Design & Impact Analysis of Automobile Chassis/Frame

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Abstract - The impact performance of a vehicle chassis is critical for safety and durability, influenced significantly by the materials used. Two common materials are AISI 4130 and AISI 1018, each with distinct properties affecting their impact resistance. AISI 4130, a chromium-molybdenum steel, is known for its high strength and toughness, providing excellent resistance to deformation and cracking. This makes it ideal for high-performance vehicles where impact resistance is crucial. However, its increased weight can be a drawback in some applications. Conversely, AISI 1018 is a low-carbon steel offering a balance of strength, ductility, and formability. It is lighter and more easily formed into complex shapes, making it a cost-effective choice for many applications. Despite its lower strength compared to AISI 4130, it is suitable for scenarios where weight and cost are more critical.

Choosing between AISI 4130 and AISI 1018 depends on specific application needs. For high impact resistance and performance, AISI 4130 is preferred. For weight-sensitive and cost-efficient applications, AISI 1018 is more suitable. The decision requires careful consideration of material properties, application requirements, and design constraints.

Key Words: AISI 4130, AISI 1018, Chromium Molybdenum Steel, Low Carbon Steel, Impact Resistance.

1.INTRODUCTION

Go-kart racing has evolved significantly over the years, with advancements in technology and materials continually pushing the boundaries of performance and safety. However, despite these advancements, the choice of materials for go-kart chassis construction remains a critical factor impacting the vehicle's overall speed, maneuverability, and safety. The existing go-kart chassis materials, predominantly AISI 4130 and AISI 1018, have shown limitations, particularly in terms of weight, which can adversely affect the kart's speed and handling characteristics. Therefore, there is a pressing need to explore alternative lightweight materials to optimize the chassis' performance and durability.

Historically, go-kart racing has witnessed a steady progression in chassis design and material selection. Traditional materials like AISI 4130 and AISI 1018 have been commonly used due to their availability and relatively favorable mechanical properties. However, as racing conditions become more demanding and safety standards more stringent, there is a growing demand for lightweight materials that can offer superior performance without compromising safety.

Existing evidence suggests that researchers have conducted impact analyses on go-kart chassis at velocities ranging from 55 to 60 km/hr., considering the vehicle's mass to be around 150-160 kg. While these studies have provided valuable insights into the chassis' behavior under impact, there are significant gaps in the research. One such gap is the lack of evaluation of the Factor of Safety (F.O.S.) of the chassis in collision scenarios with solid objects like walls or other vehicles. Additionally, there is a dearth of conclusive comparisons between the two commonly used materials, AISI 1018 and AISI 4130, regarding their performance and safety characteristics.

In light of these gaps, this research aims to address several objectives. Firstly, it seeks to identify the most suitable material for go-kart chassis construction through comprehensive material selection criteria. Secondly, it aims to design and construct a chassis that optimizes performance while ensuring structural integrity and occupant safety. Lastly, the research intends to analyze stress concentration areas and determine the Factor of Safety (F.O.S.) of the chassis in various directions, including frontal, rear, and side impacts.

The scope of this research encompasses safety evaluation, structural integrity assessment, performance optimization, and regulatory compliance. Specifically, it will focus on analyzing the chassis' behavior in frontal, side, rear impacts, and rollover scenarios to ensure the highest level of safety and performance in go-kart racing.

2.OVERVIEW OF GO-KART CHASSIS

Go-karts are simple, four-wheeled racing cars with small engines and a single seat, primarily popular in the United States. They were created in the 1950s by airmen looking for a pastime, with Art Ingles credited as the pioneer of karting after building the first go-kart in Southern California in 1956. Go-karts have since gained popularity across America and Europe. By definition, go-karts lack suspension and differentials and are typically raced on scaled-down tracks. They are also enjoyed recreationally by hobbyists.

Karting is often seen as a gateway to more advanced and costly levels of motor sports. It is recognized as the most affordable form of motor sport, accessible to nearly anyone. Licensed racing is available for individuals as young as eight years old. While commonly associated with young drivers, adults actively participate in karting as well.

Kart racing is viewed as an economical and relatively safe introduction to motor racing. It helps drivers develop quick reflexes, precise car control, and sound decision-making skills, essential for high-speed, competitive racing. Additionally, it teaches drivers about the various adjustable parameters in their vehicles, knowledge that is transferable to other motor racing forms. Karting is often the first step for serious racers embarking on their careers.

