December 7th, 2025

Group Assignment #7 – Final Report

Group 10 – Airless Tires

William Bonnell	90230715
Joshua Holmes	25724444
Cole Inverarity	28942316
Matthew Teaff	24113243
Gil Golan	91990903
Aadesh Chahal	83615823

Table of Contents

Executive Summary

This project explored whether 3D-printed airless tires can provide a low-cost alternative to conventional remote control (RC) car tires while maintaining performance and user enjoyment. Commercial foam and rubber tires wear quickly, are expensive, and offer limited tread and compound options, creating a recurring expense and barrier for hobbyists. The proposed solution is to use 3D-printed polymers to produce customizable, airless RC tires that can be printed at home for a fraction of the cost of commercial options.

Stakeholder interviews identified grip, durability, predictability, and enjoyment as the key requirements, and confirmed thermoplastic polyurethane (TPU), polylactic acid (PLA), polyethylene terephthalate glycol (PETG), and acrylonitrile butadiene styrene (ABS) as viable material options. Tests were designed and executed to assess grip, durability, and rolling-resistance of four printed compounds against an off-the-shelf foam control tire using a nitro RC car. The user experience and viability of each material was also discussed. Results showed that foam delivered the best overall performance, with TPU being the only printed material that offers viable grip, durability, and drivability without critical failure. PLA, PETG, and ABS either wore rapidly, failed structurally, or were not enjoyable to drive. Combined with a strong cost advantage per set, these findings indicate that 3D-printed TPU tires are a realistic solution with further design refinement and future validation required.

Introduction

Tires on RC cars are critical in determining performance, handling, and user enjoyment. However, unlike full-size cars, these parts can often degrade after a few uses. Their soft foam construction and higher slip rate mean that they wear out quickly and often, which presents a problem. Routinely changing these tires can introduce a high recurring cost to RC car hobbyists on top of the already expensive purchase of an RC car and subsequent repairs. If a user would like to swap out their tires depending on conditions, this could cost between $25-$50 a set, as seen on amazon and other local hobby shops [1]. Buying commercially available tires may also introduce limitations on the availability of options due to sizing and tread patterns. Much like full scale cars, there are different treads for mud, snow, rain, summer, and others. Hobbyists who want to push performance boundaries could spend a substantial amount of money to be ready for all conditions. Ultimately, the cost and availability of replacing tires can be an unforeseen cost and act as a barrier to entry.

To address these challenges, we propose the development of 3D-printed airless RC car tires as a cost-effective and customizable alternative to traditional rubber or foam options. An airless tire relies on its geometric design and material properties to provide the necessary structure, flexibility, and grip.

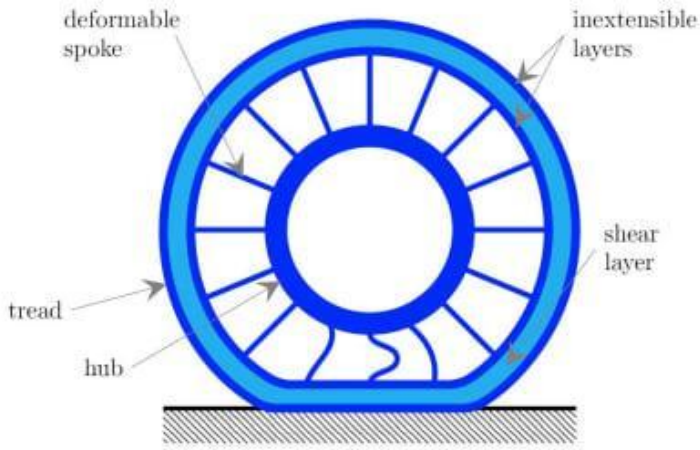


Figure 1: Airless Tire Design from [2]

These technologies have already garnered the attention of large conventional tire producers such as Michelin, Bridgestone, and Goodyear, demonstrating the potential of our solution [3], [4], [5]. The key idea is to enable RC car hobbyists to print replacement tires using flexible polymer filaments to replicate the performance that traditional foam or rubber tires offer, while being a lower-cost alternative. This approach would also allow for customizable characteristics in the form of tread pattern and structural geometry. Hobbyists could tailor tires to specific use scenarios and eliminate the need for buying dedicated tire sets, much like snow or mud tires for a conventional car. Our solution addresses the issue of high replacement costs of RC tires and increases accessibility of replacements and specific use case scenarios while offering performance.

Stakeholder Engagement and Requirements

Stakeholders are the people for whom we are making our project and products. They determine the constraints, domain, and use cases for our products. We identified the people who would be most affected by the results of our experiments and came up with the list below.

RC Car Owners: As the primary stakeholders, RC Car Owners will be the users of our product. We expect they will care primarily about the cost and performance of the tire, including how it feels to drive, the grip, rolling resistance, and durability of the tire. Through interviews with stakeholders, there was an emphasis on predictability, enjoyment, and how the tires feel when driving. Thus, these are the parameters we will base our tests around. If successful, RC Car Owners could buy or print our tires themselves, offering an alternative to the traditional foam or rubber tires that are sold at a high premium. To make this a viable option, we must ensure that it is worth it to the owners and make a product that has attractive performance for the money. Being our primary stakeholder, they are the group whose wants and needs we will consider the most throughout our project.

Hobby Shops: This is a secondary stakeholder in the sense that they could both benefit and be harmed indirectly by the success of our tire. Hobby Shops that currently sell RC tires at a high premium will be affected because of the loss in sales due to at-home printing of our tire designs. However, they may also benefit by providing the printed tires at a reduced cost to RC Car Owners who do not have access to personal 3D printers.

RC Car Manufacturers: Another secondary stakeholder, RC Car Manufacturers, provides the design parameters for the bolt and hub design of our wheels. They will care about the results of our testing as it could shape how they design cars and package the product moving forward. This will affect us for our tests, as well as any RC Car Owners looking to use a 3D printed tire (see above for primary stakeholder). Further to this, manufacturers could begin adapting their cars to suit our tires, with cars being developed on them or coming with them from the factory.

Filament Suppliers: We view Filament Suppliers as a tertiary stakeholder, as they will not be affected by the success or failure of our tests at a small scale. However, if a large market opens for 3D printed tires, filament manufacturers may choose to produce more of our selected material. In an extreme scenario, if demand becomes very high, they may choose to develop a specialized plastic for this purpose, thus furthering the market and research beyond the scope of our project.

Table 1: Key Stakeholders

Stakeholders	Connection
RC Car Owners	Drive the cars; pay operating expenses
RC Hobby Shops	Sell RC car tires; 3D printed tires could affect sales
3D Printer Users	Now able to produce RC car tires
RC Car Manufacturers	Provide design parameters for the tires; design of cars could be changed for new tire technology
Filament Suppliers	Produce the material to create the tires on the 3D printers
3D printer companies	Creates a new 3D-printer market

In the sections below, one can find the stakeholder interviews, including information of who they are and the type of stakeholder. Moreover, the stakeholders' condensed responses can be found with the reasoning behind the questions asked.

Interview One

Interviewee: Geoff Holmes
Stakeholder relationship: RC car owner

Q1: Do you feel that RC car tires are easy to source? Where would you normally source them?

Why: Understand the current market landscape.

- Depends on how much RC car activity is in your area
- Online - Amazon probably not great quality
    - If you want proper racing ones, it's harder to get
    - Drifting guys use hard plastic tires

Q2: Do you feel that RC car tires are expensive? Would a cheaper option be desirable, or are the current options cheap enough that it doesn't really matter?

Why: Understanding if there is a desire for a cheaper option

- You get what you pay for
    - If it’s good, people will pay
    - Some people will just want the cheapest
- Finding the balance between performance and cost
    - Likely losing durability more than performance

Q3: Do you have access to a 3D printer, or would you be interested in having one?

Why: Confirming if 3D printing is a relevant option for the stakeholder

- Yes has access to one
- Would be interested in having one around

Q4: What characteristics of an RC car tire are important to you?

Why: Understanding which performance metrics are important to the stakeholder

- Durability
    - How long do they last
- Performance
    - Good grip, but lasts multiple driving sessions
    - Good control over a range of speeds
- It’s a trade-off
- Willing to pay more if it’s a better product

Q5: Would you be willing to deal with a slight reduction in performance for a cheaper option? At what point does it become a problem for you?

Why: Understanding the stakeholder perception of the trade-off between performance and cost helps to justify the minimum threshold of performance for a 3D printed tire to be viable.

- When it’s not fun anymore
- Crashing too much
- Not enough grip to do what you want to do
    - Ultimately depends on your budget
        - Some people will spend as much as they want
        - Some people will just cope
- Depends on what you want to do at the end of the day

Q6: Would you consider 3D printed RC car tires as a potential alternative to traditional wheels? What would be the biggest barrier/what criteria would they need to meet for you to consider them as an option?

Why: Try to understand if the stakeholder is open to trying new tires and what criteria need to be met for them to do so.

- Always a consideration
    - Likes to experiment with new things, never know until you try things
- It would be interesting to try
- If the price is right, it’s especially interesting
- Basically, the aforementioned performance metrics
    - If it performs well enough

Interview Two

Interviewee: Ian Wang
Stakeholder Relationship: Hobby 3D print. Owns a Bambu Labs P1P.

Q1: What got you into 3D Printing? How long have you been 3D printing, and what kinds of projects do you usually do?

Why: Establishes background and relevance.

- Wanted to utilize CAD skills to solve problems in a cost-effective way
- Around 2 years of printing experience
- Mostly prints practical items and replacement parts that can be used around the house

Q2: Have you tried PLA, PETG, ABS, and TPU?

Why: These are the candidate materials for our project.

- Started with PLA and is most often used
- PETG is good for outdoor parts
- Uses TPU when the part needs to be flexible
- Limited ABS since it is hard to print

Q3: How would you compare them for strength and flexibility?

- PLA: Snaps if you bend it. Don't use it for anything that flexes
- PETG: Tougher, takes hits better than PLA. Too stiff for something like a tire
- ABS: Stronger than PLA, but again, rigid. Printing it is a headache
- TPU: Rubbery. Only one to consider for a tire

Q4: What challenges have you run into with those materials?

Why: Identifies real-world feasibility.

- PLA: Prints well but degrades with heat
- PETG: Stringy, sometimes layer adhesion issues, otherwise reliable
- ABS: Warps and cracks unless you have an enclosure
- TPU: Slow to print, nozzle can clog, and can be very stringy

Q5: Do you think any of those materials could work for something that needs to flex a lot, like a tire?

Why: Tests our design hypothesis.

- Only TPU. The other materials are too stiff

Q6: What print setting would you recommend for TPU?

- Print around 235°C and slow extrusion rate to 25–30 mm/s
- Use a gyroid infill if the part needs to flex
- TPU absolutely has to be dry before printing

Q7: How much do you spend on filament?

- PLA, PETG, and ABS are around $25/kg
- TPU can be around $50/kg
- Only buys from Bambu Labs; perhaps other vendors have filament for cheaper.

Summary of Interviews

For the interview conducted with Geoff, the main theme that came through was the balance between tire cost, durability, and overall drivability. He mentioned that where you live plays a large role in how easy it is to find decent RC tires. He also stated how higher-end racing options are much harder to come by. For casual use, cheaper options exist online, but the quality isn't always as good. Another interesting note was how he mentioned that price itself isn’t his biggest concern. He was more focused on how long the tires last and how well they grip. For him, the real measure of a tire is whether the car feels predictable and fun to drive. He also showed interest in 3D-printed tires, saying he’d be open to experimenting with them as long as they held up reasonably well and didn’t compromise too heavily on the attributes that he is looking for.

On the other hand, Ian approached the conversation from a maker’s perspective. With about two years of 3D printing experience, he’s worked with a variety of materials and was quick to point out that TPU is likely the best option for something like an RC tire. He said that the others are stiff and brittle. TPU does come with challenges, where it prints slowly, needs higher temperatures, and clogs the printer nozzle more easily. However, when tuned properly, it produces parts that flex and rebound like rubber. Ian also mentioned that although TPU costs more than standard filaments, it’s still relatively affordable and readily available enough for most people.

Our findings from these stakeholder interviews enabled us to build a framework for testing based on technical concepts that determine the desired characteristics from both a user and manufacturer's perspective.

Technical Background and Context Review

Ideal Prototype Description

Our ideal prototype would be a fully optimized 3D-printed tire designed for RC cars. This would be made by trying to perfect printing parameters such as layer adhesion, deposition rate, and controlled temperature and humidity. Assuming we have unlimited time and resources, we would develop a custom printing material tailored to create a tire that achieves high flexibility, durability, and traction. These are all qualities that are essential for the performance of RC tires. The goal would be to produce a tire that is able to replicate the mechanical response of traditional foam tires while keeping the cost savings from printing the tires at home. In an ideal world, we would also try to create a simulator test rig capable of replicating real-world driving conditions to validate parameters such as grip, durability, and rolling resistance to ensure that our prototype meets our overall performance criteria. Doing so in an extremely controlled environment would ensure that our testing can actually be applicable to real-world scenarios.

Specific Prototyping Area for Testing

We will be 3D printing and testing these tires with existing off-the-shelf 3D printing filaments to maintain consistency and make sure that we are purely evaluating the difference in material performance. For our prototype testing, we will focus on three key performance elements: grip, durability, and rolling resistance. For grip, we plan to do an acceleration test, marking a 25-meter flat surface and have the RC car accelerate as fast as possible, using a slow-motion camera to precisely time each run. We will conduct five trials and take the average to measure how effectively the tire transfers power to the ground. For durability and tread life, we will drive the car for a specified distance and record the amount of wear experienced. With this data, we could then estimate a tire’s lifespan and assess the wear characteristics of the tire. Lastly, for rolling resistance and efficiency, we’ll drive the RC car at a constant throttle, let off at a marked point, and measure the coasting distance until it stops. All tests will be conducted on a dry pavement surface, since this is the most applicable scenario for the RC car we have available for testing. We feel these tests capture the three most important aspects of tire performance while remaining realistic to test with our current tools.

Main Physical Concepts in Testing

The performance of RC car tires is primarily driven by the balance between tire grip and durability. Though there is no significant research into RC car tires specifically, a huge amount of research has been done on regular car tires. Though the scale is vastly different, it seems reasonable to assume that the underlying principles of tire performance are relatively similar if not entirely the same. Through our stakeholder consultation, grip and durability were identified as the most important factors for performance. These characteristics are driven by a variety of factors, many of which result from the properties of the tire material. Ultimately, due to the significant complexity of the underlying mechanisms, empirical tests representative of actual driving conditions will be used to draw conclusions. Testing specific properties is often not indicative of real-world driving experience simply because of factors such as, temperature, wind, and surface preparation/quality that cannot be controlled for.

