



- Young's modulus (E)
- Fracture toughness (K_{IC})
- Low density (ρ)
- Fatigue and wear resistance

Basic mechanical relations:

$$\sigma = F/A, E = \sigma/\epsilon, U = \int \sigma d\epsilon.$$

These equations are essential for analyzing materials under sports load conditions.

3. Polymers and Applications with Examples

3.1 Polycarbonate (PC)

- Chemical structure: (C₁₅H₁₆O₂)_n, linear chain with bisphenol A groups
- Properties: Very high impact resistance (Izod > 850 J/m), 90% optical transparency

*Applications:

- Bicycle helmets (Giro)
- Skate helmets (Pro-Tec)
- Ski goggles (Oakley)
- Hockey face shields
- Reason: High impact resistance and transparency for clear vision

3.2 Polyamide (Nylon 6,6)

- Structure: Strong amide bonds, tensile strength 80–100 MPa

- Applications:
- Tennis racket strings (Yonex Poly Tour)
- Volleyball nets (Mikasa)
- Bicycle internal gears (Shimano)
- Key feature: Flexibility and high wear resistance

3.3 PEEK

- Structure: Crystalline polymer, modulus 3.6 GPa, thermal resistance up to 260°C
- Applications:
- Load-bearing bike components (Trek, Scott)
- Professional inline skates (Rollerblade)
- Strength training tools
- Feature: High load and thermal tolerance, fatigue resistance

3.4 TPU

- Structure: Hard and soft chain segments, high elasticity
- Applications:
- Shoe soles (Adidas Boost, Nike Air)
- Soccer balls (Adidas Al Rihla)
- Knee and elbow pads
- Feature: Energy absorption and

rebound efficiency

3.5 UHMWPE

- Structure: Long chains, excellent toughness, low surface friction
- Applications:
- Climbing ropes (Petzl)
- Protective body armor
- Surfboards (Bic)
- Feature: High abrasion resistance and lightweight

4. Polymeric Composites and Applications

CFRP (Carbon Fiber – Epoxy)

- Properties: Modulus 230 GPa, density 1.6 g/cm³
- Applications: High-end bicycles (Trek Madone), tennis rackets (Babolat Pure Aero), golf clubs (Callaway), rowing oars (Concept2)
- Reason: High strength-to-weight ratio, vibration reduction

GFRP (Glass Fiber – Epoxy)

- Properties: Flexible, impact resistant
- Applications: Skis (Rossignol), snowboards (Burton), rowing boat hulls
- Feature: Suitable for cyclic loading and low temperature

Aramids (Kevlar)

- Properties: High tensile strength, impact energy absorption
- Applications: Boxing gloves (Everlast), shin guards, mountain biking protective clothing
- Feature: Shock absorption and athlete protection

5. Experimental Section and Detailed Analysis

5.1 Sample Preparation

Polymers and composites were molded into 10×10×2 mm plaques.



Dr. F. Nayeb Morad



Advanced Polymers in Designing Lightweight and High-Performance Sports Equipment: Applications & Experimental Analysis

*Abstract

Recent advances in materials science have elevated engineering polymers to a central role in sports equipment design. The primary goal is to achieve reduced weight, high strength, adequate flexibility, and durability against fatigue.

This study reviews key industrial polymers, including Polycarbonate (PC), Polyamide (PA), Polyether Ether Ketone (PEEK), Thermoplastic Polyurethane (TPU), Ultra-High Molecular Weight Polyethylene (UHMWPE), and fiber-reinforced composites (CFRP and GFRP), regarding their structure, mechanical and physical properties, applications in sports equipment, and experimental performance. Specific examples of equipment using these materials are provided, along with performance analysis



1-Introduction

In professional sports equipment design, achieving a combination of lightweight, strength, and impact resistance is essential. Metals, although strong, have high density and low flexibility, which increase user fatigue. Advanced polymers with densities ranging from 0.9

to 1.4 g/cm^3 and tunable elastic modulus offer an ideal solution for manufacturing lightweight, durable, and high-performance sports equipment.

2. Key Mechanical Properties

Critical properties for sports materials include:

- High tensile strength (σ)

Composites contained carbon and glass fibers oriented in layers to mimic real sports equipment loading conditions. Samples were equilibrated at 23°C and 50% humidity before testing.

5.2 Tensile Test

- Machine: Universal Testing Machine (UTM), 10 kN capacity, $\pm 0.5\%$ accuracy
- Crosshead speed: 5 mm/min
- Measured properties: Tensile strength (σ_{max}), Young's modulus (E), elongation at break (ϵ_b)
- Sports application: PEEK and CFRP for bike frames and load-bearing components

5.3 Izod Impact Test

- Machine: Izod impact tester with 5 J pendulum
- Specimens: Notched standard samples
- Measured: Absorbed energy,

fracture toughness

- Results: PC and TPU absorbed highest energy $\rightarrow$ suitable for helmets and protective gear

5.4 Fatigue Test

- Method: Cyclic sinusoidal loading, 30–70% of tensile strength
- Cycles: Up to 10^6 or until failure
- Analysis: S-N curves
- Sports relevance: Tennis rackets, bike axles $\rightarrow$ PEEK and CFRP ideal for high-cycle applications

5.5 Thermal Tests

- DSC: Determined T_g and T_m up to 350°C
- DMA: Modulus and viscoelastic behavior from 25–150°C
- TGA: Thermal stability up to 600°C
- Applications: TPU and UHMWPE for shoe soles and climbing ropes

5.6 Experimental Analysis

- PC: Excellent impact resistance $\rightarrow$

helmets, guards

- TPU: Energy absorption and rebound $\rightarrow$ shoe soles, pads
- PEEK & CFRP: High tensile strength and modulus $\rightarrow$ bike frames, rackets
- UHMWPE: Lightweight, abrasion and impact resistant $\rightarrow$ ropes, protective armor
- PA: Balanced flexibility and strength $\rightarrow$ racket strings, nets

6. Conclusion

Engineering polymers and composites, through experimental analysis and real-world examples, offer an ideal combination of lightness, strength, and flexibility. Their use enhances performance, safety, and durability in sports equipment. Advances in nanotechnology and bio-based polymers will enable next-generation intelligent and sustainable sports gear.

دو دستگاه ریسندگی ایرجت (مستقر در مشهد) با مشخصات زیر به فروش می‌رسد:

۲ X MURATEC MVS ۸۷۰
VORTEX SPINNING
Make: Muratec
Model: MVS ۸۶۱
Year: ۲۰۱۲
No of Drums: ۷۲
Spindel type: Star
Polymaster: Available
Conicity: Cylindrical
Travers: ۶
Feed Can: ۲۰
Doffer: Available
Yarn Joint: Splicer
Splicer Nozzle: G۲Z
No of Spilcer: ۳

Clearer type: MSC
Nozel type: Star
Nozel Holder type: L.۷.۹.۳
Break Draft Wheel: ۳۰T
OHTC: Pneumabol
Panel Control: VOS ۲/۸
Spindel Size: ۱*۱/۲ & ۱*۱/۴
Voltage: ۳۸۰V
Frequency: ۵۰Hz
Phase: ۳
Capacity: ۳۳kw
Current: ۷۴A

شماره تماس از طریق واتس‌آپ و تلگرام:

۰۹۱۲۰۱۵۰۷۸۵