Go-Karts in India:

Go-karts made their debut in India in 2003, introduced by MRF. These karts feature a 125cc four-stroke engine generating 15 bhp of power and are priced around 3 lakhs. Indus Motors also provides go-karts, with prices ranging from 1 lakh to 3 lakhs. Nagpur, often referred to as the home of go-karting in India, boasts dedicated racing tracks. The sport has gained popularity, attracting many enthusiasts to participate in racing events.

Go-karts in Foreign Countries:

Go-karts in foreign countries perform much better than Indians do. One type is a single engine 160cc 4-stroke kart with a maximum speed of approximately 40 mph, and the second type is a twin-engine 320cc 4-stroke kart used outdoors with a maximum speed of 70 mph. There are hundreds of racing traces in the US for karting, and they are much more professional than Indians.

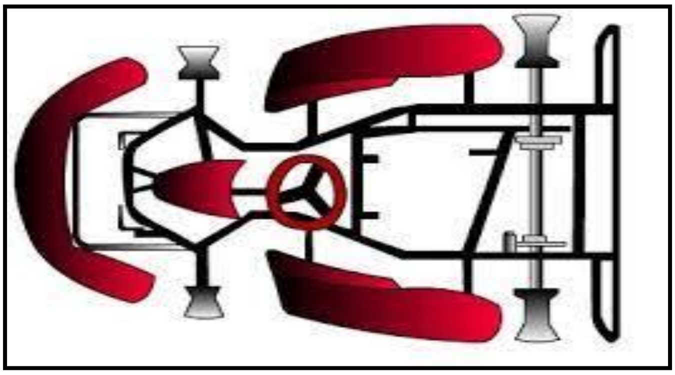

Fig 1: Go-Kart Chassis

3.LITERATURE REVIEW

The impact analysis of go-kart chassis is a critical area of research as it directly influences the safety and performance of these vehicles. Researchers have extensively investigated the impact behavior of various chassis materials, with a particular focus on AISI 4130 and AISI 1018, two steels commonly used in go-kart construction. Studies have consistently demonstrated the superior impact resistance of AISI 4130 compared to that of AISI 1018. The higher strength and toughness of AISI 4130 enable it to absorb more energy during impact, thereby reducing the risk of deformation or failure. This is particularly important for go-karts, as they often experience collisions and high-speed cornering, subjecting the chassis to significant stress.

Several studies have employed finite element analysis (FEA) to simulate impact scenarios and evaluate stress distribution and deformation patterns within the chassis. These simulations showed that the AISI 4130 chassis exhibited lower stress concentrations and smaller deformations under impact loads than the AISI 1018 chassis. This indicates that the AISI 4130 can better withstand impact forces and protect the driver during a collision. Experimental investigations also corroborated the superior impact performance of AISI 4130. Researchers have conducted physical impact tests on state-of-the-art chassis made from both materials and observed that the AISI 4130 chassis consistently sustained less damage and maintained structural integrity under similar impact conditions. These findings further validated the suitability of AISI 4130 for go-kart chassis applications, where impact resistance is a primary concern. While AISI 4130 offers superior impact resistance, AISI 1018 has advantages in terms of weight and cost. The lower density of AISI 1018 contributes to lighter chassis, which can improve the overall performance of the go-kart. In addition, AISI 1018 is more cost-effective than AISI 4130, making it an attractive option for budget-conscious manufacturers.

4.MATERIAL CHARACTERISTICS

The choice of material for an automobile frame is influenced by factors such as weight, stiffness, strength, longevity, and ease of manufacture. Historically, steel has been the primary material due to its strength, stiffness, and cost-effectiveness. Recently, the use of advanced high-strength steel (AHS) and high-manganese steel (HMS) has become more common. Additionally, there's been a trend towards lightweight materials like carbon fiber composites, aluminum, and E glass epoxy to reduce frame weight and enhance overall performance and efficiency while maintaining structural integrity.