Material Properties

In understanding the performance characteristics of a tire, it is first necessary to understand some of the key material properties. The first property of interest is the glass transition temperature (T_g). This temperature describes a point where a plastic material goes from a rigid, glassy state to a softer, rubbery state. Materials above their T_g will deflect more under the same forces and take longer to return to their original shape when the forces are removed. In terms of tires, it is desirable for the material to be above the glass transition temperature in a rubbery state during operation; in this range, the material is softer and more resilient to impacts. The melting temperature is also a critical property, since the tire must not melt while the car is in operation. It is also worth noting that the melting temperature for a material will always be above the T_g. Another important characteristic specific to 3D printed materials is the layer adhesion, which describes how well the layers in the 3D print stick together. Often, there are weak points between layers because the hot plastic from the nozzle does not stick well to the layer below. Layer adhesion depends both on the specific material being printed and the printer settings. One indicator for this property is the Z toughness, which is a specific measure of a 3D printed part's inter-layer adhesion or strength perpendicular to the print layers (Z-axis), whereas general toughness refers to the overall ability of a material to absorb energy and resist fracture across any direction. The final material property of interest is the material stiffness, where a stiffer material will deflect less for a given force. In terms of tires, a softer tire will deflect more, increasing the contact with the road. The overall stiffness of a tire can be controlled by changing the tire geometry through the geometry of the wheel itself; however, changes in geometry are beyond the scope of this project. The properties discussed for the materials being tested are summarized in Table 2 below.

Table 2: Material properties for the four 3D printed materials under consideration [6], [7], [8]

Material	Glass Transition Temperature (°C)	Melting Temperature (°C)	Z Toughness - Layer Adhesion (J/m^2)	Stiffness (GPa)
PLA	60	160	13.8	2.6
PETG	68	225	13.6	1.5
ABS	105	200	7.4	2.2
TPU	-30	177	88.5	0.0068

Grip

Tires generate grip through two physical mechanisms. First, there is road roughness or indentation effects which come from the tire material deforming around the tiny bumps in the surface of the road [9]. This is similar to how the studs on soccer cleats help you grip the field better, except that the road is acting like the cleats; a softer plastic or tire material lets the tiny bumps in the road dig into it more, letting it grab the road better. An illustration of this effect is shown in Figure 2. This additional deformation also increases the area of the tire in contact with the road, which benefits the second grip mechanism, molecular adhesion. Molecular adhesion results from temporary bonds formed between the tire and road surface molecules where they are in contact. When more tire area is in contact with the ground, more of these bonds can form, resulting in higher grip. The combination of these two mechanisms describes the overall grip performance of the tire. A notable takeaway from this is that grip benefits from softer tires, since they conform better to the road surface, improving indentation grip, and increasing the area available for molecular adhesion. The overall grip characteristics of the tire have a significant impact on how a car feels and performs. The car with more grip will accelerate faster, maintain higher cornering forces, and stop faster. Thus, the time to accelerate through a fixed distance will be used to compare the grip of different tires, with faster times assumed to mean higher grip.

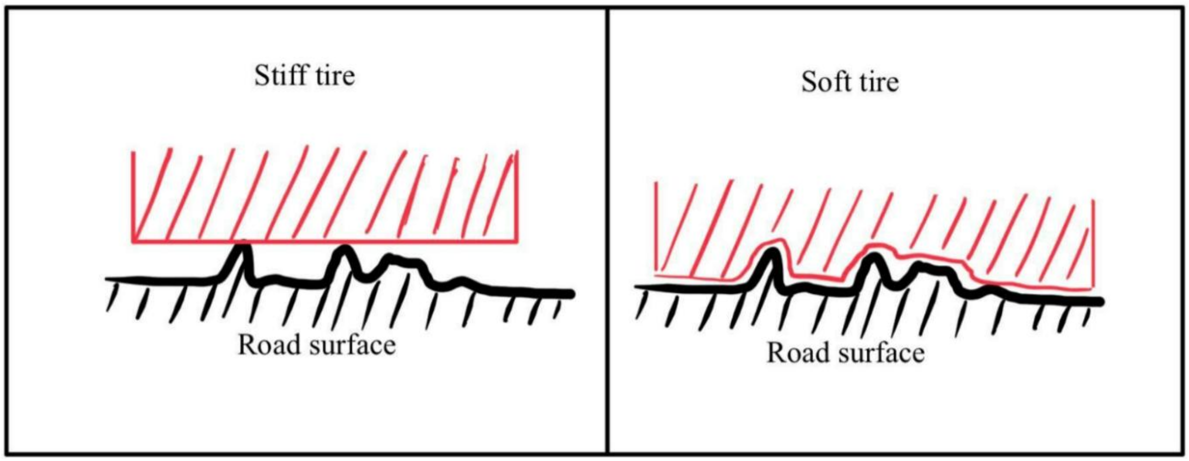


Figure 2: Visual Representation of How a Softer Tire Deforms Around Bumps in the Road Surface to Increase Grip

Durability

The durability and wear of 3D printed RC car tires are most likely influenced by three main phenomena. Unique to 3D printed tires, layer adhesion is expected to have a significant impact on how the tire wears. For materials with poor layer adhesion, it is possible that the tire fails catastrophically by splitting along the layer lines while in use. If the tire does not split apart, then it will be expected to wear more gradually over time. Softer tires typically experience high elastic deformation wear, in which the tire wears by small pieces of the tire stretching and tearing off as the tire runs [10]. Conversely, hard tires tend to wear by plastic deformation wear in which the tire is effectively sanded down over time by contact with the road surface [10]. Ultimately, all tire wear is some combination of these two mechanisms, but depending on the tire characteristics, different mechanisms will dominate. From the materials being tested in this experiment, ABS would be the most likely to experience layer adhesion failure. PLA and PETG are expected to show plastic wear, while TPU will likely demonstrate elastic wear [11]. Overall, layer adhesion failures need to be avoided, but neither wear mechanism is necessarily better than the other for durability. In the scope of this project, it is not useful to attempt to quantify which wear mechanism dominates; instead, tire wear will be quantified by taking the difference between the initial and final tread thickness after driving a given distance.

Background Research on Industry Standards

There are many established industry standards for evaluating car tires, with a few that relate closely to the three performance areas we are testing. Those areas being grip, rolling resistance, and tread life. While these standards provide insight into how these performance criteria are measured, there is no direct application to 3D printed RC car tires.

Grip

First off, for testing the grip of a car tire, *ASTM F1805 - Standard Test Method for Single Wheel Driving Traction in a Straight Line on Snow and Ice-Covered Surfaces* is a standard that comes up [12]. This standard evaluates tire traction by measuring the force generated and the velocity of the tire under controlled conditions. For RC car tires, no standards were found for dry or general traction testing. Some of the searches tried were "RC tire traction test standard," "3D printed tire grip test," and "small-scale traction measurement," which revealed some research methods but no industry standards. The lack of standards for our project exists because RC and 3D printed tires are not used in a regulated transportation system, so the testing remains within performance hobbyist or research domains.

Rolling Resistance

Secondly, the most relevant standard for rolling resistance is *SAE J2452 - Stepwise Coastdown Methodology for Measuring Tire Rolling Resistance* [13]. This standard defines a coastdown-based method for determining rolling resistance under simulated conditions. In the standard, a tire is mounted on a test machine and allowed to coast through several speed steps while recording reaction forces at the tire spindle or the torque input to the test machine.

Treadlife

For the third test metric, treadlife, *ASTM F762 - Standard Test Method for Determining Change in Groove (or Void) Depth With Distance Traveled for Passenger Car Tires* is a standard implemented [14]. ASTM F762 measures tire wear by recording the reduction in groove depth after controlled distances and test cycles. The testing procedure uses road circuits with specific loads, speeds, and temperatures to quantify wear rate. Once again, no standards exist specific to RC car tires or 3D printed tires; however, similar methods can be reproduced by measuring tread depth or mass loss after repeated test cycles, providing comparative rather than absolute wear data.

To summarize, while standards such as ASTM F1805, SAE J2452, and ASTM F762 outline testing procedures, equivalent tests for RC-scale or 3D printed tires do not exist; therefore, we then need low-budget adaptations of these procedures, such as simplified coast down, wear, and acceleration tests that can approximate industry approaches for comparative analysis.

Experimental Procedures

Acceleration

Grip (25 m sprint with high-speed timing).

Objective

Compare materials by a proxy for dynamic friction (launch traction) using 25 m acceleration time.

Apparatus

- RC car
- 25 m straight, flat, lane (tape start/finish); roof of North Parkade
- Phone @ 240 fps on tripod, perpendicular to course at the finish line

- Tape measure; thermometer (surface temp); notebook/data sheet

Controlled Variables

- Same driver and track
- Same environmental conditions
- Same suspension set up and fuel level

Procedure (per material, 5 reps)

1. Sweep lane; record ambient & surface temperature
2. Place the car behind the start line. The driver accelerates as fast as possible while maintaining control
3. Record each run; cool 1–2 min between runs
4. In video, note frame when wheels first move and frame when nose crosses finish

$$t_{25} = t_{final} - t_{initial}.$$

5. Repeat for all materials and the benchmark foam tire

Data Captured

Time car crosses the start line ($t_{initial}$), time car crosses the finish line (t_{final})

Quality Controls & Error

- If the run shows obvious steering or a false start, re-run the trial.

Analysis

- Mean ± SD t_{25} for each material
- Graphs / Charts to visualize

Rolling Resistance

Efficiency (coast-down distance).

Objective

Compare rolling losses by measuring coast-down distance from a repeatable low speed.

Apparatus

- RC car
- 25 m straight flat lane; tape to mark start (throttle-cut) and finish lines
- 3D printed trigger block to apply constant throttle position

Controlled Variables

- Same initial throttle position
- Same driver and track
- Same environmental conditions
- Same suspension set up and fuel level

Procedure (per material, 5 reps)

1. Warm tires with one run; then accelerate from well before the start line to the same throttle position.
2. Cut throttle exactly at the start line; allow the car to coast to rest
3. Measure coast-down distance, D_{stop} from start line to nose position at stop
4. Repeat 5 times; record ambient T and notes (any drift/steering)

Data Captured

Distance for car to coast to a stop (D_{stop})

Analysis

- Mean ± SD of D_{stop} per material
- Graphs / Charts to visualize

Durability

Objective

Quantify lifetime and wear behaviour of 3D-printed tires under continuous operation

Apparatus

- RC car (Same state as previous tests)
- Cones for setting up a short racetrack

Controlled Variables

- Same initial throttle position
- Same driver and track
- Same environmental conditions
- Same suspension set up and fuel level

Procedure

1. Set up a test course approximately 100 m in length, depending on available area. The course should consist of a variety of different corners, with at least one right hand corner, one left hand corner, and one significant straight
2. Sweep track before running, record ambient temperatures
3. Mount tires on the car, ensure that the car is at reasonable temperature and tune
4. Drive in increments of 5 laps, checking for visual damage and wear at each interval
5. Tire diameter with calipers
6. After 25 laps measure mass of tire and calculate difference from start

Data Captured

- Change in tire diameter after 25 laps
- Tire mass after 25 laps
- Visual observations of wear

Analysis

- Mean ± SD of Δm and $\Delta thickness$ per material
- Graphs / Charts to visualize

Drivability

Objective

Provide insight into the driver experience aspects of each tire.

Apparatus

- RC car
- Cones for setting up a short racetrack

Controlled Variables

- Initial fuel level and temperature

- Ambient temperature and weather conditions
- Identical car set up and alignment

Procedure

1. Set up a test course approximately 100 m in length, depending on available area. The course should consist of a variety of different corners, with at least one right hand corner, one left hand corner, and one significant straight
2. Sweep track before running, record ambient temperatures
3. Mount tires on the car, ensure that the car is at reasonable temperature and tune
4. Each 5 laps of the endurance test, switch drivers
5. Record driver feedback
6. Repeat for each material

Data Captured

Note that this test will take place in parallel with the durability testing. After each durability testing run, we will also collect driver feedback. The feedback will be in the form of a short survey with the questions shown below. Any additional feedback will also be noted.

- Did you find the car enjoyable to drive? Why or why not?
- Did you feel like you were able to control the car? Were you able to push the car?
- What is the biggest difference you noticed compared to the off the shelf tires?
- Would you choose to drive the car on these tires again? Are there any adjustments you could think of to improve the experience?
- Follow up questions to be asked as required.

Analysis

The final survey responses will be summarized and compared. Recurring themes and feedback will be compared with stakeholder needs from the initial consultation to assess the drivability of the tire. This is a qualitative test that is heavily dependent on personal preferences, and as such, the results provide a basis for discussion rather than a quantitative result.

Test Rationale

Acceleration (Grip) Test:

This test measures how well the 3D printed tires can transfer power to the ground by timing the RC car over a 25 m straight using frame-by-frame video analysis. We hope to learn how the traction and grip of our 3D printed tires compare to traditional off-the-shelf rubber ones. Our main hypothesis and hope is that at least one of the materials of 3D printed tires, most likely TPU, will achieve similar acceleration performance or only a small loss in grip due to material stiffness or surface finish. Success would mean the car completes the 25 m sprint within about ±10% of the time recorded by the control foam tires, showing comparable traction and controllable launches. Failure would mean that the 3D printed tires produce significantly slower times, slip excessively, or show poor consistency between runs, indicating poorer grip or unstable traction.

Rolling Resistance (Efficiency) Test:

This test evaluates how efficiently the tires roll by running the RC car at a constant throttle to a marked line, cutting power, and measuring how far it coasts. We hope to learn how much energy is lost to friction in the 3D printed tire material. We hypothesize that the stiffer printed compounds, such as ABS, will have rolling resistance close to or better than that of standard tires, leading to similar coast distances. Success would be shown by coasting distances within about ±10% of the control, indicating comparable efficiency and minimal energy loss. Failure would mean a much shorter coast distance, showing that the 3D printed tires waste too much energy, reducing run time and maybe performance.

Durability (Wear and Lifetime) Test:

To assess wear resistance, tires will be mounted to the car as normal and run around a track of known distance, ensuring constant run and real-life wear until failure. We hope to learn how long the 3D printed tires last under continuous stress and what types of failure occur. Our hypothesis is that printed tires made from resilient materials, such as the TPU, will withstand prolonged stress and show gradual wear rather than cracking or layer adhesion failures. Success would mean the tire would last at least 40% as long as the off-the-shelf tire while maintaining structural integrity and predictable wear patterns. Failure would be early cracking, delamination between print layers, or rapid material breakdown, proving the design or material choice unsuitable for this use case.

