Design and manufacturing basalt and carbon fiber road bike frame.

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SUMMARY

Bicycle frame manufacturing are dominated by use of carbon fiber due to its excellent specific mechanical properties (meaning the specific property value divide by its density). The stiffness and light weight of this material allows to obtain high pedal efficiency and safety cornering at high speed.

However, carbon fiber bike frames show a handicap in order to do long distances on bumpy roads. It is in this aspect where basalt fiber can play an important role with the objective to obtain better flexibility properties and shock absorption, but without compromising the overall structure stiffness.

Three types of analysis are made in this article, all of them are based in the “Racing bicycles - Safety requirements and test methods” norm. In which it seeks to study the feasibility of building basalt fiber bicycle frames.

As a conclusion, is was obtained that the optimum configuration is to divide the bicycle frame in two parts: comfort zone made of basalt fiber and power zone made of carbon fiber.

KEYWORDS: analysis, basalt fiber, carbon fiber bike.

1. INTRODUCTION

The high-end bicycles market are fully of carbon fiber. The use of this material allows to obtain excellent stiffness to weight ratio in comparison with other materials. This structure stiffness results an immediate power transmission and in a great stability at high speed corners. However, in the longitudinal plane, all tarmac irregularities taken directly to the rider’s body, causing more muscle fatigue.

The aim of this work is to study the viability to build a bicycle frame using basalt fiber. Basalt fiber strength, flexibility and low density are well known, its application in certain parts of the frame could improve the ride comfort and shock absorption, but without damage the overall structure stiffness, and consequently, the optimum power transmission and lightweight of carbon fiber bikes.

In order to find a compromise between stiffness and comfort, we proceed to analyse the same bicycle frame, with the same composite layup, but changing the materials. Analyses were made using finite element software Abaqus and they are based on UNE-EN 14781 [1].

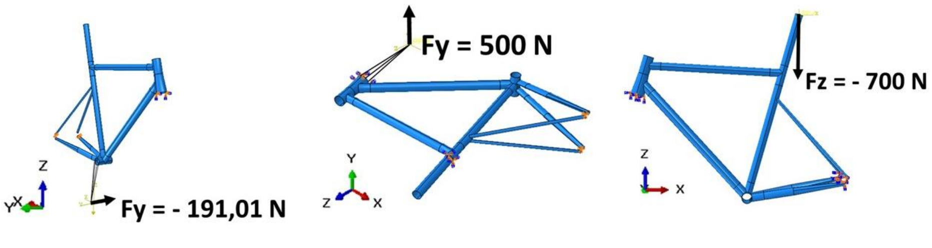
All test are focused on thinking in the bicycle frame manufacture, which is made by filament winding. The manufacturing process is known like tube to tube construction.

2. TESTS

The three load cases are analysed based on the UNE-EN 14781. We proceed to study the viability of the basalt fiber for the construction of racing bicycle frames, in order to improve the vertical flexibility of the structure without compromising the lateral-directional stiffness.

The load cases are based on calculate the overall structure stiffness with the application of loads, as shown in Figure 1 (a), (b), (c).

1. Power transmission test: Goal, minimum bottom bracket deflection.
2. Torsional steering stiffness test: Goal, minimum structure turning.
3. Vertical flexibility test: Goal, minimize stiffness in the vertical plane.



(a) **(b)** **(c)**

Figure 1. Test loads based on UNE-EN 14781 rule: (a) Power transmission test, (b) Torsional steering stiffness test, (c) Vertical flexibility test.

In each test, the displacement u is measured produced by the load F at the point of application to subsequently obtained structure stiffness in each case according to (1).

$$K = F / u \tag{1}$$

The main work objective is to obtain the highest bottom bracket stiffness value and the highest head tube torsional stiffness value. On the other hand, the vertical flexibility test stiffness must be the lowest.

All load cases are made on the geometry shown in Figure 2, always using the same tube sections and the same laminate. The laminate is shown in Table 1.

Table 1. Filament winding tubes layup.