Aluminum is favored for its excellent strength-to-weight ratio and corrosion resistance, making it popular in high-end and competitive sports car production. Magnesium, although less common, offers an even better strength-to-weight ratio than aluminum and is lighter, making it ideal for applications requiring maximum weight reduction. Carbon fiber, known for its superior stiffness and strength-to-weight ratio, is widely used in sports cars and for constructing entire frames. Carbon fiber frames are also safer due to their ability to absorb significant impact energy. However, carbon fiber is expensive, and machining it can weaken specific areas, reducing its strength.

AISI 1018 Carbon Steel:

AISI 1018 mild/low-carbon steel is renowned for its excellent weldability and ability to produce a uniform and hard case, making it ideal for carburized parts. This steel offers a well-balanced combination of toughness, strength, and ductility. Additionally, AISI 1018 hot-rolled steel boasts enhanced mechanical properties, improved machining characteristics, and increased Brinell hardness.

Chemical Composition of AISI 1018:

Element	Content (%)
Manganese, Mn	0.60-0.90
Sulphur, S	0.15-0.20
Carbon, C	0.05 (Max)
Phosphorous, P	0.04 (Max)
Iron, Fe	Balance

Mechanical Properties of AISI 1018:

Properties	Metric
Tensile Strength	440 MPa
Yield Strength	370 MPa
Modulus of Elasticity	205 MPa
Shear Modulus	80 MPa
Poisson's Ratio	0.29
Elongation at Break (at 50 mm)	15%
Hardness, Brinell	126

AISI 4130 Carbon Steel:

Alloy steels are identified by AISI four-digit numbers and are more amenable to mechanical and heat treatments than carbon steels. These steels have compositions that go beyond the limits of elements like B, C, Mn, Mo, Ni, Si, Cr, and Va found in carbon steels. AISI 4130 alloy steel, specifically, contains chromium and molybdenum, which serve as strengthening agents. With its low carbon content, AISI 4130 is easily weldable. Further details can be found in the datasheet.

Chemical Composition of AISI 4130

Element	Content (%)
Iron, Fe	97.03 – 98.22
Chromium, Cr	0.80 – 1.10
Manganese, Mn	0.40 – 0.60
Carbon, C	0.280 – 0.330
Silicon, Si	0.15 – 0.30
Molybdenum, Mo	0.15 – 0.25
Sulphur, S	0.040
Phosphorous, P	0.035

Mechanical Properties of AISI 4130:

Properties	Metric
Tensile Strength	560 MPa
Yield Strength	460 MPa
Modulus of Elasticity	190-210 MPa
Shear Modulus	80 MPa
Poisson's Ratio	0.27-0.30
Elongation at Break (at 50 mm)	21.50%
Hardness, Brinell	217

5. 2D & 3D MODEL OF GO-KART CHASSIS

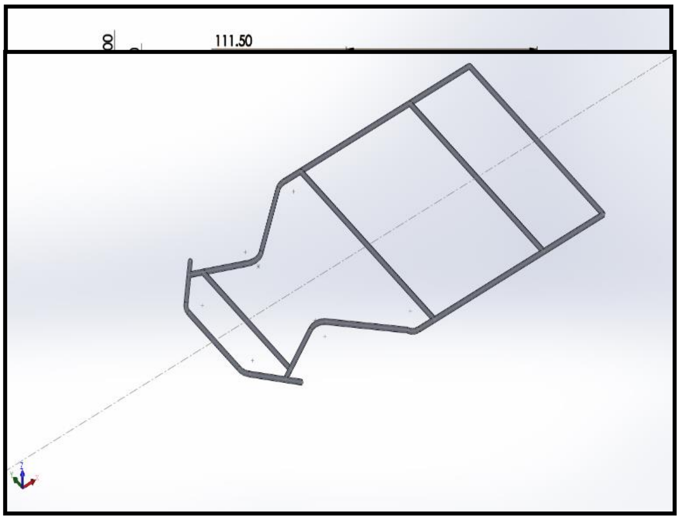

Fig.2: 2D Sketch of Go-Kart Chassis
Fig.3: 3D Model of Go-Kart Chassis

6. DESIGN CALCULATIONS

The construction of a go-kart chassis is vital for its performance and safety. The chassis must be robust enough to withstand racing forces while being lightweight to allow for quick acceleration. Additionally, it should be designed to ensure optimal control and handling for the driver.