Drivability (Subjective Evaluation) Test:

Throughout testing, drivers will compare how the car feels to drive on the 3D printed tires versus standard ones, focusing on handling, responsiveness, and overall enjoyment. We hope to learn whether the printed tires preserve the “fun” and control that make RC driving engaging. Our hypothesis is that despite small differences in stiffness or traction, 3D printed tires will deliver a satisfying driving feel with stable steering and predictable behavior, proving them a worthy substitute. Success would be positive driver feedback and lap times close to the off-the-shelf tires, showing the tires are enjoyable and as well as on par with performance. Failure would occur if drivers reported harshness, vibration, unpredictable grip, or a loss of control that makes the car less enjoyable or unsafe to drive.

Exit Criteria

Our exit criteria will be determined by our 3 testing parameters: durability, grip, and rolling resistance. The quantifiable thresholds that we must reach are determined by comparing the performance of our 3D printed alternatives to that of commercially available options. Our problem statement implies that performance must be like that of commercial options. This means that our exit threshold is driven by our interpretation of similar performance. As a group, we felt that our tires must be as enjoyable to use as traditional options, and we believe the thresholds below reflect this.

Durability:

This criterion will be largely determined by the actual price of our tires. In accordance with our problem statement, we want our alternative to be cheaper than commercially available options while delivering similar performance. The price per roll for our selected materials is in the table below:

Table 3: Price of 3D Printing Filament

Filament	Price (CAD/kg)
TPU	25
PLA	19
PETG	19
ABS	25
Spool Mass (g)	1000

All of these filaments were sourced from the Canadian ELEGOO website [15]. Each roll selected comes with 1 kg of filament. Below, we take this information to determine how many sets of tires we can make per roll. The outer diameter and width measurements were taken in reference to commercial options in this category. We are comparing tire types for a 1/10 scale RC car variant, as this is the same platform we will use for testing. The touring, buggy, and short course truck (SCT) tire types are compared. The grams per tire were pulled from designs already available on services such as GrabCAD. Within each variant type, there is a light, medium, and heavy option, which refers to the infill of the print. This allows us to compare both a low and a high estimate for the price.

Table 4: Estimating Sets of 3D Printed Tires per Spool of Filament

1/10 Scale Tire Variants

Variant	Outer Ø (mm)	Width (mm)	Grams per Tire	g per set (x4)	Sets per Spool
Touring – Light	65	26	28	112	8.93
Touring – Medium	65	26	34	136	7.35
Touring – Heavy	65	26	40	160	6.25
Buggy Front – Light	86	34	45	180	5.56
Buggy Front – Medium	86	34	55	220	4.55
Buggy Front – Heavy	86	34	65	260	3.85
Buggy Rear – Light	90	42	65	260	3.85
Buggy Rear – Medium	90	42	80	320	3.13
Buggy Rear – Heavy	90	42	95	380	2.63
SCT – Light	106	42	90	360	2.78
SCT – Medium	106	42	105	420	2.38
SCT – Heavy	106	42	120	480	2.08

Taking the mass per set, we then calculated the cost per set for each tire variant and material type, with the commercial cost shown in the furthest right column.

Table 5: Estimating Cost per Set of Tires

Variant	Cost per TPU set (CAD)	Cost per PLA set (CAD)	Cost per PETG set (CAD)	Cost per ABS set (CAD)	Commercial Set (CAD)
Touring – Light	2.80	2.13	2.13	2.80	58.786
Touring – Medium	3.40	2.58	2.58	3.40	
Touring – Heavy	4.00	3.04	3.04	4.00	
Buggy Front – Light	4.50	3.42	3.42	4.50	61.6
Buggy Front – Medium	5.50	4.18	4.18	5.50	
Buggy Front – Heavy	6.50	4.94	4.94	6.50	
Buggy Rear – Light	6.50	4.94	4.94	6.50	
Buggy Rear – Medium	8.00	6.08	6.08	8.00	

Buggy Rear – Heavy	9.50	7.22	7.22	9.50	
SCT – Light	9.00	6.84	6.84	9.00	
SCT – Medium	10.50	7.98	7.98	10.50	84
SCT – Heavy	12.00	9.12	9.12	12.00	

As we can see, the most expensive set is the SCT variant with a heavy infill. This comes to an estimated cost of 12 CAD. The commercial options for this variant have an average cost of 84 CAD when looking at hobby stores [16]. This allows us to now set a durability criterion that will result in a lower cost when using our 3D printed tires.

$$Cost\ \% = \frac{12}{84} \cdot 100 = 14.29\%.$$

With this difference in cost, technically, if our tires have a durability that is greater than 14.3% of commercial alternatives, then they would still be cheaper per use. However, we must also account for price differences between tires and then designs. We also acknowledge that a tire with this little durability would also detract from the user experience, as so much time would be spent manufacturing and replacing tires. This is why we feel that a durability that is within 40% of a commercial alternative would represent our exit criteria. In terms of determining the durability, it will be a function of initial and final thicknesses after conducting the durability test. The process is below:

$$\Delta x_{thickness} = x_{initial} - x_{final}.$$

$$\%\Delta x = 100 \cdot \frac{\Delta x_{3DPrint} - \Delta x_{Commerical}}{\Delta x_{Commerical}}.$$

As mentioned above, if this number is within 40% then it is a pass in this criterion. In terms of exit criteria for grip and rolling resistance, it is far more subjective than the calculation-based durability threshold.

Grip:

As grip will be determined by a timed 25-meter acceleration test, our criteria would need to reflect the performance of our 3D printed tires relative to commercial options. We felt that setting the target at 10% less grip means that our tires would not make a tangible difference in the user's experience, while still leaving some margin of performance. The way this will be calculated is shown below:

$$\%\Delta t = 100 \cdot \frac{t_{3DPrint} - t_{Commerical}}{t_{Commerical}}.$$

In this case, the variable t is time in seconds. If %Δt is less than or equal to 10% then this would be considered a pass. A similar approach is taken for determining the exit criteria for Rolling Resistance.

Rolling Resistance:

We will be measuring rolling resistance as a relative value by comparing the distance to stop from a constant speed for different tires and compounds. Much like the reasoning above, we will be setting the pass threshold for this test at 10%. This was expanded upon in the Testing Plan. To determine whether we are within 10% of the performance of the commercial tire, we calculate the following:

$$\%\Delta D = 100 \cdot \frac{D_{3DPrint} - D_{Commerical}}{D_{Commerical}}.$$

If %ΔD is less than or equal to 10% then this would be considered a pass. D is the distance covered in the rolling resistance test according to the test plan.

Ultimately, we have set our exit criteria as a numerical value for the level of performance we want our tires to reach. This allows us to ensure that we propose a solution to our problem statement that is satisfactory for both us and the primary stakeholder, the user.

Results

General Experimental Conditions

All tests were performed on the same day, in the same location, under the same weather conditions. The temperature was recorded initially and monitored for changes throughout the testing period. Testing was conducted on the 8th floor of the North Parkade on UBC campus. The test area was cleared of debris before any testing was started, and additional debris was cleared away as necessary. The tests were run tire-by-tire, where one tire was installed, all tests were conducted for that tire, and then the next tire was installed. Fuel mass was considered negligible for testing purposes. All track set-ups were referenced using existing pavement markings, and distances were measured using a 100-foot tape measure. For specific details, see the table below.

Table 6: General Testing Parameters Similar Across all Tests

Location	UBC North Parkade, 8th floor
Road Surface	Flat, Very Rough surface with waterproof coating
Weather	10°C, Cloudy, no wind
RC car	Mugen Seiki MTX-3 Nitro-powered RC car

Figure 3: Mugen Seiki MTX-3 RC Car Used for Testing

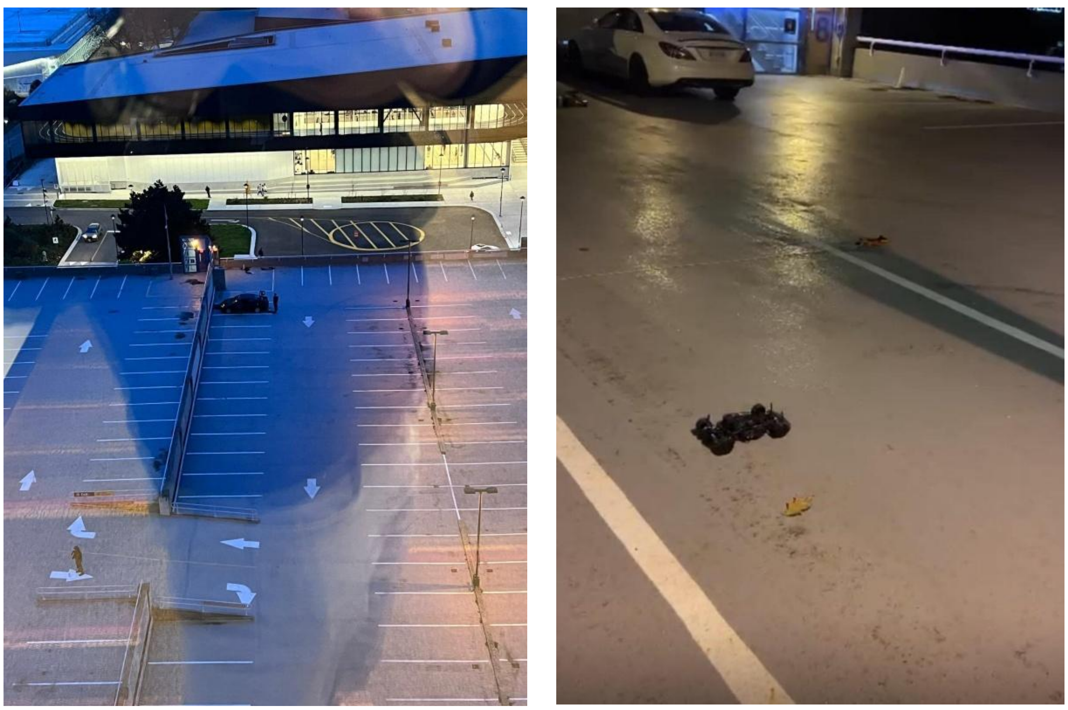


Figure 4: Left to right: Image of Test Location Taken from Building Above, RC Car on Track for Coast Down Testing, Measuring Tape Shown in Background.

Basic Material Properties of Test Filaments

Acceleration Test

Hypothesis

It was hypothesized that the control rubber tires would have the shortest acceleration time due to their high coefficient of friction, owing to their foam construction, and optimized tread compound designed for grip. The TPU tires were expected to perform closest to the control, as the softer, more compliant nature of TPU should increase traction and, as such, increase acceleration. The ABS, PETG, and PLA tires are all expected to produce slower acceleration times due to their higher stiffness, limited surface compliance, and reduced frictional contact with the concrete surface. We expect that the ABS, PETG, and PLA tires will all have similar performance.

Methodology

Testing was conducted on the top floor of the North Parkade, where a straight, flat concrete surface with a rough waterproof coating was expected to provide consistent traction.

The proposed 25 m test distance was changed to 23.93 m to align with existing parking stall lines, which served as visual start and finish markers for consistent timing. This was done so that we would not introduce measurement or setup error with our own lines. Timing was conducted using high-frame-rate video recordings, allowing the time to traverse the course to be measured frame-by-frame for accuracy. Each tire material, including the foam control set, was mounted on the car and had five recorded runs each, except where material failures prevented all runs from being completed. The updated procedure is provided below.

Experimental Procedure as Performed

1. Two painted parking lines were selected as start and finish lines to establish a 23.93 m course.
2. The camera was set up with the whole range of the course in view, with focus on the start and end lines.
3. The test vehicle was placed at the start line, and the throttle was pressed in a controlled way to try to optimize the launch.
4. The car was timed from the moment of launch (when the wheels began to turn) until the frame that the frontmost portion of the vehicle crossed the finish line.
5. Each tire material was tested in five trials.
6. Trials were terminated and marked as N/A in cases where tire failure occurred before the completion of five runs.

Results

Table 7: Acceleration Test Results by Material

Trial	TPU (s)	ABS (s)	PETG (s)	PLA (s)	Control (s)
1	4.28	5.33	6.18	5.66	3.86
2	4.00	5.95	5.65	5.88	3.71
3	3.98	6.03	6.11	N/A	3.52
4	4.23	7.01	5.56	N/A	3.33
5	4.19	5.70	N/A	N/A	3.18

**Cells marked “N/A” indicate critical tire failures that rendered further testing impossible.*

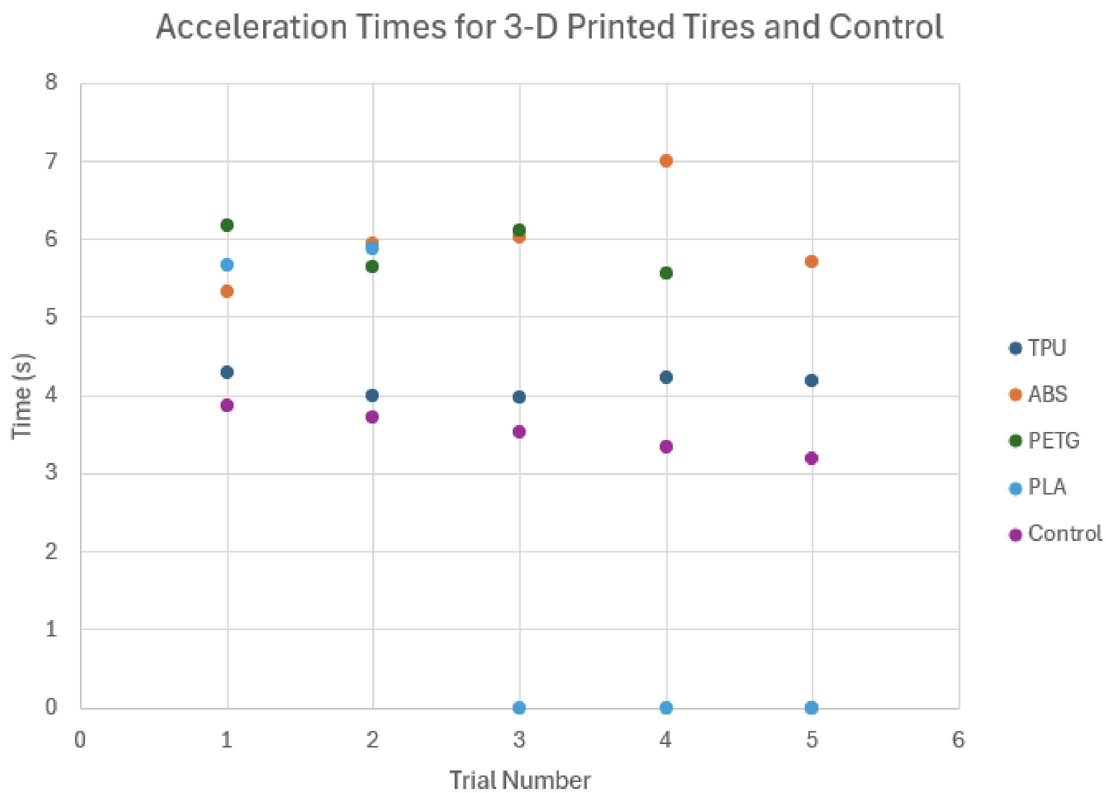


Figure 5: Acceleration Test Results by Compound

The average acceleration times were calculated as follows:

