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Fracture studies on Basalt Fiber

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Abstract— This fracture studies focus on the mechanical properties of textile composites with respect to their matrix and reinforcement. This analysis of composites represents the fabrication of ceramic reinforcement materials and matrix to form a new composite. This combination of the new framework for the mechanical properties of textile composites used on spacecraft will be tested.
Index Terms— textile composites, ceramic reinforcement, matrix, fabrication

I. INTRODUCTION

Composites Materials are combinations of two phases in which one of the phases, called the reinforcing phase, which is in the form of fiber sheets or particles and are embedded in the other phase called the matrix phase. The primary functions of the matrix are to transfer stresses between the reinforcing fibers or particles and to protect them from mechanical and environmental damage whereas the presence of fibers or particles in a composite improves its mechanical properties such as strength, stiffness etc. A composite is therefore a synergistic combination of two or more micro-constituents which differ in physical form and chemical composition and which are insoluble in each other. Our objective is to take advantage of the superior properties of both materials without compromising on the weakness of either. Composite materials have successfully substituted the conventional materials in several applications like light weight and high strength. The reasons why composites are selected for such applications are mainly due to their high strength-to-weight ratio, high tensile strength at elevated temperatures, high creep resistance and high toughness. Typically, the reinforcing materials are strong with low densities while the matrix is usually a ductile or tough material. If the composite is designed and fabricated correctly it combines the strength of the reinforcement with the toughness of the matrix to achieve a combination of desirable properties not available in any single traditional material. The strength of the composites depends primarily on the amount, arrangement and type of fiber or particle reinforcement in the resin.

Composites can be categorized into three groups on the basis of matrix material. They are Metal Matrix Composites (MMC),Ceramic Matrix Composites (CMC) and Polymer Matrix Composites (PMC)

Metal Matrix Composites have many advantages over monolithic metals like higher specific strength, higher specific modulus, better properties at elevated temperatures and lower coefficient of thermal expansion. Because of these attributes metal matrix composites are under consideration for wide range of applications viz. combustion chamber nozzle (in rocket, space shuttle), housings, tubing, cables, heat exchangers, structural members etc.

Ceramic matrix Composites are to increase the toughness. And there is a concomitant improvement in strength and stiffness of ceramic matrix composites.

Polymer Matrix Composites are the most commonly used matrix materials.In general the mechanical properties of polymers are inadequate for many structural purposes. In particular their strength and stiffness are low compared to metals and ceramics. These difficulties are overcome by reinforcing other materials with polymers.

The processing of polymer matrix composites does not require high pressure and high temperature. The equipments which are required for manufacturing polymer matrix composites are simpler. For this reason polymer composites developed rapidly and soon became popular for structural applications. Polymer composites are used because overall properties of the composites are superior to those of the individual polymers. The elastic modulus is greater than the neat polymer but is not as brittle as ceramics.

II. MATERIALS AND METHODS

The materials and methods used for the processing of the composites under this investigation. It presents the details of the characterization and Physical/Mechanical tests which the composite samples are subjected to. The numerical methodology related to the determination of Physical properties.

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Matrix Material used are the epoxy resin, chemically belonging to the epoxide family is used as the matrix material. The low temperature curing epoxy resin and the corresponding hardener are mixed in a ratio of 10:8 by weight as recommended. Epoxy is chosen primarily because it happens to the most commonly used polymer and because of its insulating nature and Silicon carbide elevated temperature performance and the fact that they reported only a 35% loss of strength at 1350°C. Silicon carbide-tungsten and silicon carbide-carbon have both been seen to have very high stress-rupture strength at 1100°C and 1300°C.Silicon carbide fibers are produced with a nominal 0.0055 in. (140mµ) filament diameter and are characteristically found to have high strength, modulus and density expansion values range, in percentage of original dimension, from 0.05 at 390°F (200°C) to 1470°F (0.30% at 800°C).