Designing a go-kart chassis is a complex task requiring careful consideration of multiple factors. Designers need a thorough understanding of engineering and mechanics principles, along with in-depth knowledge of go-kart racing dynamics. With careful planning and precise execution, it is possible to create a chassis that is both fast and safe. The following list includes essential design calculations:

Parameter	Value
Wheel Base	1000 mm
Vehicle Track	Front = 900 mm Back = 1000 mm
Tube Dimensions	1 Inch
Roll Cage Materials	AISI 4130 & AISI 1018
Roll Cage Mass	15 Kg
Ground Clearance	25.4 mm

7. SIMULATION PROCEDURE

Ansys develops and markets engineering simulation software applicable throughout a product's lifecycle.

Ansys Mechanical, a finite element analysis tool, is intended to simulate computer models of structures, electronics, and machine components. This software is used to evaluate properties such as strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and more. Ansys helps predict a product's performance under different conditions without the necessity of creating test prototypes or performing crash tests.

The following steps need to be performed in order to conduct an Impact Analysis of Go-Kart chassis:

1) **Geometry**: Crate a 3D model of Go-kart chassis on 3D model software like SolidWorks, CATIA V5 etc. and upload a CAD model into static structural Analysis.

2) **Material Properties**: Add material properties in the Engineering

3) **Meshing**: Mesh all the elements of chassis to reduce the amount of time and effort spent to get accurate results.

4) **Static Structural**: Insert magnitude of Force & Fixed support elements for every type of analysis.

5) **Solution:** Evaluate the results of a chassis to determine its stress, strain & Deformation magnitude after the application of load.

8. SIMULATION RESULTS

Following results are obtained for each material showing the maximum stress, strain and total deformation.

Impact Analysis of Chassis using AISI 4130

The design is imported to Ansys workbench and the impact analysis of Static Structural is done using Structural Steel. The obtained results are given below in tabular format.

- **Front Impact Analysis of AISI 4130:**

Properties	Magnitude
Force	1323 N
Maximum Stress	705.39 MPa
Total Deformation	2.85 mm
Normal Stress	361.57 MPa
Factor of Safety (FOS)	460/705.39 = 0.65

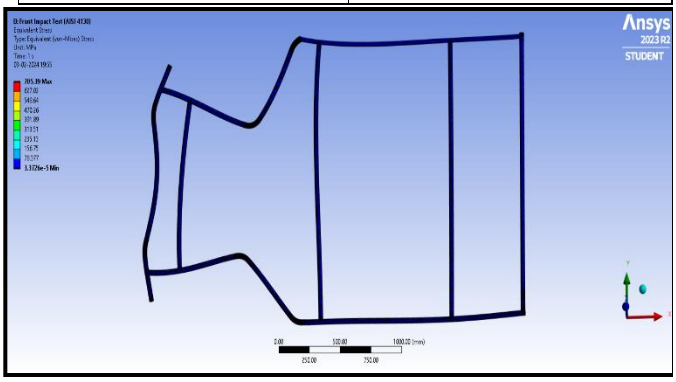

Fig.4: Front Impact Analysis of Chassis (AISI 4130)

- **Rear Impact Analysis of AISI 4130:**

Properties	Magnitude
Force	1323 N
Maximum Stress	367.92 MPa
Total Deformation	5.09 mm
Normal Stress	131.06 MPa
Factor of Safety (FOS)	460/367.92 = 1.25

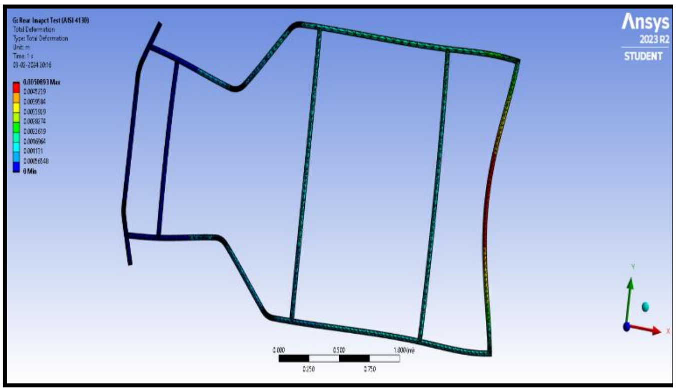

Fig.5: Rear Impact Analysis of Chassis (AISI 4130)