Table 8: Tire Material Analysis Results

Compound	Average Time (s)	Standard Deviation (s)	% Performance to Control
Control	3.52	0.26	-
TPU	4.14	0.12	117.6
ABS	5.80	0.64	164.8
PETG	5.88	0.26	167.0

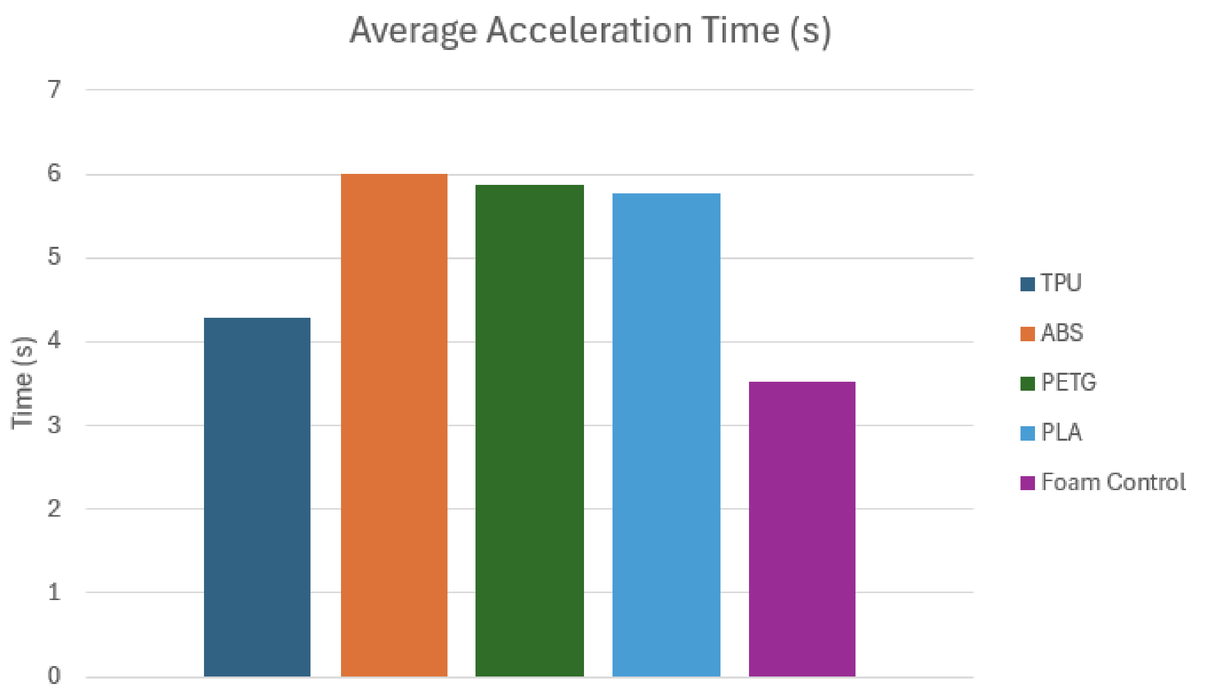


Figure 6: Average Acceleration Times by Filament (s)

These results are also visualized in the bar graph above, showing the relationship between compound type and average acceleration time (see figure in final report).

Analysis

The acceleration data were processed by averaging the recorded times across all successful trials for each compound. The standard deviation was calculated to quantify the consistency in tire performance. As expected, the control foam tires produced the fastest times, confirming that the more expensive off-the-shelf tires have superior traction. TPU followed closely behind, performing significantly better than the other printed materials. The stiffer filaments of ABS, PETG, and PLA showed poor acceleration performance, consistent with their low friction, higher hardness, and resultant tendency to slip under torque load.

The significant spread in the ABS data (standard deviation ≈ 0.64 s) suggested more inconsistent traction between runs, likely due to momentary loss of grip at the start of the test. This is most likely caused by the lower friction of the ABS tire, creating a more unpredictable launch as the tires could not maintain traction with the ground. The TPU's lower standard deviation (≈ 0.12 s) demonstrated more repeatable traction behavior, despite lower peak grip than off-the-shelf tires (≈ 0.26 s).

Discussion

The results generally support the initial hypotheses. The control tires, with optimized foam compounds, provided the highest traction and fastest acceleration. The TPU tires, due to their flexibility and inherent material properties, produced the next best results. TPU showed a favorable alternative to the control tires, maintaining drivability with an admittedly large drop in peak performance. TPU's best acceleration was 3.98 seconds, while the control tire was 3.18 seconds. Conversely, the ABS, PETG, and PLA tires all exhibited inadequate traction, shown by their acceleration times, frequent wheel spin, and outright failure of the tire's structure.

A notable change that was made between the proposed GA3 plan and the actual procedure was the shortened track length (23.93 m instead of 25 m). This modification was made for practical alignment with the physical markings on the test site (the lines in the parking garage), which improved measurement precision and removed some measurement and human error. Additionally, the PETG and PLA tires experienced complete failure during runs five and three, respectively. This prevented the completion of five full trials for these materials, making the results that were recorded less robust. This indicates that these materials are not fit for this application with the current tire design.

As was stated previously in our GA3 assignment, success for this test was defined to be performance within 10% of off-the-shelf tires. None of the compounds met this criterion, with the closest being TPU, which had, on average, 17% higher acceleration times and, as such, 17% worse acceleration than the control foam tires. This was by far the best out of the filaments tested, with the other being 164.8%, 167.0% and 163.9% of the off-the-shelf tire performance, respectively, as can be seen in Table 8.

Rolling Resistance

Hypothesis

For the efficiency test, it is expected that the ABS, PETG, and PLA all perform very similarly, since their stiffness and hardness properties are similar. As the assumption is to expect minimal deflection, it is reasonable to think that these tires will absorb the least energy and have the least rolling resistance, making them more efficient. The TPU is expected to perform the worst as it should have the most deflection and the highest rolling resistance due to relatively low stiffness and hardness.

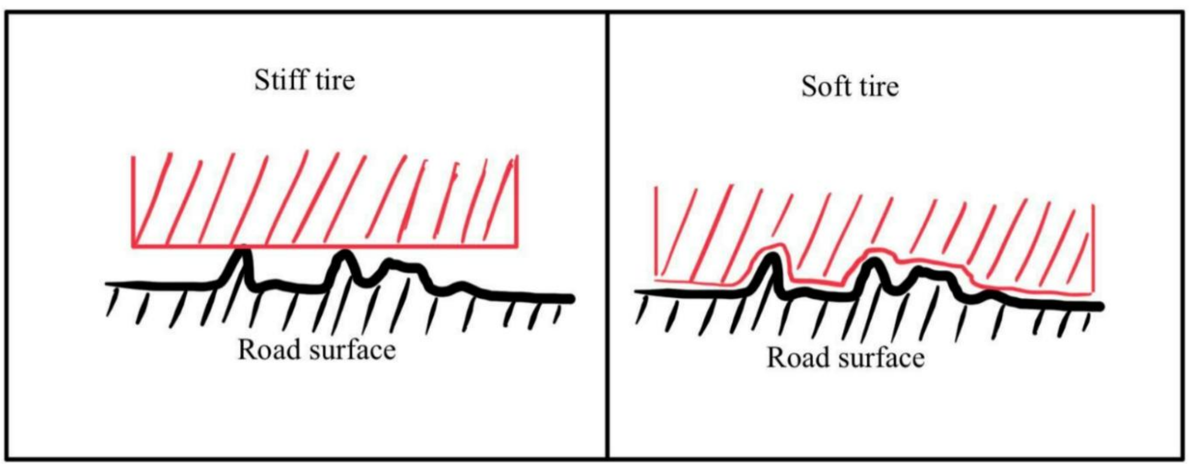


Figure 2: Visual Representation of How a Softer Tire Deforms Around Bumps in the Road Surface to Increase Grip

Above is an example of how the stiff tires vs soft tires function over a road surface. The soft tire provides more mechanical grip, which increases the friction of the tire. As friction increases, more energy is required to keep the car rolling, resulting in a higher rolling resistance.

Methodology

For this test, the same road area was used as for the acceleration test. The initial plan to make a 3D printed throttle stop was changed since we realized the same result could be achieved by simply taping a pencil in place.

Figure 7: Pencil Taped in Place, Used to Achieve a Constant Throttle Input

Experimental Procedure as Performed

1. A pencil was taped behind the throttle on the remote to have a defined limit for each run. The same pencil was used for each material.
2. The Lane was inspected to ensure a clear surface.
3. A pavement line was selected as the start line.
4. The car was started a reasonable distance from the starting line and accelerated before the line to reach desired speed for given throttle position.
5. When crossing the start line, the throttle was released and the car was allowed to coast to a stop.
6. Distance from the start line to the front end of the car at rest was measured.
7. Coast down distance, D_{stop} , was recorded.
8. Repeated the acceleration, coast down, and measurement steps 5 times for each tire material.

Results

Below is the table of results for each trial run of each compound. It is important to note that both the PETG and PLA were not tested due to critical failures while conducting another test. Therefore, there is only rolling efficiency data for the TPU, ABS, and control tires.

Table 9: Stopping Distance by Tire Material

Trial	TPU (m)	ABS (m)	PETG (m)	PLA (m)	Control (m)
1	22.49	19.58	N/A	N/A	24.05
2	20.95	15.92	N/A	N/A	28.15
3	17.75	12.07	N/A	N/A	23.72
4	22.09	19.09	N/A	N/A	21.44
5	22.63	17.27	N/A	N/A	24.07

Below is a visual representation of the average stopping distance for each tire. This was done by taking the mean value of all trials for a given compound.

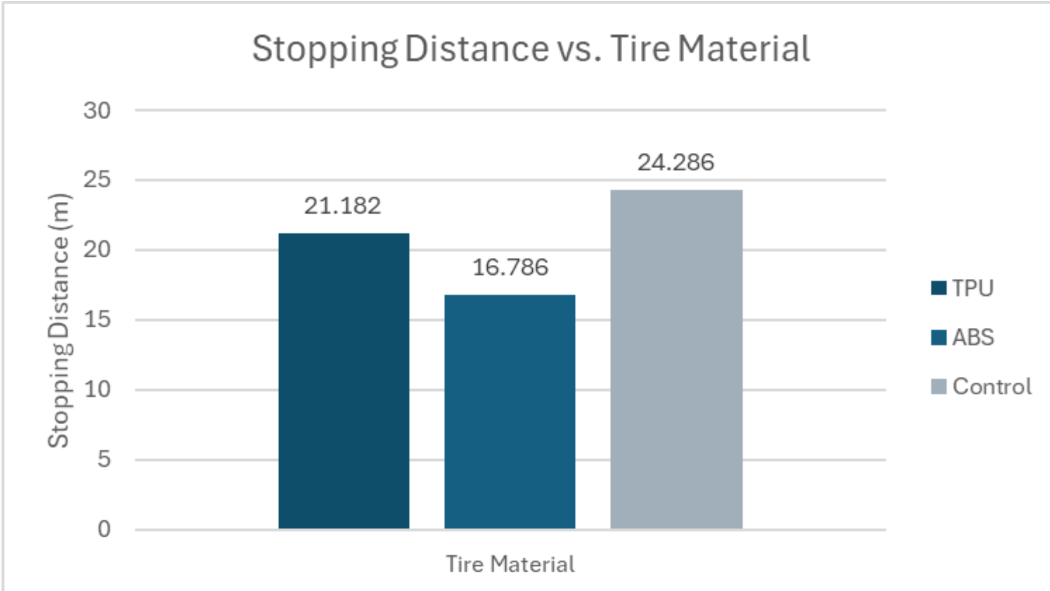


Figure 8: Mean Stopping Distance per Material Type

To further explore the relationship between compliance and rolling resistance, the Young's modulus, a material property that defines stiffness, and the stopping distance were compared below.

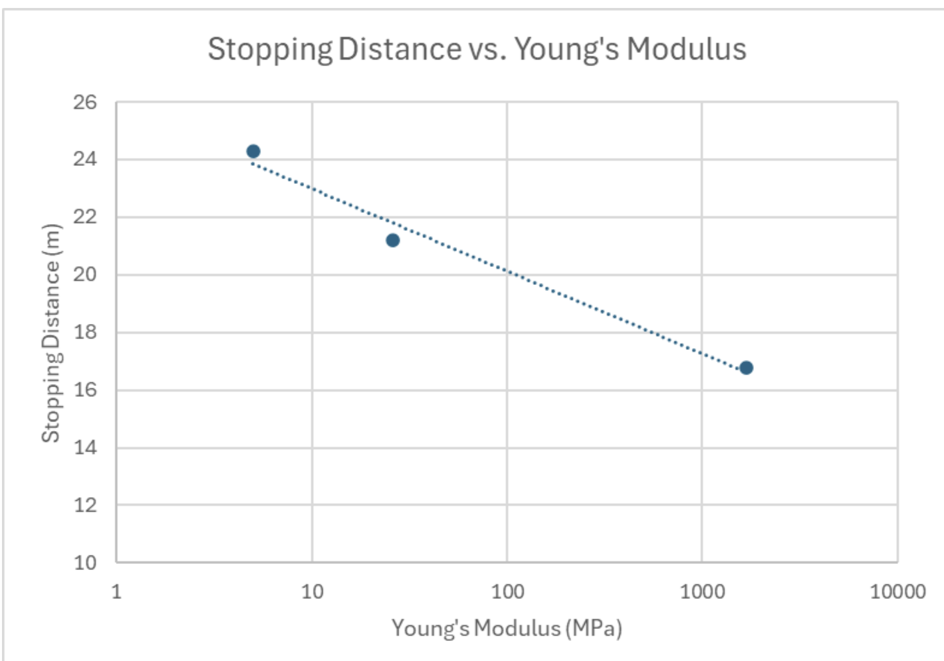


Figure 9: Stopping Distance versus LOG(Elastic Modulus)

Below is the chart with the raw data for the properties shown in Figure 9. The ABS and TPU Young's modulus numbers were found from the technical data sheet. The control young modulus was an estimate derived from a paper exploring the grip of rubber compounds on ice from Virginia Tech.