	LAYUP (°)
Head tube	9 x [0, 90]
Top tube	[±25, ±45, ±45, ±25]
Down tube	[±25, ±45, ±25, ±25, ±45, ±25]

Seat tube	[90, 90, ±45, ±25, ±25]
Bottom Bracket	[90, 90, ±45, ±25]
Seatstays	[±25, ±45, ±25]
Chainstays	[±25, ±45, ±25, ±45, ±25]

In different load cases discussed, we proceed to make conclusions due to the structure of carbon fiber, basalt fiber and using a hybrid configuration using carbon fiber and basalt. To the mixed configuration, it is considered to divide the structure into two parts, as shown in Figure 2:

1. Comfort zone, made of basalt fiber: top tube, seat tube and seatstays. It is considered that these profiles are those that contribute to improving the performance of flexibility and shock absorption.
2. Power zone, made of carbon fiber: head tube, down tube, bottom bracket and chainstays. It is in this part of the structure where seeks to maximize the results of pedaling stiffness and torsional steering stiffness.

Figure 2. Bicycle frame parts.

2.1. Power transmission test.

Bottom bracket stiffness and pedalling power transmission are discussed in this section. As shown in Figure 1 (a), a 1100 N load is applied on the pedal which decomposes in the X, Y, Z axis as F = [0, -191.01, -1083.29] N. The study is due to the application of lateral force to the lateral plane of the structure, F_Y. The boundary conditions in displacements are:

- Rear dropouts (rear wheel anchor): Displacement disabled and rotations allowed.
- Head tube lower part: Displacement and rotations disabled, axis Y rotation allowed.

It is represented, in Table 2 the displacement obtained by analyzing the structure at the three configurations described.

Table 2. Y axis displacements due to the Figure 1 (a) load application.

	u_y (mm)
Carbon fiber	-2,746 mm
Basalt fiber	-6,152 mm
Basalt and carbon fiber	-3,154 mm

Therefore, according to (1), the overall structure stiffness due to pedaling forces are shown in Figure 3.

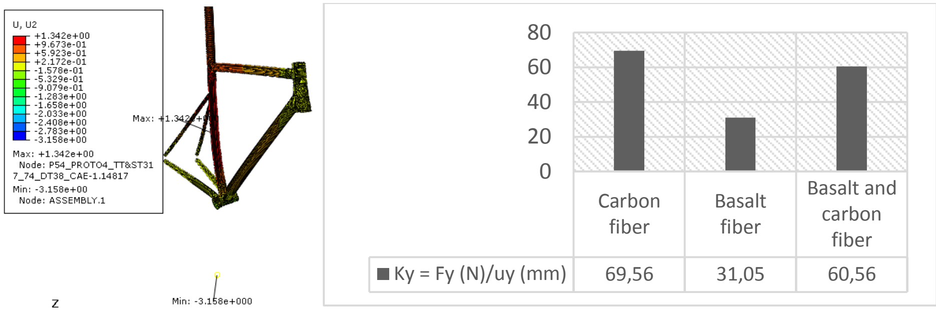


Figure 3. Bottom bracket stiffness

Figure 3 shows that the highest pedaling stiffness value corresponds with the carbon fiber frame, worsening basalt fiber the results up to 50%. However, a mixed configuration, does not involve a significant reduction in stiffness results.

2.2. Torsional steering stiffness test.

Torsional steering stiffness is evaluated in this case, in order to evaluate cornering stability at high speed. As shown in Figure 1 (b), the displacement boundary conditions are:

- Rear dropouts (rear wheel anchor): Displacement disabled and rotations allowed.
- Head tube lower part: Displacement and rotations disabled, axis X rotation allowed.
- Seat clamp: Displacement and rotations are disabled.

A F_Y = 500 N load is applied as shown in Figure 1 (b), at a distance of 352.5 mm from the bottom of the head tube, generating a X axis moment equal to 176.25 Nm. It is represented in Table 3 the X rotation produced in the head tube, due to the application of this force, measured in degrees.

Table 3. X rotation due to the force applied in Figure 1 (b).

	u_{RX} (deg)
Carbon fiber	0,816°
Basalt fiber	1,828°
Basalt and carbon fiber	0,764°

Global parameters of steering torsional stiffness are shown in Figure 4, due to the analysis of the carbon fiber bike frame, the basalt fiber bike frame and the hybrid configuration.