III. PROPERTIES OF SILICON CARBIDE

Property	Value	Reference
Flexural strength	700-7000 70-400	Single crystal,90% purity Polycrystalline material, 78-80% purity
Compressive strength	3000-7000 70-170	Single crystal,90% purity Polycrystalline material, 78-80% purity
Tensile strength	30-140	Single crystal,90% purity Polycrystalline material, 78-80% purity
Modulus of elasticity	50-66 30-48	Single crystal,90% purity Polycrystalline material, 78-80% purity

Table.3.1. Mechanical properties of Silicon Carbide Physical Properties of Silicon Carbide

Physical Properties	Silicon Carbide
Density	3.21 g/cm^3
Tensile strength	1,397 MPa
Compressive strength	3,900 MPa
Elastic modulus	410 GPa
Linear expansion coefficient	2.77 m/mk
Elongation at break	0.1-0.3 %

Table 3.2.Physical properties of silicon carbide Thermal Properties of Silicon Carbide

Thermal properties	values
Maximum operating temperature	600-1,600 ^{o}c
Maximum sustained temperature	1,370 ^{o}c
Thermal conductivity	350 W/mk
Melting temperature	2,730 ^{o}c
Thermal expansion	4.0x10^{-6}/^{o}c

Tale3.2 Thermal Properties of Silicon Carbide

IV. REINFORCEMENT MATERIAL

Basalt fiber or fibre is a material made from extremely fine fibers of basalt, which is composed of the minerals plagioclase, pyroxene, and olivine. It is similar to carbon fibre and fiberglass, having better physic mechanical properties than fiberglass, but being significantly cheaper than carbon fibre. It is used as a fireproof textile in the aerospace and automotive industries and can also be used as a composite to produce products such as tripods. Basalt fibres are used in a wide range of application areas such as the chemical, construction and marine sectors, not to mention the offshore, wind power, transport and aerospace industries. This is due to their superior properties: not only do they boast good mechanical and chemical resistance, but also excellent thermal, electric and acoustic

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insulation properties.

The raw material for basalt fibres is a naturally occurring mineral that belongs to the family of volcanic rocks. As a mineral, basalt ranges from dark gray to black. Basalt fibres are mineral fibres, which are 100% inorganic. Fibre compatibility to matrix resins is ensured by using organic sizing agents. The fibre is composed of 100 % mineral continuous filaments. The focus is on the range of 9 to 13 µm for the filament diameters. These diameters give the best compromise between tenacity, suppleness and cost. They are also safely larger than the 5 µm limit for non-respirability. As the product presents no hazard to health and environment, it is very suitable for asbestos replacement. The natural golden-brown appearance of the resulting fabrics, incidentally, can be covered for decorative purposes. Main features of basalt fibre reinforcements are High strength and modulus, Corrosion resistance, High temperature resistance, extended operating temperature range and Easy to handle.

The specific tenacity (ratio: rupture stress divided by density) of basalt fibres exceeds that of steel fibres, many times. Basalt is roughly 5 % denser than glass. The tensile modulus (E modulus, Young modulus) of basalt fibers is higher than the one of E-glass fibers.

A. Basalt fiber

Component	Basalt
Silicon dioxide	52-55%
Calcium oxide	5-10%
Aluminum oxide	16-18%
Sodium and potassium oxide	3-4%
Magnesium oxide	3-7%
Iron oxide	10-12%
Tilanium oxide	0.6-2%

Table.4.1 Typical composition of Basalt fiber

B. Mechanical and physical properties

The low elongation perfectly elastically up till rupture results in dimensionally very stable fabrics. Basalt textiles show sufficient suppleness and drape ability.

Physical/mechanical Properties	Basalt
Density	2.66 g/cm^3
Tensile strength	4500 Mp_a
Compression	3790 Mp_a
Elastic modulus	85-92 Gp_a
Linear expansion coefficient	5.5×10/k
Elongation at break	4.0%

Table.4.1.Physical properties of Basalt

Thermal properties

Basalt fiber or fibre is a material made from extremely fine fibers of basalt, which is composed of the minerals plagioclase, pyroxene, and olivine. It is similar to carbon fibre and fiberglass, having better physicomechanical properties than fiberglass, but being significantly cheaper than carbon fibre. It is used as a fireproof textile in the aerospace and automotive industries and can also be used as a composite to produce products such as tripods. Basalt fibres are used in a wide range of application areas such as the chemical, construction and marine sectors, not to mention the offshore, wind power, transport and aerospace industries. This is due to their superior properties: not only do they boast good mechanical and chemical resistance, but also excellent thermal, electric and acoustic insulation properties.

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Main features of basalt fibre reinforcements are High strength and modulus,Corrosion resistance, High temperature resistance, Extended operating temperature range and Easy to handle.