- **Side Impact Analysis (Left) of AISI 4130:**

Properties	Magnitude
Force	1323 N
Maximum Stress	84.57 MPa
Total Deformation	0.56 mm
Normal Stress	40.2 MPa
Factor of Safety (FOS)	460/84.57 = 5.71

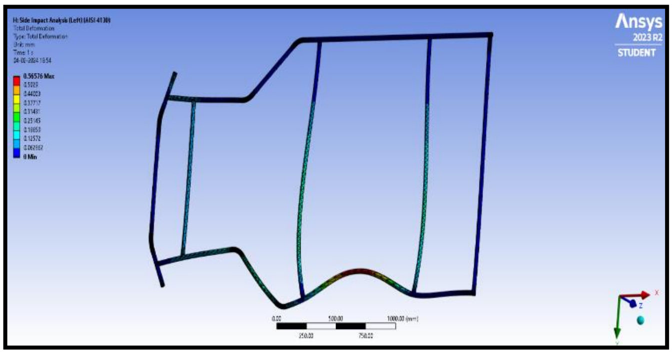

Fig. 6: Side Impact Analysis (Left) of Chassis (AISI 4130)

- **Side Impact Analysis (Right) of AISI 4130:**

Properties	Magnitude
Force	1323 N
Maximum Stress	83.97 MPa
Total Deformation	0.56 mm
Normal Stress	40.11 MPa
Factor of Safety (FOS)	460/83.97 = 5.48

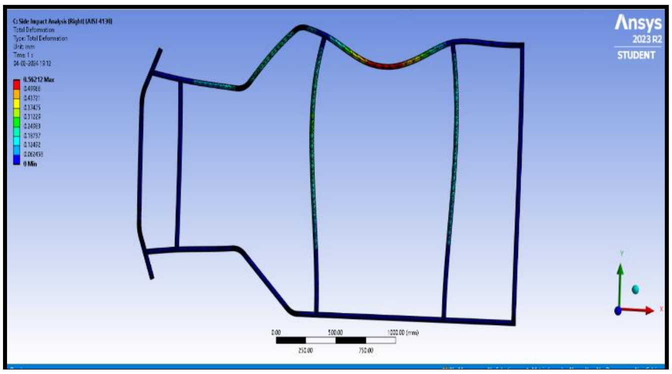

Fig.7: Side Impact Analysis (Right) of Chassis (AISI 4130)

Impact Analysis of Chassis using AISI 1018:

The design is imported to Ansys workbench and the impact analysis of Static Structural is done using Stainless Steel. The obtained impact result given in table.

- **Front Impact Analysis of AISI 1018:**

Properties	Magnitude
Force	1323 N
Maximum Stress	509.63 MPa
Total Deformation	2.34 mm
Normal Stress	84.53 MPa
Factor of Safety (FOS)	370/509.63 = 0.73

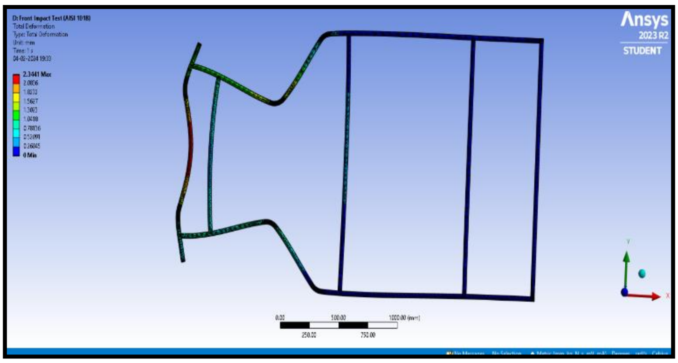

Fig.8: Front Impact Analysis of Chassis (AISI 1018)

- **Rear Impact Analysis of AISI 1018:**

Properties	Magnitude
Force	1323 N
Maximum Stress	370.42 MPa
Total Deformation	5.11 mm
Normal Stress	116.52 MPa
Factor of Safety (FOS)	370/370.42 = 0.9