Table 10: Figure 9 Data

Compound	Young's Modulus (MPa)	Log (Young's Modulus)	Stopping Distance (m)
Control	5	0.699	24.286
TPU	26	1.415	21.182
ABS	1685	3.227	16.786

Table 11: Standard Deviation and Percentage Difference Between Test Runs by Material

Compound	Standard Deviation	Percentage Difference
TPU	1.815	8.567
ABS	2.696	16.060
Control	2.166	8.918

Analysis

The data collected is quite interesting and generally disproves the hypothesis that was made. The reasons for this will be expanded upon in the discussion portion of the write-up. This is exceedingly obvious from the bar graph. From there, it was noted that the trend we would have expected to see was inverse to what was experienced. This led to plotting the Young's modulus and stopping distance to further explore why this was. Above, in Table 11, are the calculations for the standard deviation of the 5 trials for each compound, as well as the percentage difference of the standard deviation vs the average value. This illustrates how inconsistent our results were for each run.

Discussion

Firstly, it should be stated that the original hypothesis predicted that the softer tires would perform more poorly than the harder compounds in a rolling efficiency test. From the results, it is exceedingly obvious that this was not the case. However, it is believed that this had little relation to the rolling resistance of the tires but rather was a function of the initial grip of the car. By observation, it appeared that the tires with more grip achieved higher initial speeds with the same throttle position. When looking at Figure 9, comparing stopping distance vs. Young's modulus, it can be seen that the softer the tire, the further the stopping distance. This is congruent with the observations made during testing. It was found that with the higher-grip, softer tires, higher speeds were reached more quickly when compared to the ABS alternative. This means that although a constant throttle position was maintained, consistent speeds were not achieved between tests, which ultimately led to this flipping of results. It was not a matter of rolling efficiency but instead a result of a longer stopping distance due to an increased momentum force as a consequence of the increased speed. This claim is further supported by the variation in results within each compound. In the standard deviation and error figure in the results, on average, each trial was not exceedingly representative of the tire's performance. When looking at a compound like ABS, a standard deviation of about 2.7 meters was observed, which is around 16% of the overall stopping distance. As no other factors were changed between runs, this points to inconsistency in controlling the speed.

Ultimately, the results did not align with the initial hypothesis. However, it is still believed that the hypothesis was correct and that the results were a function of a faulty test rather than the rolling efficiency of each tire. Unfortunately, with variability in speed, the test was not successful, as it was not able to accurately and consistently measure the stopping distance for each compound at the same speed. In the future, this test would need to be based on speed and not just throttle position to ensure that only the rolling efficiency of the tire influences the comparative results in stopping distance.

Durability Test

Hypothesis

For the durability test, it is expected that PLA would have the best durability of the four 3D printing filaments tested, since it has the highest yield strength. From the materials being tested in this experiment, ABS would be the most likely to experience layer adhesion failure due to low Z toughness. PLA and PETG are expected to show plastic wear, while TPU will likely demonstrate elastic wear.

Methodology

The goal of the durability test is to compare the lifecycle and wear behaviour of the four filaments. As shown in the image below, the track is composed of a simple rectangle due to limited time and resources. Laps were run in both directions to ensure more even wear.

Figure 10: Sketch of Track Set Up on North Parkade

The total length of the track was measured to be 84 m on the inside line with a tape measure. In reality, the car travelled roughly 100 m each lap for an estimated total distance of 1 km. Before the test was conducted, large debris was removed to ensure a clean track surface.

Compared to the proposed test procedure, we were forced to make several changes due to available time and resources. We did not have a power source for the scale we had at the test location, and we did not have the time to find an alternative. Thus we were unable to collect weight data for the tires. Second, we reduced the number of laps run to 10 to save fuel and time. Third, we did not do a driver switch, since we did not have two people available who could drive the RC car.

Experimental Procedure as Performed

1. Measure the tire diameter at the center of the tread on each of the four tires using calipers
2. Drive the car five laps of the track clockwise
3. Turn the car around

4. Drive the car five laps of the track counterclockwise
5. Measure the tire diameter at the center of the tread for each of the four tires using calipers

Results

Table 12: Diameter Measurements for Durability Tests

	TPU		ABS		PETG		PLA		Control	
	Initial (mm)	Final (mm)	Initial (mm)	Final (mm)	Initial (mm)	Final (mm)	Initial (mm)	Final (mm)	Initial (mm)	Final (mm)
FR	59.20	59.00	60.80	59.40	N/A	N/A	N/A	N/A	59.20	58.95
FL	59.00	59.00	60.85	59.55	N/A	N/A	N/A	N/A	58.75	58.60
RR	60.65	60.10	61.70	61.20	N/A	N/A	N/A	N/A	62.30	61.45
RL	60.40	59.45	61.50	60.80	N/A	N/A	N/A	N/A	62.15	61.35

**FR: Front Right, FL: Front Left, RR: Rear Right, RL: Rear Left*

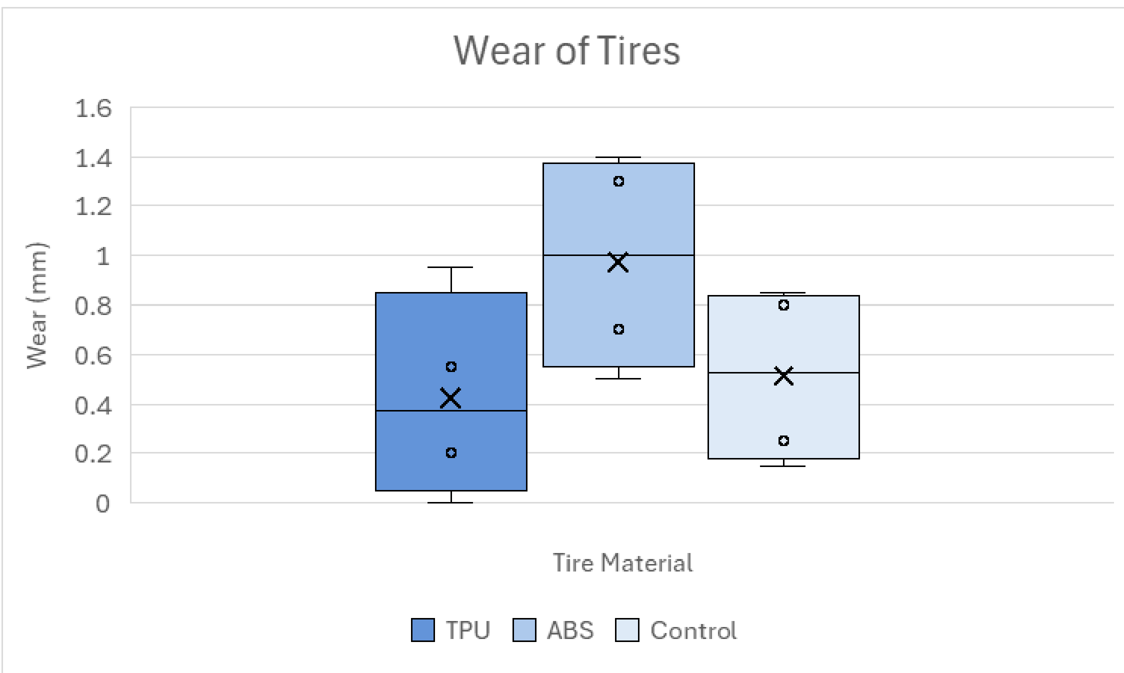


Figure 11: Box Plot of Tire Wear for a Given Material

The box plot shows the mean, median, standard deviation, maximum wear, minimum wear, and the interquartile range, which is the middle 50% of the data set. The wear is defined as the initial diameter of the tire minus the final diameter.

Analysis

From the plot, it can be seen that the TPU tires had both the lowest mean wear and the lowest wear of a single tire. With TPU, there was no critical failure of the tire, either with layer delamination or plastic failure; wear was observed as small material loss on the tread, consistent with elastic deformation, where the tread was tearing rather than experiencing layer separation.

Figure 12: TPU Tread Wear

ABS had the highest mean wear of the tires tested, which is consistent with the hypothesis, as ABS is more brittle and has worse layer adhesion than TPU. With ABS, the tread surface was quite rough after testing. The tread material did not tear, but instead chipped and fractured. This is likely due to ABS being a hard and brittle material.

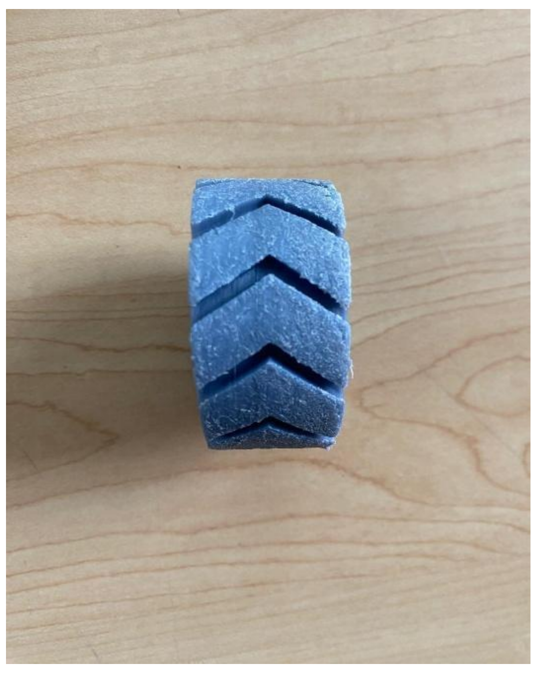


Figure 13: ABS Tread Wear

It is clear from the table that both PETG and PLA performed the worst. They both suffered from critical failures where the tire broke; therefore, the tests could not be continued. Much like ABS, PLA exhibited material wear through chipping and fractures. The PETG tire exhibited wear more similar to TPU, with the material shedding and having a more elastic response.

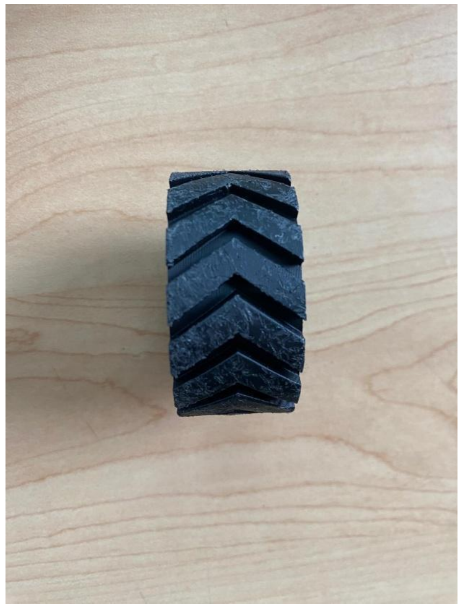


Figure 14: PLA Tread Wear

Figure 15: Left to right: PETG Tread Ware, Remains of Failed PETG Tire on Hub

The control tire had a slightly higher mean wear than the TPU tires; however, the control tires wore more evenly, as can be seen by the smaller range of wear in the plot. The control tires did not show evidence of tread wear. The tires are made of foam, which, unless large pieces have been worn off, will not show macroscopic changes in tread.

Figure 16: Off-the-Shelf Tread Wear

Discussion

The test showed that TPU had the lowest mean wear with a change in diameter of 0.425 mm over 1 km. This test result is not consistent with the hypothesis that PLA would have the lowest wear.

ABS was expected to show larger plastic wear and possible layer-adhesion-related issues. The data showed that ABS lost nearly twice the tread thickness on average (0.975 mm) compared with TPU (0.425 mm) over the same distance. Surprisingly, ABS did not suffer from layer adhesion issues as was hypothesized.

The off-the-shelf control tire had a mean wear of 0.513 mm. Thus, TPU performed slightly better than the commercial tire for this short test, while ABS performed worse. This result suggests that TPU is a promising candidate for printed RC tires when the focus is on wear resistance over short distances. The off-the-shelf tire did not illustrate noticeable tread wear. This is likely due to it being a foam tire, so the surface does not show scratches.

The initial hypothesis expected PLA and PETG to behave more like ABS; however, both the PLA and PETG tires failed critically in earlier tests, resulting in a lack of testing data. There were also significant differences in the amount of wear between tire positions. The tire wear relative to tire position can be quantified by the standard deviation of the data. The standard deviation represents the spread of the data relative to the mean. The standard deviations for TPU, ABS, and the control were 0.417 mm, 0.443 mm, and 0.364 mm, respectively. This suggests that tire position on the car affects how much the tire wears.

When considering exit criteria, the goal was to have the durability of the 3D printed tires to be within 50% of the wear seen by the off-the-shelf tire. This means that the 3D printed tires would be considered a valid alternative if the mean wear is between 0.2562 mm – 0.7687 mm, which represented 50% and 150% of the off-the-shelf tire mean wear, respectively. From the results, the mean wear for TPU falls within this range, whereas ABS falls outside of this range. Thus, TPU meets the exit criteria.

In the original testing procedure, the plan was to drive in increments of 5 laps up to 25 laps, measuring after each 5-lap increment. Due to time and fuel constraints, the run was reduced to 10 laps total. Consequently, wear data for the longer distance was not obtained, and thus this test data is limited to only be applicable to short distances. A change in mass over the test duration was also not obtained, as there was a lack of access to a battery-operated scale, nor was this test repeated multiple times.

Drivability

Hypothesis

It was hypothesized that the control foam tires would have the best drivability characteristics due to their high coefficient of friction and optimized tread compound designed for grip. The TPU tires were expected to perform closest to the control, as the softer, more compliant nature of TPU should increase traction and, as such, increase acceleration. The ABS, PETG, and PLA tires are all expected to have suboptimal driving performance due to their higher stiffness, limited surface compliance, and reduced frictional contact with the concrete surface. We expect that the ABS, PETG, and PLA tires will all have similar performance.

Methodology

A dedicated, stand-alone drivability test was not executed. Instead, drivability was assessed qualitatively in parallel with the three quantitative tests that were carried out:

1. Acceleration sprints
2. Durability/endurance laps
3. Coast-down (rolling resistance).

Observations about handling, controllability, and breakaway behaviour were collected throughout the tests and from short, exploratory maneuvers that were performed between runs. Endurance was the most heavily considered, since it is most similar to a recreational driving scenario. The summary results are provided below.

