft vises were used on the CNC milling machine, likewise, a precision stop was used to generate repeatability and faster advance during the change of block positions.

SETUP OF THE WORKPIECE IN THE MACHINE

Once the workpiece was secured, adjusted with the soft vises and properly placed on the machine, with the support of the precision stop, it was necessary to identify the zeros from the workpiece for a correct execution of the previously processed programs, this process of determining the zeros was performed by doing tangency with the workpiece and the tool, while the spindle was being manually moved. Once the X, Y and Z axes were found, the positions were saved in the CNC machine.

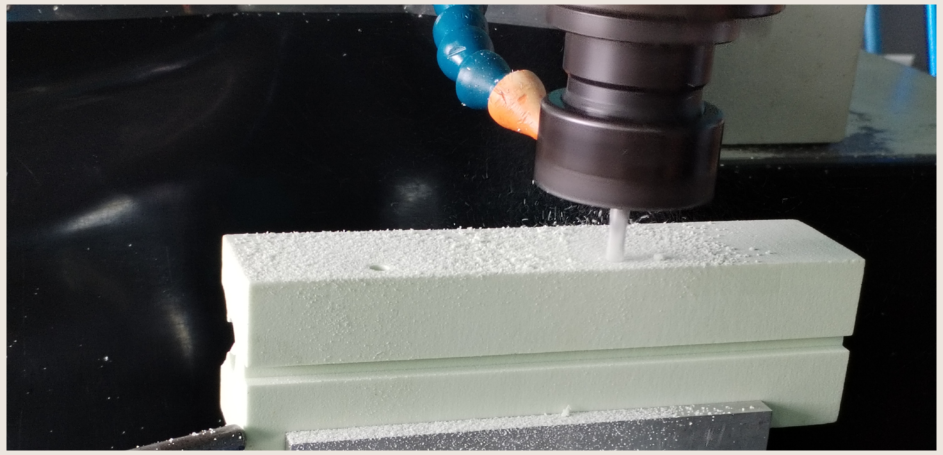
Simultaneously, the CAM program was downloaded to the CNC machine, and then we setup the machine to receive the instructions of the operations that were included in the thre parts of the program. Each program included different operations to optimize time and perform a quality control process in each part of the manufacturing process. Since each program included different operations, the corresponding tool changes, changes in the tools offsets or the machine adjustments were made once the different machining processes were done.

FABRICATION PROCESS

For the fabrication process of the car, the participation of the car engineers from the team, as well as the support of our tutor and the other team members, was necessary to initiate this process.

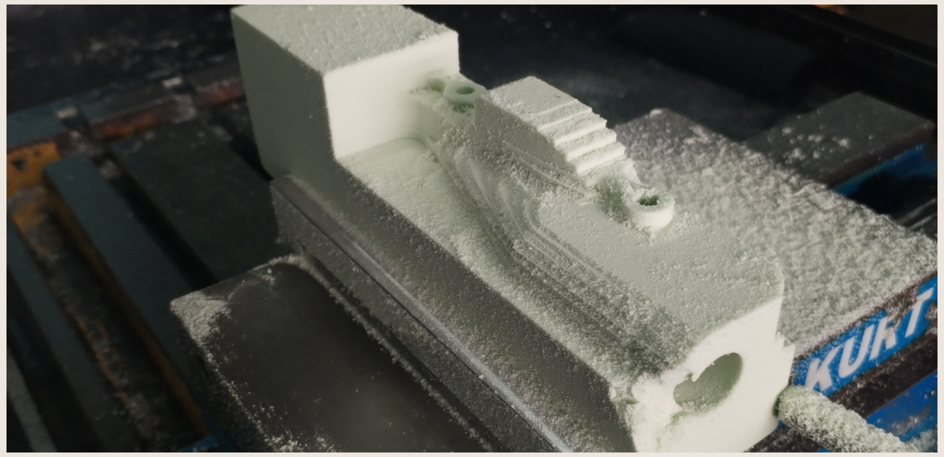
DRILLING

The first CNC program transmitted the instructions to perform the drilling, having as result of this the holes where the axles of the car's tires are placed, this was done with a 6mm drill bit.