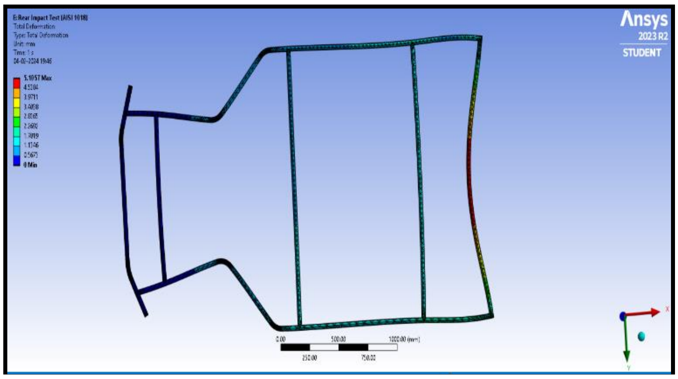

Fig.9: Rear Impact Analysis of Chassis (AISI 1018)

- **Side Impact Analysis (Left) of AISI 1018:**

Properties	Magnitude
Force	1323 N
Maximum Stress	151.62 MPa
Total Deformation	0.75 mm
Normal Stress	32.67 MPa
Factor of Safety (FOS)	370/151.62 = 2.44

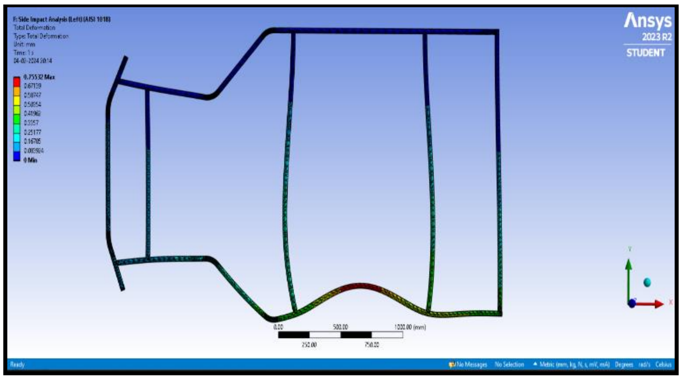

Fig.9: Side Impact Analysis (Left) of Chassis (AISI 1018)

- **Side Impact Analysis (Right) of AISI 1018**

Properties	Magnitude
Force	1323 N
Maximum Stress	85.08 MPa
Total Deformation	0.58 mm
Normal Stress	40.02 MPa
Factor of Safety (FOS)	370/40.02 = 9.24

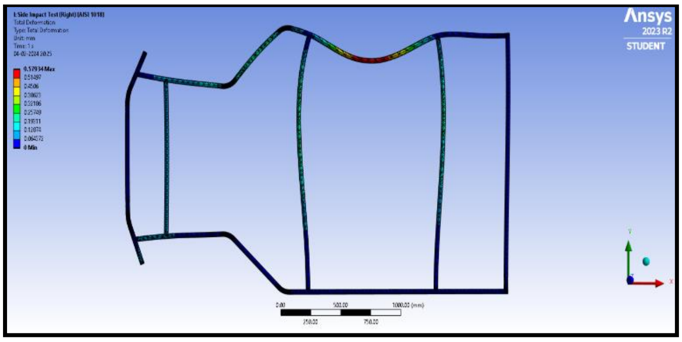

Fig.9: Side Impact Analysis (Right) of Chassis (AISI 1018)

9. CONCLUSIONS

In this project, the impacts and collisions involving a go-kart frame model were simulated and analyzed using ANSYS software. The given model was tested under different collision conditions, and the resultant deformation and stresses were determined with respect to a time of 2 sec. for ramp loading using ANSYS software. Static Structural analysis was performed on the chassis frame in different directions using ANSYS software. From the above analysis results, it can be concluded that the go-kart chassis frame is safe for impact loading.

After analyzing both materials on ANSYS, It came into consideration that, Both the materials have barely any variation between them. However, if there is one material we have to pick for the manufacturing of the Go-kart Chassis, then we should go for AISI 4130.

As per results, AISI 4130 shows less deformation after the impact as well as it has high Factor of Safety (FOS) as compared to AISI 1018.

AISI 4130 is lighter as compared to AISI 1018 & offers a good balance of toughness, strength and ductility. AISI 4130 has excellent weldability, produces a uniform and hard case, and is considered the best steel for carburized parts.

The use of continuous bended pipes also reduced the number of joints; the lack of sharp edges on the roll cage allows for the design of more streamlined body panels which not only look smoother, but may also have a positive effect on the overall aerodynamic drag force

The difference in deformation faced by all these both materials was negligible.

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