Thermal properties	Basalt
Maximum operating temperature	980 ^oC
Sustained operating temperature	700 ^oC
Minimum operating temperature	-2.60 ^oC
Thermal conductivity	0.031-0.038W/mK
Melting temperature	1280 ^oC
Vitrifiction conductivity	1050 ^oC
Thermal expansion coefficient	8.0 ppm/^oC

Table.4.2 Thermal properties of basalt

Composite Fabrication

The low temperature curing epoxy resin (LY 556) and corresponding hardener (HY951) are mixed in a ratio of 10:8 by weight as recommended. Silicon carbide powders with average of 30gms are reinforced in epoxy resin to prepare the composites. The composites are cast by conventional hand-lay-up technique in glass plate so as to get rectangular specimens. Composites of eight layers are made from hand-lay-up method. The fabrications are left to cure at temperature for about 2 hours after which the plates are broken and samples are released.

Fig.4.1.Basalt fibre

Samples	Composition		
1	Epoxy + 0 vol% (0 wt %) Filler		
2	Epoxy + 30gms SiC + 30gms Portland cement		
3	Epoxy + 30gms SiC + 30gms Plaster of Paris		

Table 4.3 List of particulate filled composites

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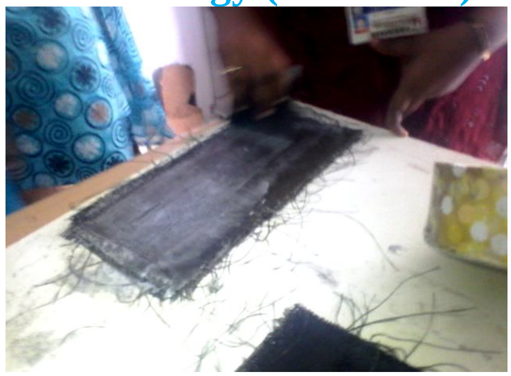

Fig4.1Fabrication of Composite material

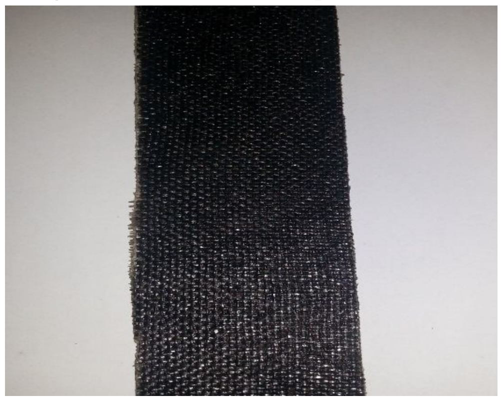

Fig4.2.Fabrficated Composites

Mechanical characterization of materials

Mechanical testing plays an important role in evaluating fundamental properties of engineering materials as well as in developing new materials and in controlling the quality of materials for use in design and construction. If a material is to be used as part of an engineering structure that will be subjected to a load, it is important to know that the material is strong enough and rigid enough to withstand the loads that it will experience in service. As a result engineers have developed a number of experimental techniques for mechanical testing of engineering materials subjected to tension, compression, bending or torsion loading.

Fig4.3Universal Testing Machine

Tensile Test and Compressive Test

Uniaxial tensile test is known as a basic and universal engineering test to achieve material parameters such as ultimate strength, yield strength, % elongation, % area of reduction and Young's modulus. The tensile testing is carried out by applying longitudinal or axial load at a specific extension rate to a standard tensile specimen with known dimensions (gauge length and cross sectional area perpendicular to the load direction) till failure. The applied tensile load and extension are recorded during the test for the calculation of stress and strain. For tensile testing a range of universal standards provided by Professional societies such as American Society of Testing and Materials (ASTM). The equipment used for tensile testing ranges from simple devices to complicated controlled systems

Fig.4.4.Failure due to compressive load

Fig.4.5. Failure due to tensile load

Physical characterization of combination of basalt, silicon carbide and plaster of paris

1) Tensile strength:

Length = 140 mm
Width = 12.7 mm
Thickness = 2 mm
Load = 150 kN

Tensile strength $= \frac{\text{Tensile load}}{A_o}$

$= \frac{150 \times 10^3}{(12.7 \times 2)10^{-6}}$

$= 5905$ MPa

2) Compression strength:

Length = 70 mm
Width = 10 mm
Thickness = 2 mm
Load = 147 kN

Compressive strength $= \frac{\text{compressive load}}{A_o}$

$= \frac{147 \times 10^3}{(5 \times 10)10^{-6}}$

$=$ 2940 MPa

3) % of elongation for Tensile test:

L_o (Initial length) = 140 mm
L_f(Final length) = 147 mm
% of elongation $= \frac{L_o - L_f}{L_o}$

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$= \frac{140-147}{140} \times 100$

` $= 5\ \%$

4) % Reduction area for compressive test:

A_o(Initial area) = 70 mm^2

A_f (Final area) = 67.5 mm^2

% of reduction $= \frac{L_o - L_f}{L_o} \times 100$

$= \frac{70-67.5}{70} \times 100$

= 3.5 %

5) Young's modulus for tensile load

σ(Stress) = 5905 MPa

ε(Strain) = 5 %

Young's modulus $= \frac{\sigma}{\varepsilon}$

$= \frac{5905}{5} \times 100$

$= 118$ GPa

6) Elastic modulus for compressive load

σ (Stress) = 2940 MPa

ε (Strain) = 3.5 %

Young's modulus $= \frac{\sigma}{\varepsilon}$

$= \frac{2940}{3.5} \times 100$

$= 84$ GPa

Physical characterization of combination of basalt and epoxy resin

1) Tensile strength:

Length = 140 mm

Width = 12.7 mm

Thickness = 2 mm

Load = 144 kN

Tensile strength $= \frac{\text{Tensile load}}{A_0}$

$= \frac{144 \times 10^3}{(12.7 \times 2) 10^{-6}}$

$= 5669$ MPa

2) Compressive strength:

Length = 70 mm

Width = 10 mm

Thickness = 2 mm

Load = 142 kN

Compressive strength $= \frac{\text{compressive load}}{A_o}$

$= \frac{142 \times 10^3}{(5 \times 10) 10^{-6}}$

$= 2840$ MPa

3) % of elongation of basalt fiber for Tensile test:

L_o (Initial length) = 140 mm

L_f(Final length) = 142 mm

% of elongation = $\frac{L_o - L_f}{L_o}$

$= \frac{140-142}{140} \times 100$

` $= 1.42\ \%$

4) % Reduction area of basalt fiber for compressive test:

A_o(Initial area) = 70 mm^2

A_f (Final area) = 65 mm^2

% of reduction = $\frac{L_o - L_f}{L_o} \times 100$

$= \frac{70-65}{70} \times 100$

= 7.1%

5) Young's modulus for tensile load

σ (Stress) = 5669 MPa

ε (Strain) = 1.42 %

Young's modulus = $\frac{\sigma}{\varepsilon}$

$= \frac{5669}{1.42} \times 100$

= 399 GPa

6) Elastic modulus for compressive load

σ (Stress) = 2880 MPa

ε (Strain) = 7.1%

Young's modulus = $\frac{\sigma}{\varepsilon}$

$= \frac{2840}{7.1} \times 100$

= 40 GPa

Physical characterization of combination of basalt, silicon carbide and Portland cement

1) Tensile strength:

Length = 140 mm

Width = 12.7 mm

Thickness = 2 mm

Load = 148 kN

Tensile strength = $\frac{\text{Tensile load}}{Ao}$

$= \frac{148 \times 10^3}{(12.7 \times 2)10^{-6}}$

= 5826 MPa

2) Compressive strength:

Length = 70 mm

Width = 10 mm

Thickness = 2 mm

Load = 145 kN

Compressive strength = $\frac{\text{compressive load}}{A_o}$

$= \frac{145 \times 10^3}{(5 \times 10)10^{-6}}$

= 2900 MPa

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3) % of elongation of basalt fiber for tensile test:

L_o (Initial length) = 140 mm

L_f (Final length) = 145 mm

% of elongation= $\frac{L_o - L_f}{L_o}$

$= \frac{140-145}{140} \times 100$

` $= 3.5\ \%$

4) % Reduction area of basalt fiber for compressive test:

A_o (Initial area) = 70 mm^2

A_f (Final area) = 66.7 mm^2

% of reduction = $\frac{L_o - L_f}{L_o} \times 100$

$= \frac{70-66.7}{70} \times 100$

$= 4.7\%$

5) Young's modulus for tensile load

σ (Stress) = 5905MPa

ε (Strain) = 3.5%

Young's modulus = $\frac{\sigma}{\varepsilon}$

$= \frac{5826}{3.5} \times 100$

$= 166$ GPa

6) Elastic modulus for compressive load

σ (Stress) = 3000MPa

ε (Strain) = 4.7%

Young's modulus = $\frac{\sigma}{\varepsilon}$

$= \frac{2900}{4.7} \times 100$

$= 61.7$ GPa

V. COMPARISON OF PHYSICAL PROPERTIES OF COMPOSITES

The physical properties such as tensile strength, compressive strength, elastic modulus and elongation length of basalt, basalt Epoxy, basalt +Sic +pop +epoxy and Basalt +Sic +Portland +epoxy

PROPERTIES	BASALT	BASALT +SiC +POP +EPOXY	BASALT+ EPOXY	BASALT +SiC +PORTLAND +EPOXY
Tensile strength	4500 MPa	5905 Mpa	5669 MPa	5826 MPa
Compressive strength	3790 MPa	3000 Mpa	2880 MPa	2960 MPa
Elastic modulus	85-92 GPa	118 Gpa	399 GPa	166 GPa
Elongation length	4.0%	5.0%	1.4 %	3.5 %

Table 4.8. Comparison of physical properties

V. CONCLUSION

This experimental investigation on physical properties of basalt with epoxy composites have led to the conclusion of successful fabrication of epoxy based composites filled with micro-sized Silicon carbide by hand-lay-up technique is possible and the physical properties of the tested material are greater than the properties of basalt.