Results

TPU

With TPU tires, controllable driving was achieved. Sufficient grip was available for routine maneuvering, although the vehicle had relatively low grip and did not respond well to sudden throttle or steering inputs; for example, spinouts could be induced at low speed with abrupt throttle inputs. Drifts were reported as predictable and repeatable. Relative to the foam control, lower absolute grip and reduced steering precision were noted; however, the breakaway characteristics were more predictable than those of the foam tires, enabling consistent, controllable slides. Continued development via sidewall/lattice tuning and alternative tread patterns was identified as a path to additional grip.

Summary: Enjoyable to drive and controllable; less ultimate grip than foam, but more predictable breakaway behaviour than foam.

ABS

With ABS tires, controllability was poor. Frequent, unwanted slides were observed, and steering inputs often produced little response from the car. Maintaining a straight line for coast-down was difficult, and the car could not be driven quickly without immediate loss of traction. Overall grip and precision were inadequate.

Summary: Not enjoyable; very low usable grip; frequent spinouts.

PETG

PETG tires exhibited drivability similar to ABS and PLA. Unpredictable behavior with low grip was observed, requiring cautious throttle application even for driving in a straight line. Spinouts were common due to low traction. An early failure was observed on one tire during the acceleration test, reinforcing the unsuitability of the material for RC car tires.

Summary: Not enjoyable to drive; Failure was observed early on in testing.

PLA

When PLA tires were fitted, the vehicle could only be guided at very gentle inputs. Traction was consistently low, and the onset of slip was abrupt, producing oversteer rather than a controllable slide. Even with the throttle feathered, straight-line stability was difficult to maintain, and clean laps were rarely completed. Early signs of edge chipping and surface glazing were observed before a rapid loss of drivability. Overall behaviour tracked closely with PETG and ABS.

Summary: Very limited usable grip; fastest deterioration among the three rigid plastics.

Off-the-shelf Foam (Control)

The foam tires provided the performance benchmark. Substantially higher grip, sharper turn-in, and precise, predictable responses were recorded at moderate to high inputs. Breakaway was less predictable when compared to TPU, producing a sharper transition from grip to slide.

Summary: Highest grip and precision; more abrupt breakaway behaviour than TPU.

Analysis/Discussion

The working hypothesis proposed that the foam control would deliver the best drivability because of high friction and an optimized tread compound; that TPU would perform next-closest owing to its compliance; and that ABS, PETG, and PLA would behave similarly and remain sub-optimal due to stiffness and limited surface compliance. The observations were consistent with this ordering: overall grip and precision followed foam > TPU >> ABS ≈ PETG ≈ PLA. While foam provided the highest peak grip and the sharpest turn-in, TPU exhibited a more progressive and predictable breakaway than foam, which enabled consistent, controllable slides even though peak grip was lower. In contrast, ABS, PETG, and PLA presented very low usable traction with abrupt loss of grip and poor steering authority; early functional issues were noted for PLA and PETG, whereas ABS generally remained intact but was undriveable.

Driver perception aligned with these behaviours. Driver enjoyment was reported to be highest with foam for outright performance and was positive with TPU for controllable drifting and predictable breakaway behaviour; negative assessments were recorded for ABS, PETG, and PLA. It is also interesting to note that the acceleration test performed showed the strongest correlation with the car being enjoyable to drive. From an operational standpoint, TPU completed sessions without catastrophic failure, supporting its suitability as the printed tire material in this configuration, while the rigid plastics did not. Collectively, the results confirm the hypothesis and further indicate that TPU's limit characteristics can be considered an advantage worth preserving as future design refinements (tread pattern and sidewall/lattice tuning) are pursued to narrow the remaining grip gap to foam.

Discussion

Reflection on Methodology

Below you will find the reflection and sentiment towards the methodology for each test. They are split up individually to speak to the faults and successes of each test, as well as the adjustments made.

Acceleration (Grip) Test:

We feel that this was our most successful and consistent test for a variety of reasons. Firstly, we were starting from a standstill and driving in a straight line. This eliminated a lot of the issues introduced with driver skill and the grip of the car. We found that the Control and then TPU performed the best, which is what we expected to see. We made an adjustment to the test during testing, where we reduced the length of the distance accelerated from 25 meters to 23.93 meters. This was done to allow us to use the parking stall lines as a start and finish point. This ultimately helped us in having very defined start and end points when looking at the videos to determine the time it took to complete the acceleration run. We think that overall, there would not need to be any changes made to this test. However, a change in a broader sense would be to have wheel replacements. We saw that the PETG and PLA wheels failed critically during their trials, and therefore, we could not take a 5-trial average nor continue testing them. This is something that did cross our mind, but we felt it would not be an issue, as printing multiples of each tire set would have also been far more time-intensive. Seeing as the week before testing was very busy for all of us, we don’t think this would have been a possibility. Again, we don’t think any changes would have to be made to the test in any way, simply the preparation for testing.

Durability Test

For the durability test, we drove in a circuit both clockwise and counterclockwise. The inside line of the track was 84 m; however, the travelled distance per lap was likely closer to 100m. Although we tried our best to keep a consistent line, we could not ensure that each tire was covering the same total distance at the end of the test. Furthermore, tire wear is dependent on the forces acting on it. This means that at higher cornering speed and angle of slip within a lap then the tire tread would be decreased at a greater rate. This means that for fair testing, the lap time would have to be consistent with the line and distance travelled being consistent as well. Ultimately, this means that the driver's inputs have a significant effect on the results of the test. We also changed the test to complete 5 laps in each direction, compared to the planned 25 laps. This was due to time constraints imposed by the amount of fuel. We felt that at 25 laps, we could not complete a consistent run on one tank of gas and therefore decided to shorten the travel distance. In terms of how we measured the tread depth and results, we felt it was done in a way that was accurate, and the variability in results was a result of driver inputs and minor differences in runs. We felt that this test went according to plan and were satisfied with the results we got. However, we do feel that it could be improved to achieve a greater level of consistency and results. It is worth noting that again, we were not able to test PETG and PLA, as these tires had failed critically on the acceleration test.

Rolling Resistance Test

Our methodology for the rolling resistance proved to be the most flawed of the tests conducted. The difference in grip between each tire was so drastic that although we had consistent throttle position, it did not equate to consistent speed. In the future, this test would have to be changed to account for initial speed to find more consistent results. During testing, we tried our best to fix this problem by changing the run-up distance for the lower grip compounds. This would give them a better chance to reach the same speed as the higher grip compounds. From looking at the results, this was not successful as we had hoped, as the results do not indicate any improvement from this. Unfortunately, we were also not able to test the PETG and PLA performance in this test. This was due to a prior critical failure in the acceleration and grip test.

As a group, we felt that the greatest shortcomings were due to the rolling resistance test and our preparation of tires. We were only able to complete a few runs of acceleration for the PLA and PETG options before they failed critically. This could be because of the internal geometries, but it could also speak to their unsuitability to this application. Ultimately, some improvements could have been made, but we felt that our testing methodology gave us a good picture of the performance of our tires compared to that of the control, which was an off-the-shelf tire.

Test Representation

Considering the fact that the efficiency test was deemed ineffective due to factors previously discussed, our hypotheses were mostly accurate regarding the general performance for each material. As we had anticipated, TPU had performed best out of the printed tires regarding both acceleration and driver feel. Furthermore, ABS, PETG, and PLA ended up having small differences in results when the tires were actually intact. However, we did not expect any of the tires to break in such a dramatic fashion, like how PLA and PETG did. What caught our eyes was the actual difference in performance between our control foam tires compared to TPU. Although we did expect the foam tires to perform better, the magnitude by which it did over its other 3D printed counterparts was significant.

Test Setup Reflection

If we could start from the beginning of our testing procedure and project process, we would hope for more time and resources. This would allow us to explore a more niche set of materials, such as cast nylon or moulded soft plastics that we would expect to perform better than the stiffer 3D printed plastics we tested. From the beginning, we expected that the harder, stiffer filaments of PLA, ABS, and PETG were likely going to be hard to drive due to their inherent material properties. With more money and time, we could truly explore the range of materials out there that meet a similar ease of production level without the lack of performance and drivability seen in most of the 3D printed tires we tested.

Given that a few of our tests did not prove what they initially intended, we would alter the tests to ensure that the results characterize what we want. We would also improve the standard of the tests conducted. Have a more uniform and controlled test track and environment to reduce variability in test results. Then, building off of that, we would introduce more tests to further characterize the tires.

Technical & Process Recommendations

Next Steps and Key Points for Iteration

The next logical step would be to focus on refining both the tire design, material selection, and the weakest parts of the test methodology. On the testing side, the rolling-resistance procedure failed to produce reliable data, since the difference in initial speed dominated any effect of true rolling resistance. A follow-up iteration should therefore introduce a way to control or measure speed directly and trigger the coast-down from a consistent velocity rather than a fixed throttle position. It would also be worth standardizing our durability test further. Creating a more repeatable driving circuit, longer total distance, and multiple runs would all aim to reduce driver-input variability and better measure material performance metrics.

With regard to the prototype itself, the data and qualitative feedback both point to TPU as the only printed material that is viable for our application. Our next iteration would branch into different TPU filaments and geometries rather than putting in any effort across the brittle filaments that consistently failed. That could include testing different TPU filaments with varying material properties and exploring new tread geometries. By changing the infill, sidewall stiffness, and tread patterns, we would aim to close the gap in performance to the foam control tires. An additional benefit would be if we manage to preserve the predictable and progressive breakaway that made TPU fun to drive. Finally, we would ideally investigate the internal structure that caused the catastrophic failures in PLA and PETG, even if only as a robustness check, and print spare sets so that early failures don't prevent the completion of our full test plan.

Future Testing Strategy

Given the constraints of limited time, limited fuel, one RC car, and one set of each tire, the next steps would focus on improving consistency and addressing the major shortcomings identified during our testing. The most important next test would be a revised rolling resistance test. Our original procedure failed to produce meaningful results due to inconsistent speeds and grip differences between materials. As noted in GA4, constant throttle did not translate to constant speed, especially since softer tires reached higher speeds much quicker. This not only made the coast down distance data invalid but also showed a relationship inverse to what would be expected. A follow-up test would therefore aim to standardize initial speed. This could be done using a simple visual speed marker or via filming and analyzing with software. We would also have to increase the run-up area to give the lower grip tires a chance to accelerate to the desired speed. This would allow us to isolate rolling resistance from acceleration.

With Limited Resources

A second priority would be to repeat the durability test over a longer cumulative distance. Our original 25-lap plan was shortened to a 10-lap procedure, which limited the amount of wear and observations we could make. Limited time and fuel resources made running longer distances unfeasible in this scenario, but a longer test is possible if more fuel is available. Increasing the laps would also give more representative wear behaviour without requiring new equipment. This is especially important because TPU appeared to outperform even the control tire in short-distance wear, and further distance would help determine whether this trend persists.

Finally, considering the unexpected early failures of PLA and PETG, the team would next test reprinted identical sets of PLA and PETG tires to confirm whether the failures were random print-quality defects or inherent material limitations. Time constraints prevented printing backups, which in turn prevented complete datasets for these materials. Printing a second set would allow us to determine whether the failures were reproducible, which is necessary before making any final conclusions about their suitability. With more time, it would have also been possible to test multiple geometries amongst materials to ensure we are maximizing the potential performance. When looking at the positive results of TPU, further testing should include varying factors such as infill, geometry, and tread pattern. This would allow us to determine a better benchmark of how this material performs compared to the control for our use case.

With Full Resources

With access to more time, funding, and university/industry equipment, the project would be run like a small product program rather than a one-day experiment. First, several 3D printers would be set up, including a few that can print two materials at once. This would allow many tires to be printed in parallel so that multiple design ideas (different tread patterns, sidewall thicknesses, and infill densities) could be tested at the same time. Since prints would finish faster, and spares would be available, each idea could be tested, tweaked, and retested over many cycles.

Next, testing would move from “best effort” field runs to controlled stations. A small rolling road test machine would be used to hold the car at a steady speed and measure how hard the tires are working (rolling resistance) without any driver variability. A simple indoor skid pad or marked circle would be used to measure cornering grip the same way every time. A wear drum or long indoor loop would be used to run tires for many kilometers so that tread life could be compared fairly. If available, a wind tunnel would be used to check how much air drag the car creates, so the tire tests can focus on tire effects only.

Basic materials checks would also be added, but kept practical. Shore A hardness using a durometer reading would be taken to see how soft or firm each material is; softer grades usually give more grip and comfort, while harder grades steer more precisely and last longer. A simple abrasion check (rubbing each filament sample on the same sandpaper under the same load, or using a small drill fixture) would show which compound wears more slowly. Bend/tear checks on thin printed strips would be used to see if cracks start at layer lines, since that is where printed tires often fail. A quick layer-adhesion pull would confirm that layers have fused well enough for cornering loads. Also, warm-up checks (repeating hardness and bend tests at ~40–50 °C) and brief water/UV exposures would show how the material changes when hot or used outdoors. Before each track session, printed tires would be quickly quality-checked (weight, dimensions, quick visual check for gaps) so that bad prints do not confuse results.

Finally, a simple design-test-learn loop would be followed for several months. Each week, a small set of changes (for example: deeper tread, firmer sidewall, or a two-material tire with soft tread and stiffer sidewalls) would be printed on the multiple printers, tested on the same course and dyno, and then either kept or dropped based on clear goals: get closer to foam grip, keep wear at least as good as foam, and don’t increase rolling losses. Short driver surveys and lap times would still be collected, but the main comparison would come from the repeatable stations above.

By the end of this “proper resources” phase, the team would hope to have: (1) a few refined TPU designs that clearly out-perform the first prototypes, (2) a repeatable test kit (steady-speed test, cornering test, long wear run) that anyone on the team can use, and (3) enough printed parts and data to show steady improvement across several design iterations, made possible by having multiple printers running in parallel.

Revisions to Exit Criteria

After conducting the characterization tests, our thinking about the original exit criteria has shifted. Initially, the idea of the exit criteria was to be implemented as strict thresholds; either the tire passes, or it does not. Those thresholds are durability within 50%, grip, and rolling resistance within 10% with respect to the off-the-shelf foam tire. While the exit criteria thresholds are still important, the testing showcased that our prototypes need iterations. There is a lot more that goes into the tire than just the material. Committing to rigid thresholds too early limits our ability to refine and develop more promising prototypes. In other words, our exit criteria should not only define "ready to advance" performance, but also reflect whether a design is close enough that, through fine-tuning of a few iterations, it could reasonably achieve commercial-like performance.