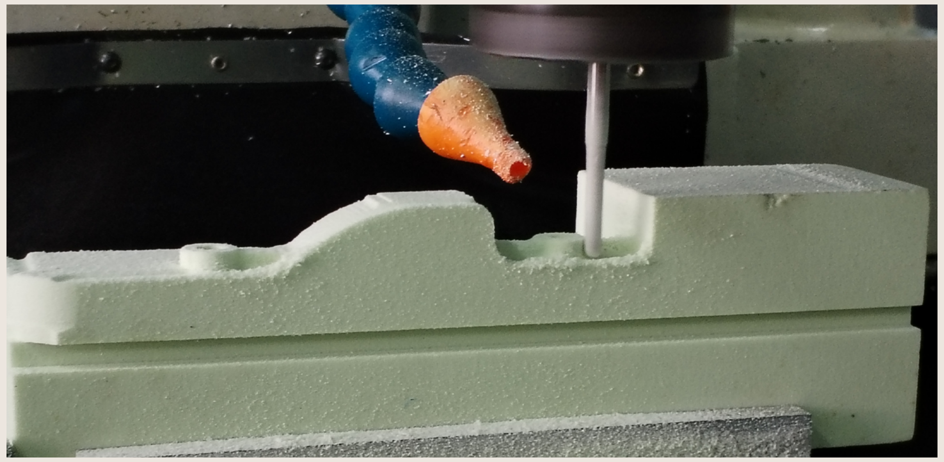
ROUGHING

The next process to manufacture was the lateral and upper roughing of the car, thus giving the shape that had been specified in the design, this was done with a 1/2 flat milling cutter.



FINISHING

Once the roughing process was carried out, the surface of the lateral part was left with spaces without machining, because the flat cutter of 1/2 by its size didn't reach all the parts. The following operation was made with a 3/16 round milling cutter. This process not only manufacture the areas that had not been worked, but also performed a finishing process on the car to leave its surface without imperfections and the required measurements.

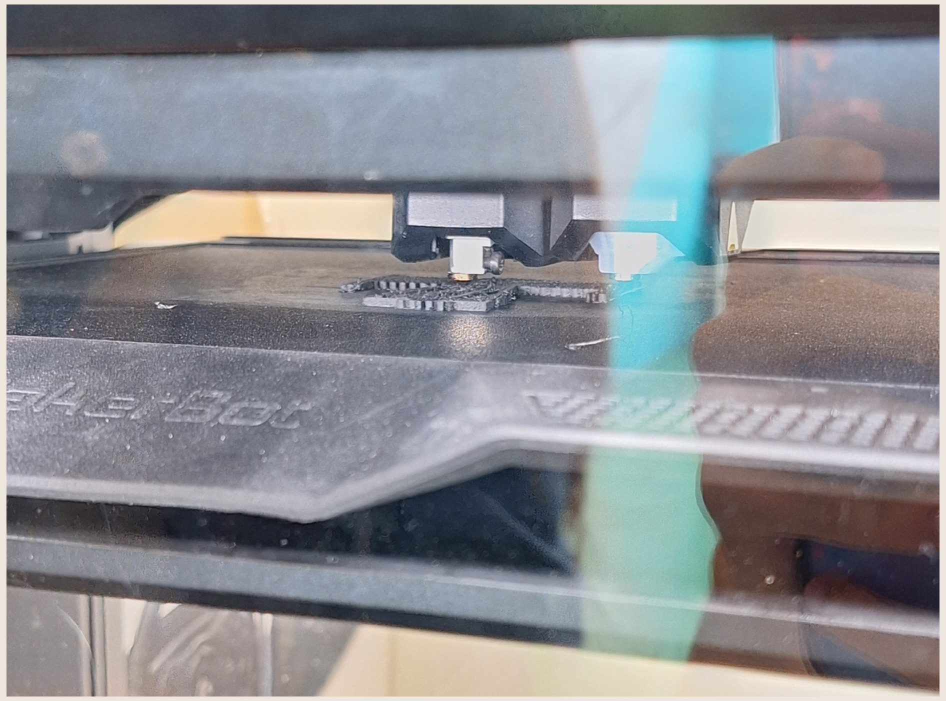


With this program we realized that the tooltpath was being inefficient because it was performing some machining paths that were not necessary, therefore the manufacturing took more time than what it was supposed to take. That's the reason why the CNC programming had different changes to improve the efficiency of the manufacturing process. Once the changes were made, the manufacturing of the other side of the car was more efficient and took less time than the previuous one.

3D PRINTING

3D printing with Nylon carbon fiber was used to manufacture the rear and front Wings. We used a 3D Stratasys machine with an engineering production method.