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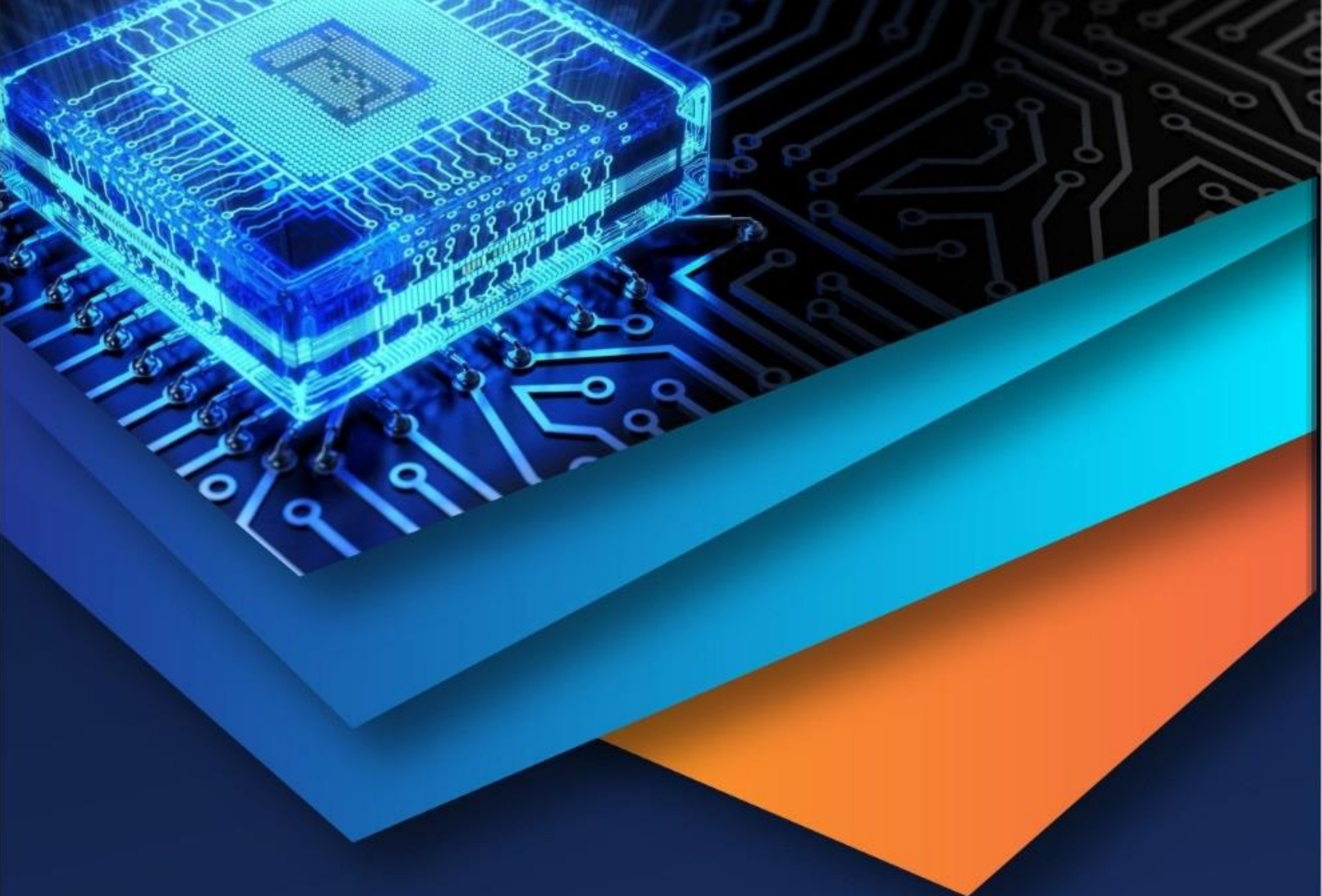

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