To be within our conceptual exit criteria, we would need to have the prototype demonstrate viability across all three performance metrics. The prototype would not necessarily have to fully meet the exit criteria to demonstrate viability, but by being within a range where iteration is likely to close the gap. Almost as if the exit criteria have their own exit criteria. For example, if a material fails in the durability test but subsequent evaluation reveals that the prototype failed because of something unrelated to the material, this indicates a clear path for iteration. Similarly, observing how different materials and geometric structures influence the grip or rolling resistance of the prototype helps us identify which aspects of the tire can be adjusted. In this way, the main requirement for meeting the exit criteria becomes related to our confidence that with two or three focused design modifications, the prototype could bring performance to within the target range.

Overall, our exit criteria would become more flexible and more closely aligned with the early stages of a realistic engineering workflow. Instead of implementing a hard go-no-go limit, the exit criteria now act as indicators of whether we understand the issues of a given design and have an attainable route to achieving comparable performance to the off-the-shelf foam tires. This mindset better reflects the ideas behind prototyping, where learning from testing and intentionally designing for rapid iteration is as important as the performance of the prototype itself.

Planning the Engineering Validation Test Phase

Material Selection for Next-Phase Prototyping

In our experiment, we tested common 3D printer filaments that almost anyone with a 3D printer could buy and make relatively easily. From the test results, TPU is the only option proven to be viable as an RC car tire material. The other tested options, PLA, ABS, and PETG, were difficult to control and not enjoyable to drive. With the resources that we have, follow-up prototypes would most likely also be produced from TPU. It would also be beneficial to investigate softer TPU filaments since testing showed that the softer tire materials performed better. The TPU filament that we used for testing was TPU 95A filament, which is the most common. There are also less common 90A and 95A filaments, which are softer, and thus we would expect improved tire performance. Though these materials would likely offer better performance, improvement could probably be found through a better tire design. One possible example of this could include strategically placed cutouts that let the tire surface bend more to maintain contact with the road. Ultimately, with the resources we currently have, the next stage prototypes would still be produced with 3D printed TPU.

With access to more advanced resources, there are two main steps that could provide better performance while still being 3D printable. The first possible path is exploring multi-material 3D printing. With most RC car wheels, the center (wheel) section of the tire is typically a more rigid plastic, and the tread, which contacts the road surface, is a soft foam material, as seen in Figure 17. This is desirable since it reduces the deflection in the side of the tire, while still having a soft tire material in contact with the road. There are 3D printers available that would also be capable of printing tires composed of multiple materials; however, it is a relatively new technology. These printers are still expensive, but the cost will most likely decrease over time, making them more accessible to the general population. The second area to explore would be the development of a filament specifically for RC car tires. This would most likely include experimenting with different formulations of TPU with additives to make the material softer and increase the friction between the material and a road surface. For each formula, testing would also be needed to ensure that the material is still easy to print on most 3D printers. Additionally, the cost of the material must stay relatively low, such that the 3D printed tires are still more cost-effective than the off-the-shelf alternative. Overall, these two changes to the prototype materials could significantly improve the performance.

Figure 17: Off-the-Shelf Foam Tire

Manufacturing Approach with Limited Resources

Our goal was to create a tire that could be 3D printed at home by hobbyists and the end user. It is essential that the engineer-validate-test (EVT) build must do this, too. In keeping with the spirit of the project, the EVT build would continue to rely on accessible at-home 3D printing methods, ensuring that the design remains practical for hobbyists seeking an affordable alternative to conventional RC tires. Under limited resources, we would still use FDM printing, but with upgraded settings and materials. As in part A, a softer TPU, such as 90A or 85A, would be a good option to look at to better reflect production intent performance. Printing the tire in a single TPU material allows us to validate deformation behavior, tread engagement, and structural response without departing from the benefits of a DIY approach. We could also further refine slicer parameters such as infill density, perimeter count, and print temperature to achieve consistent mechanical properties and reduce print defects that could skew performance testing and add cost to the per tire production.

Manufacturing Approach with Proper Resources

With full resources, however, the EVT phase could leverage more advanced fabrication methods while still aligning with the original accessibility goals. This could include dual-extrusion FDM printing, enabling a hybrid structure. A good first route for this could be a stiffer PLA or ABS wheel, paired with a softer TPU 60A tread layer. This approach would allow us to explore better grip, improved structural integrity, and higher durability without compromising manufacturability on consumer-grade printers. We could also consider higher resolution processes like SLS or MJF printing, which provide better layer adhesion and isotropic strength. These processes use powders and build parts in layers with heat, and make a much more uniform part. The intention would be to use these methods primarily for validation, not as a required production route, as these are not commonly available to the average hobbyist consumer.

Overall, the manufacturing plan must balance performance improvements with the overarching goal of keeping the tires easy, affordable, and realistic for hobbyists to produce themselves.

Final Project Assessment

Project Stakeholder Reflection

We think that if we were to present our findings to stakeholders, they would be very intrigued by the possibility of further development of TPU as a viable DIY alternative to high cost foam RC car tires. Looking at this mostly from the perspective of our primary stakeholder, RC car owners, the test results for ABS, PLA, and PETG would likely not surprise them much, as hard plastic tires were not expected to perform very well. The results for TPU would likely surprise them because it performed much closer to or better than the foam control tire than we had initially expected, despite not meeting the grip performance exit criteria. Further tests being done on softer TPUs such as 90A and 85A should excite RC car owners. The idea of a good tire for recreational driving at a fraction of the cost is an intriguing proposition and, to some extent, meets their initial needs. Similarly, development of this could be furthered by our secondary stakeholders, with the involvement of filament manufacturers attempting to create softer TPUs or similar plastics. Hobby shops getting involved in testing and self-development of different treads and geometries would also speed up progress and create competition in the market, furthering the drive of innovation.

The results of our test have addressed the concerns of stakeholders, although not solved them completely. We believe that 3D printed RC car tires are a promising option, and hope that more stakeholders, specifically RC car owners and hobbyists, would become involved helping speed up iteration and innovation. This would be valuable on both the material and newly realized geometric fronts of development for our project. We believe this is something that many owners and hobbyists would be excited to participate in and would be a real possibility if our tire and idea were to try to be commercialized. Following our recommendations from GA5 to begin with and then branching out and beginning new developments and innovations is the path we hope would be taken. We believe this to be the most natural and inevitable path if our project were followed through to market.

Overall Project Reflection

Overall, we are satisfied with our project and the results we achieved. Through the experiments we conducted, we proved that the overall concept has promise. The concept of a 3D printed RC car tire was intriguing primarily due to the significant potential cost savings. Combined with the fact that there is an increasing number of people with 3D printers at home, it was an idea worth investigating further. When we analyzed potential materials, TPU was the most intriguing option since it was much softer and more compliant, making it a good candidate for tire materials. The process of printing the prototypes went smoothly and confirmed our expected cost of about 3 dollars per wheel. This was a positive early result, and it proved that people with 3D printers would be able to produce these tires relatively easily at home. The more extensive driving testing we conducted also showed positive results. The hard plastic tires were difficult to drive, but the TPU tires proved to be enjoyable. Ultimately, the test results showed that the overall concept was sound, and the TPU tires proved to be a promising option throughout testing.

Our testing process also proved to be reasonably effective and provided us with sufficient data to make a well-justified decision. The low cost of our part meant that it was practical for us to simply print and test the product in the final use case. This simplified our testing process because we were able to directly measure the final performance metrics. Our acceleration test was our best-designed and implemented test. We were able to follow our procedure, and the results were robust and repeatable. It also showed extremely clear performance differences, which provided a strong basis for decision-making. The durability test was similarly beneficial, though it was less repeatable than the acceleration test. It was not always possible to follow the exact same path around the track that we set out, so the exact distance driven was slightly different for each tire. There was also a significant spread in the measured wear for the tires in different locations on the car, which indicates uneven wear. However, the results from this test still showed significant differences between materials, and observation of the different tires before and after the test also provided insights into the wear characteristics of each tire. In addition to the quantitative data, we were also able to collect driver feedback during the tests, which provided a very clear context for which tires were fun to drive. Most of the results that we observed correlated well with our theoretical understanding of the scenario. There were really no results that we were unable to rationalize with the underlying theory. Ultimately, we are very pleased with how we developed our testing processes and conceptual understanding.

If we were to approach this project again, there are a few changes we would look to make. First, all filaments other than TPU would be completely eliminated from consideration. From the beginning, we were skeptical of how they would perform, and testing confirmed that they were extremely poor for the application. It would have been more beneficial to compare TPU filaments with different hardnesses; they are a more viable material for this application. Second, the rolling resistance test that we developed failed to provide meaningful data since it was not possible to get the RC to reach the same initial speed on the different tires. There is not really an easy solution to this with the resources available, especially since we do not have an effective way to measure the initial speed of the car. Future testing would need to reassess the value of this test and determine a new procedure if there was still desirable data to collect. Third, we also ran into driver skill limitations, where our group members are not good enough drivers to test the RC car to the limit. For this reason, the data we collected is really only relevant to the recreational use case. Overall, we feel that these flaws did not significantly impact our conclusions, and we are very satisfied with our execution of the project as a whole.

Overall Project Satisfaction

We were overall satisfied with how the project went, even with the challenges and unexpected issues that came up during testing. The biggest surprise for us was how well the TPU tires performed compared to the off-the-shelf foam tires. We expected TPU to be the best of the printed materials, but we did not expect it to come as close as it did in both durability and drivability. Additionally, the rapid failures of PLA and PETG were more dramatic than we anticipated. We also found it interesting how different the tires felt to drive, especially how predictable and controllable the TPU was, even though it had less overall grip. These moments showed us that our assumptions at the start only told part of the story and that real testing often reveals behaviour that can easily be overlooked.

The most difficult part of the project was achieving consistent testing conditions. The rolling resistance test in particular showed us how sensitive the results were to small changes in speed and grip, and it became clear that our setup did not fully isolate the variable we were trying to measure. Time limitations, fuel consumption, printing delays, and the fact that some tires failed before we could finish the full test plan made the process even harder. Despite that, we would still choose this project again. We felt very engaged, and it taught us a lot about materials, testing, and the importance of design iterations. Even though not everything went perfectly, the project felt meaningful and left us with a sense of progress and curiosity about future iterations. Finally, we all enjoyed working together very much and discovered that we are able to find a great balance between having fun and actually getting our work done to a high standard. This wasn't something we took for granted.

References

[1] https://www.amazon.ca/Shaluoman-Road-Tires-2080-3mm-Racing/dp/B0BXNMVSS1?th=1

[2] https://www.techbriefs.com/component/content/article/36035-how-to-design-airless-car-tires

[3] https://interestingengineering.com/transportation/puncture-proof-tires-revealed-by-gm-and-michelin

[4] https://tires.bridgestone.com/en-us/learn/tire-technology/airless-concept-tires#

[5] https://www.motorauthority.com/news/1135976_goodyear-developing-airless-tires

[6] J. O'Connell, "Glass Transition Temperatures of PLA, PETG & ABS," *All3DP*, 20 Apr. 2024. [Online]. Available: https://all3dp.com/2/pla-petg-glass-transition-temperature-3d-printing/

[7] "3D Printer Filament | Bambu Lab," *Bambu Lab Store*. [Online]. Available: https://ca.store.bambulab.com/collections/bambu-lab-3d-printer-filament

[8] B. O'Neill, "TPU Glass Transition Temperature, Printing Temperature, and Other Thermal Considerations," *Wevolver*, 10 Dec. 2024. [Online]. Available: https://www.wevolver.com/article/tpu-glass-transition-temperature-printing-temperature-and-other-thermal-considerations#tpu-glass-transition-temperature-(tg)

[9] A. G. Veith, "Tire treadwear: The joint influence of Tg, tread composition and environmental factors—A proposed 'two-mechanism' theory of treadwear," *Polym. Test.*, vol. 7, no. 2, pp. 177-207, Dec. 1987. [Online]. Available: https://www.sciencedirect.com/science/article/pii/0142941887900316

[10] J. Toutain, *Grip on road surfaces*, Clermont-Ferrand, France: Société de Technologie Michelin, 2001. Available: https://docenti.ing.unipi.it/guiggiani-m/Michelin_Tire_Grip.pdf

[11] https://ultimaker.com/learn/petg-vs-pla-vs-abs-3d-printing-strength-comparison/

[12] "Standard Test Method for Single Wheel Driving Traction in a Straight Line on Snow- and Ice-Covered Surfaces," *Astm.org*, 2025. Available: https://compass.astm.org/content-access?contentCode=ASTM%7CF1805-20%7Cen-US

[13] "J2452_201707: Stepwise Coastdown Methodology for Measuring Tire Rolling Resistance - Recommended Practice," *Sae.org*, 2017. Available: https://saemobilus.sae.org/standards/j2452_201707-stepwise-coastdown-methodology-measuring-tire-rolling-resistance

[14] "Standard Test Method for Determining Change in Groove (or Void) Depth With Distance Traveled for Passenger Car Tires," *Astm.org*, 2025. Available:

https://compass.astm.org/content-access?contentCode=ASTM%7CF0762_F0762M-08R20E01%7Cen-US

[15] “Collections,” *ELEGOO CA*. [Online]. Available: https://ca.elegoo.com/collections

[16] “Wheels, Tires & Inserts - 1/10 Scale - Short Course Truck - Tires - Small Addictions RC,” *Smalladdictionsrc.com*. [Online]. Available: https://www.smalladdictionsrc.com/wheels-tires-inserts/1-10-scale/short-course-truck/tires/

Appendix

Group Deliverables Planning Sheet

GA7 - Group Deliverable Planning Sheet

Group 10 - Airless Tires
Joshua Holmes, Matt Teaff, Aadesh Chahal, William Bonnell, Cole Inverarity, Gil Golan

1. Task Breakdown & Schedule

Task	Assigned to… (team member name)	Interim Check-in date (11:59 PM)	Due date	Notes/comments
PAQ 1	Cole	Dec 3	Dec 5	Reflecting on stakeholder consultation and what results mean for them
PAQ 2	Josh	Dec 3	Dec 5	Overall project assessment - support with evidence from testing
PAQ 3	Gil	Dec 3	Dec 5	Overall satisfaction with project - speaking for group
Formatting and combining documents: Title, ToC, ES, GA2,	Matt	Dec 3	Dec 5	Formatting, additional content as necessary, generally editing for cohesion
Formatting and combining documents: GA4, References	Will	Dec 3	Dec 5	Formatting, additional content as necessary, generally editing for cohesion
Formatting and combining documents: GA3, GA5	Aadesh	Dec 3	Dec 5	Formatting, additional content as necessary, generally editing for cohesion
Notetaking	Josh	N/A	N/A	Maintaining meeting agendas, keeping

				track of key dates and information
Compiling and submitting document	Will	Dec 5	Dec 7	

2. Meeting Schedule

Meeting Date	Meeting Duration	Meeting Type (in-person, virtual, hybrid)	Members Present (indicate lateness in [minutes])	Notes/Comments
Nov 26	2 hours	In person, Rec North	Gil, Matt, Cole, Will, Aadesh Josh excused	Group ball (team bonding)
Dec 3	30 min	In person, EDC Atrium	Gil, Matt, Cole, Will, Aadesh, Josh	Check in on progress for GA7, address any concerns
Dec 5	1 hour	Hybrid, EDC Atrium	Josh, Matt, Cole, Will, Aadesh, Gil	Go over parts for GA7, make sure all work is complete and up to standard

3. Consensus Actions & Penalties

Infraction	Penalty
Didn't meet internal deadline	1. Warning 2. 5% Reduction
Did not to show up to meeting without prior notice	1. Warning 2. 3% Reduction
Inadequate work product or attitude	1. Warning and slide of shame

4. Penalties (if applicable)

List here who incurred a penalty and what the consequence was.