Once the design of the components was done in Fusion 360, it was exported in an STL format, to be shared with the software specialized in 3D printing" which allowed us to define the parameters for the 3D printing. We used Nylon-Carbon Filament 12% compositional for the printing of the rear and front wing. We also configured its density to be 3% so that its weight would not affect the total weight of the car. It was carried out with a speed of 200mm/min. Also, the impression was with 3 outer layers and with a honeycomb-shaped filling.



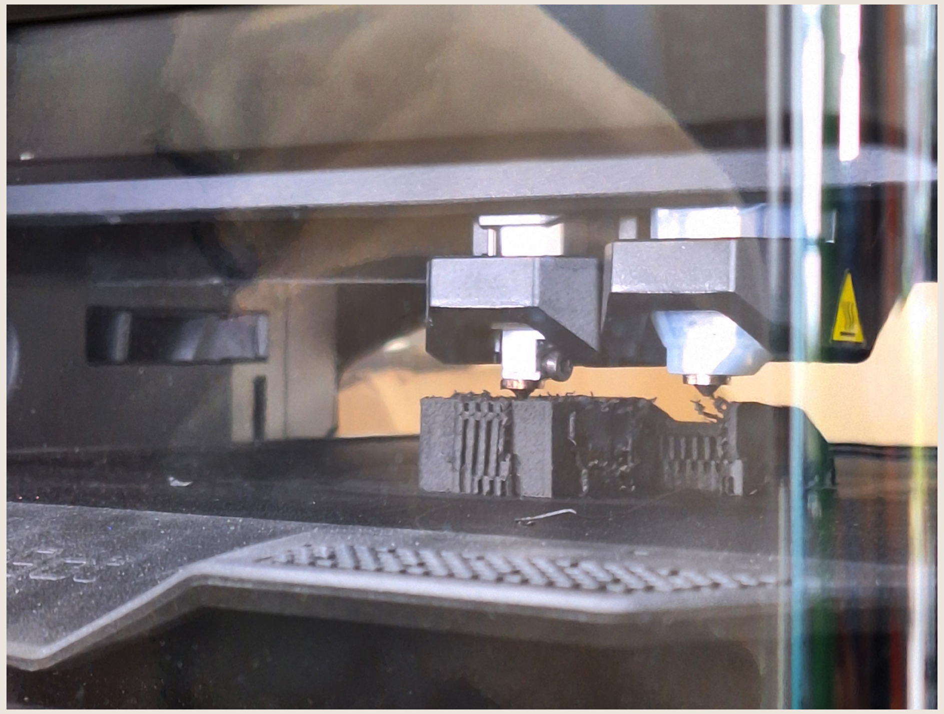
FDM NYLON 12CF (CARBON FIBER)

FDM stands for Fused Deposition Modeling. FDM printers extrude a thermoplastic in different layers onto a build plate to create a three-dimensional object, in this case the rear and front Wings.

FDM Nylon 12CF carbon fiber combines Nylon 12 and carbon fiber parts to achieve strength and flexibility; It also provides a cleaner carbon fiber additive process than other materials, which is show with strength properties. It provides heat resistance to printed components, this makes the components suitable for applications where durability and lightweight characteristics are needed.

PRINTING PROCESS

In a printing process involving carbon fiber, the filament is heated to its melting point within the printer's extruder assembly. Subsequently, the heated material is precisely deposited layer by layer onto the build plate in accordance with the digital design of the object being printed. The print head moves along the X, Y, and Z axes, depositing the melted material onto the build plate. The extruder nozzle moves horizontally to deposit the melted material, while the build platform moves vertically to enable the construction of each layer.



WORKPLACE SAFETY

Safety is essential to guarantee the security of the manufacturing engineering of the team during the car manufacturing process. CNC machinery is generally safe, but workplace accidents can still occur. While performing the car in the CNC milling machine, there was always a trained and certified operator, ensuring the safety. Wearing safety glasses is crucial during manufacturing to prevent potential eye injuries to operators. The use of hearing protectors and appropriate clothing is also important. Securing the workpieces properly prevents movement accidents. It's also important to make a regular tools inspection and maintenance to minimize different risks while performing the manufacturing process. Careful handling of both the monitor and the machine itself, as well as caution around the moving spindle, is necessary.

As NINTAI NEXUS™ we extend our heartfelt gratitude to each and every collaborator who has contributed to the success of our project. Your dedication, expertise, and passion have been the driving force behind our journey, propelling us toward our shared vision of excellence.