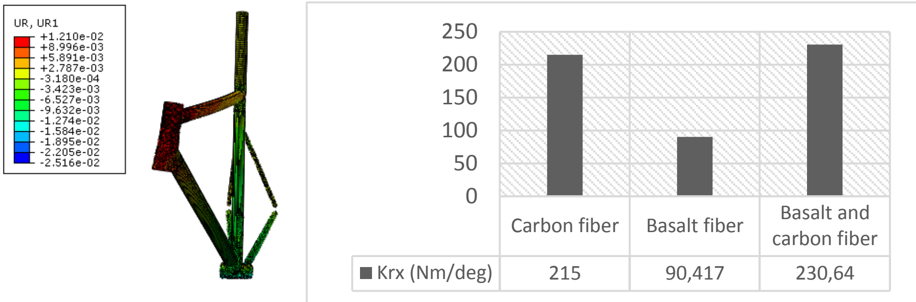


Figure 4. Torsional structure stiffness.

The aim of this section is to have the maximum steering torsional stiffness value of the structure, as this will result in greater safety and confidence to the rider when turning corners at high speed. It is observed in Figure 4 that the highest value corresponds with the hybrid configuration structure.

2.3. Vertical flexibility test.

The main goal of this section is to evaluate the ride comfort. The objective is to have more vertical flexibility, in order to improve the shock absorption over bumpy roads.

Figure 1 (c) shows the vertical force applied, F_z = - 700 N and u_z displacement is measured at the point of application. The boundary conditions in displacements are:

- Rear dropouts (rear wheel anchor): Displacements and rotations disabled.
- Bottom head tube: Displacements and rotations disabled, except X displacement and Y rotation.

In all cases, the seat tube remains basalt fiber. It is shown in Table 4, the u_z displacement generated at the load application point.

Table 4. Z axis displacements due to the Figure 9 load application.

	u_z (mm)
Carbon fiber	-1,272 mm
Basalt fiber	-2,544 mm
Basalt and carbon fiber	-2,407 mm

Figure 5 shows the vertical compliance global parameters obtained by analysing the three types of structures.

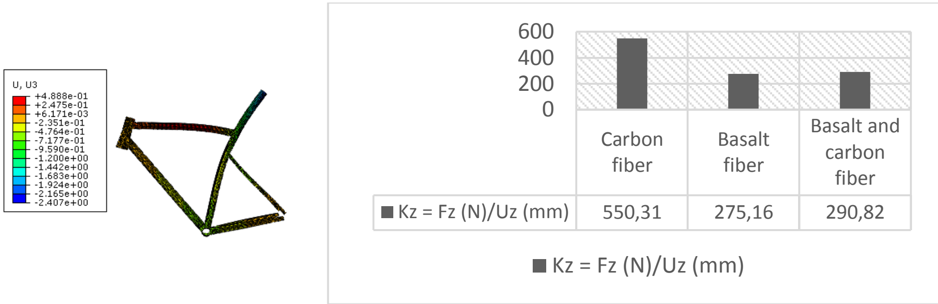


Figure 5. Vertical compliance.

Basalt fiber use for to make the top tube, seat tube and the seat stays means a high improvement in comfort and muscle fatigue reduction compared with a carbon fiber frame and a low increment in stiffness compared with a basalt fiber frame.

3. CONCLUSION

The analysis were performed to corroborate the feasibility of using basalt fiber for making bicycle frames. The tests carried out show like a correct bicycle frame tubes configuration made using basalt fiber and carbon, optimizes both stiffness parameters pedaling and steering and increase the degree of vertical compliance of the structure improving the ride comfort.

Dividing the structure into two zones; Comfort Zone made of basalt fiber (top tube, seat tube and seatstays) and Power Zone made of carbon fiber (head tube, down tube and chainstays), its obtain a great results of stiffness and comfort in order to provide an excellent pedaling performance and steering stiffness and, on the other hand, a high vertical compliance meaning a better ride comfort.

REFERENCES

1. UNE-EN 14781. Racing bicycles - Safety requirements and test methods