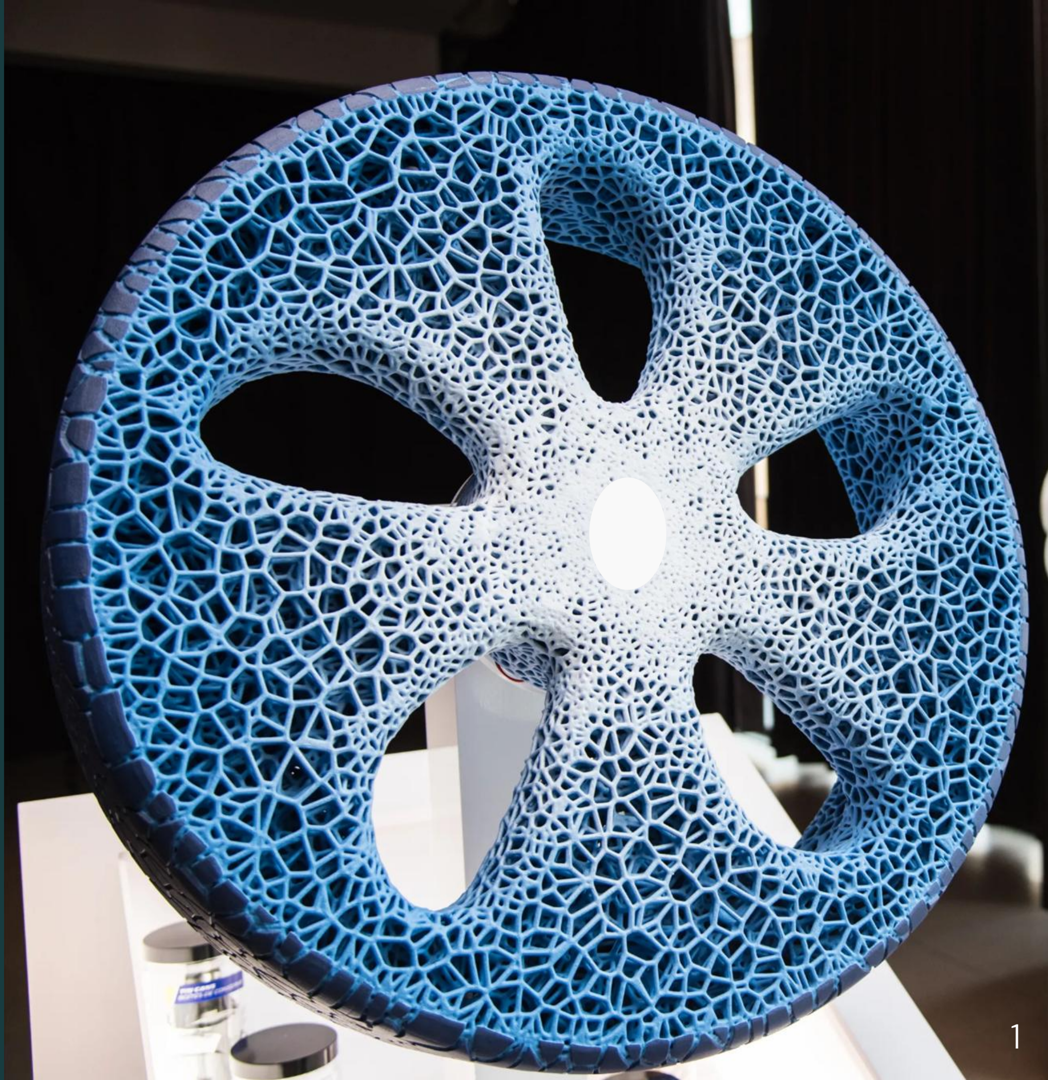
- No Penalties incurred

GA6 Final Presentation Slides

Void Grip

By:

Josh Holmes
Matthew Teaff
Aadesh Chahal
Gil Golan
William Bonnell
Cole Inverarity

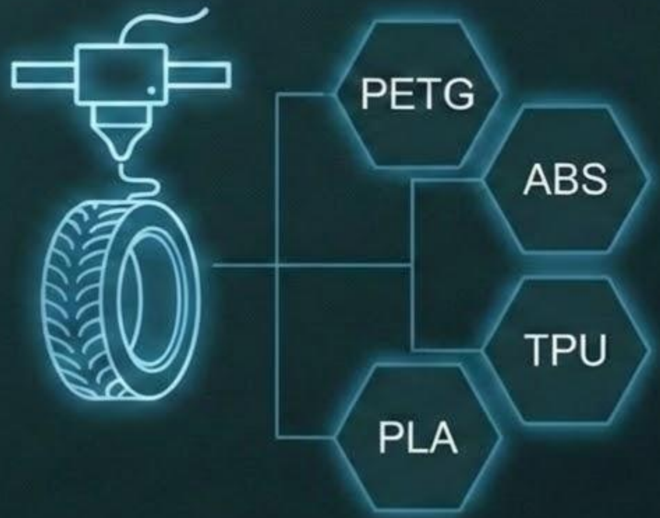


Overview

Idea

Produce an RC car tire cheaper than commercial alternatives delivering similar performance.

Proposed Solution



Technical Tests & Results

Acceleration

Durability

Rolling Resistance

Results compared with off the shelf foam tires.

Stakeholders

- RC Car Owners
- Hobby Shops
- 3D-Printing Companies
- Filament Suppliers
- RC Car Manufacturers

Testing Plan

Acceleration - Grip

- Marked 25m on a flat even surface
- Operator accelerated as fast as possible
- Used a slow motion camera to time moment of start to moment of finish
- Ran 5 trials and took average

Durability - Treadlife

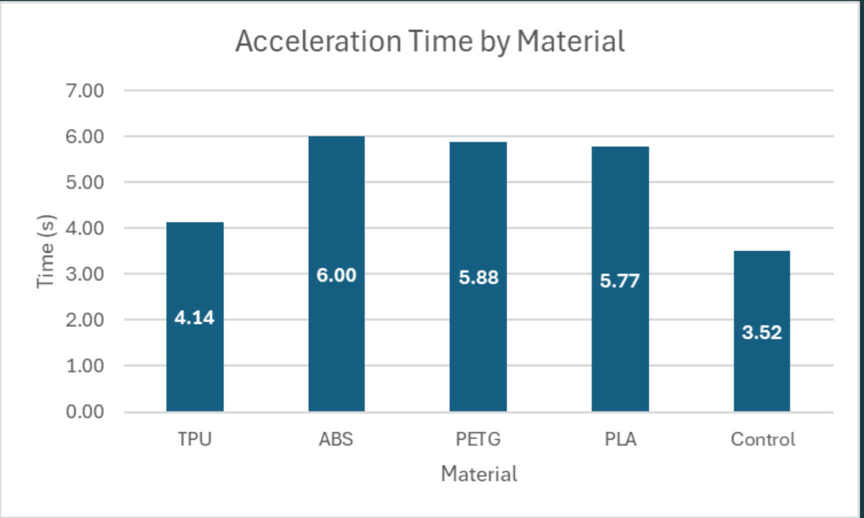
- Drove 10 laps around predetermined track, 5 in each direction
- Measured difference in diameter after run
- 100m track on flat even surface

Rolling Resistance - Efficiency

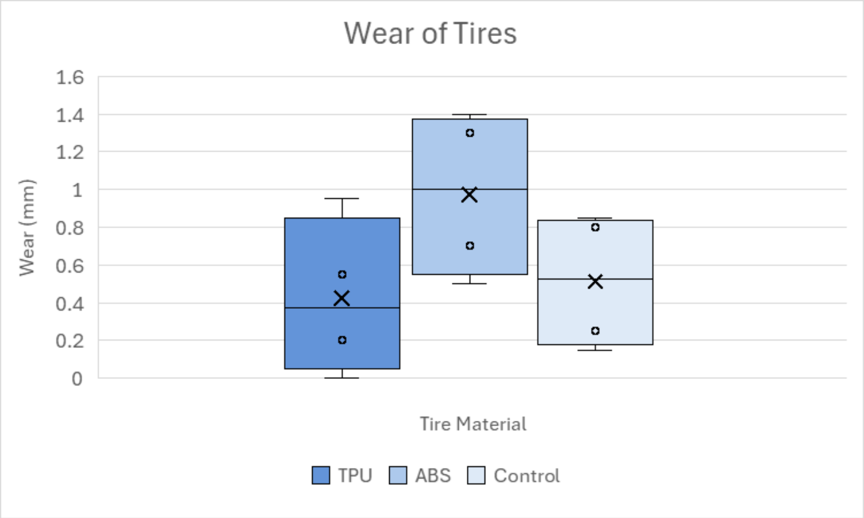
- Drove car at a constant throttle position
- Let off accelerator at marked point and coast to stop
- Measured distance of stopping point from marked point
- Ran 5 trials and take the average

Test Results

Acceleration Test:



Durability Test:



Rolling Resistance Test:

Rolling resistance was a largely unsuccessful test as the constant speed requirement was impossible to hit given the testing space we had and due to low tire grip of hard compounds.

Test Results Discussion

Exit criteria was determined for each test based on cost and performance targets

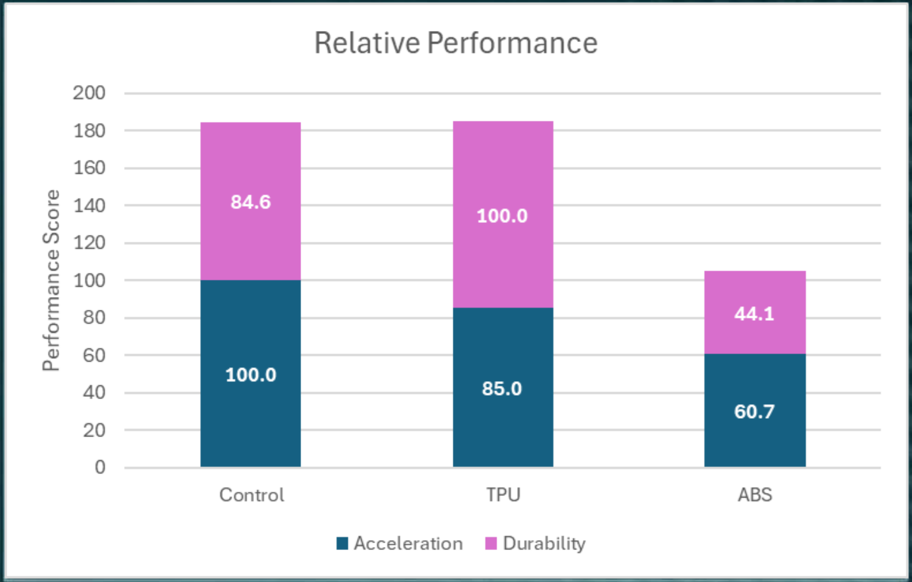
Durability:
- Within 50% of control tires
- Results: TPU = −17.2%

Grip:
- Within 10%
- Results: None met criteria

Rolling Resistance:
- Within 10%
- Omitted due to issues with test methodology

Drivability:
- PLA, PETG, and ABS were undriveable

Relative Performance Comparison Across Tests



Next Steps

Recommendations:

- Eliminate all rigid plastics: ABS, PLA and PETG
- TPU is a viable option for recreational and drifting applications

Steps for future development:

- Further investigated softer TPU filaments
  - TPU 85/90A ; Previously 95A
- Viable for recreational driving and drifting where less traction is welcome

Thank you

For your attention

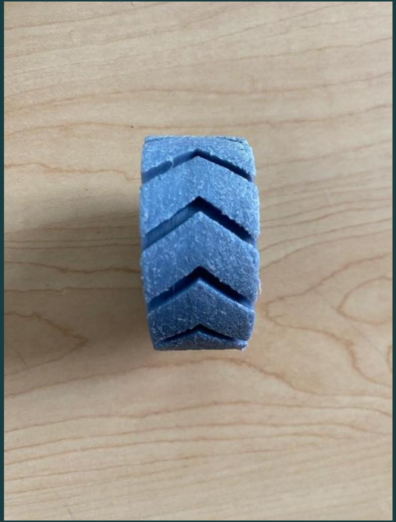
Appendix

Material Properties Data:

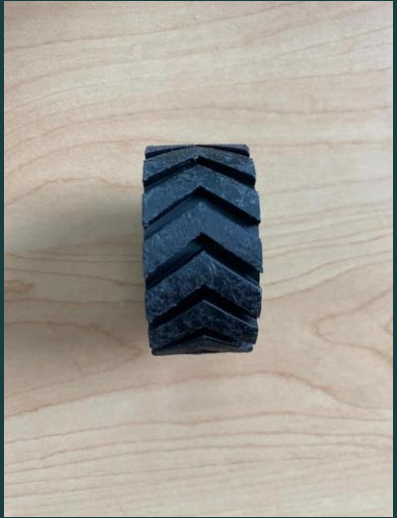
Property	TPU	ABS	PLA	PETG
Young’s Modulus (GPa)	0.067	2.1	3.29	1.94
Yield Strength (MPa)	37.9	40	59.0	50.3

Appendix

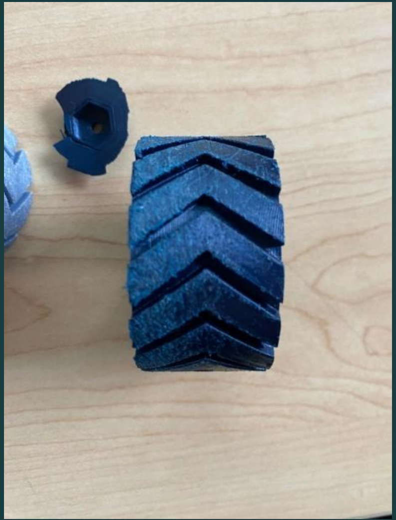
TPU



ABS



PLA



PETG