



The lower weight of carbon brakes results in slightly lower fuel consumption, which can reduce CO<sub>2</sub> emissions.

# Operational Advantages of Carbon Brakes

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Carbon brakes offer a significant weight savings compared to steel brakes. This translates into a lighter airplane, which directly contributes to decreased fuel consumption and associated reductions in engine emissions.

Carbon brakes are a practical alternative to steel brakes. Advances in engineering and manufacturing mean that retrofitting carbon brakes onto existing airplanes can decrease fuel costs for certain models.

This article provides historical background about carbon brakes and outlines their operational advantages, including their positive environmental impact. It is important to note that this article does not address total cost of ownership topics such as usage and overhaul costs. Operators should weigh the decisions on brake type based on several considerations, including specific model usage, route utilization, and cost structure.

## CARBON BRAKE HISTORY

Carbon brakes were originally used in high-performance military aircraft applications. The lower weight and higher energy absorption capability of carbon brakes justified their cost, which historically was higher than the cost of steel brakes. These cost considerations often resulted in the use of steel brakes on smaller, short-haul commercial airplanes and carbon brakes on larger, long-haul commercial airplanes. In the past, the higher cost of carbon brakes could more easily be justified for larger airplanes because of the cost savings associated with reduced weight and longer service life.

However, recent improvements in carbon brake manufacturing and overhaul



**Figure 1: Carbon brakes offer high performance**

A Next-Generation 737-900 Extended Range (ER) airplane performs a high-speed rejected takeoff test to verify that an airplane at maximum weight with greatly worn carbon brakes can stop safely after a refused takeoff decision.

**Figure 2: Carbon brake weight savings**

Weight comparison: steel vs. carbon brakes

AIRPLANE MODEL	WEIGHT SAVINGS IN LBS (KILOGRAMS)
737-600/-700	550 (250)*
737-600/-700/-700IGW/-800/-900/-900ER	700 (320)**
757	550 (249)
767	800 (363)
MD-10 Freighter	976 (443)

\* Carbon brakes weigh 550 lbs (250 kg) less than standard-capacity steel brakes for 737-600 and -700 models.

\*\* Carbon brakes weigh 700 lbs (320 kg) less than high-capacity steel brakes on 737-600/-700/-700 Increased Gross Weight/-800/-900/ and -900ER models.

procedures have reduced the per-landing cost of carbon brakes to the point that they are cost competitive with steel brakes. Carbon brake manufacturing has become more efficient and overhaul procedures now allow for optimal use of refurbished carbon material.

These improved operating economics — along with the weight savings and performance improvements offered by carbon brakes — have led to increased application of carbon brakes on commercial airplanes.

#### OPERATIONAL ADVANTAGES

Carbon brakes are well-suited to the high-performance braking demands of commercial airplanes (see fig. 1). Carbon brake material is characterized by high temperature stability, high thermal conductivity, and high specific heat. Carbon brakes have a number of operational advantages relative to steel brakes:

- **Longer life:** Carbon brakes offer up to twice as many landings per overhaul as steel brakes.
- **Cost effectiveness:** For most operations, the life-cycle costs of carbon brakes are now similar to those of steel brakes.
- **High performance:** Carbon brakes have greater energy absorption capability than steel brakes.
- **Lightweight:** Carbon brakes are significantly lighter than steel brakes.

#### ENVIRONMENTAL IMPACT

One of the primary benefits of carbon brakes is the amount of weight they remove from an airplane (see fig. 2). The lower weight of carbon brakes results in slightly lower fuel consumption, which reduces carbon dioxide (CO<sub>2</sub>) emissions.

#### CARBON BRAKE AVAILABILITY

Carbon brakes became widely available for commercial airplanes in the 1980s. They are or were basic equipment on the Boeing 747-400 and -400ER, 757-300, 767, and 777 and the MD-11 and MD-90. They are basic equipment on the 787 Dreamliner and 747-8.

Carbon brakes are optional and will be available for retrofit for the Next-Generation 737 via no-charge service bulletins. They are also available for retrofit via master change service bulletins on the 757-200, 767-200, and 767-300 and MD-10 models.

#### SUMMARY

In addition to offering a number of operational advantages relative to steel brakes — including longer life and higher performance — carbon brakes save weight, which lowers fuel consumption and can reduce CO<sub>2</sub> emissions.

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## Taxi braking recommendations for carbon and steel brakes

Because the wear mechanisms are different between carbon and steel brakes, different taxi braking techniques are recommended for carbon brakes in order to maximize brake life.

Steel brake wear is directly proportional to the kinetic energy absorbed by the brakes. Maximum steel brake life can be achieved during taxi by using a large number of small, light brake applications, allowing some time for brake cooling between applications. High airplane gross weights and high brake application speeds tend to reduce steel brake life because they require the brakes to absorb a large amount of kinetic energy.

Carbon brake wear is primarily dependent on the total number of brake applications — one firm brake application causes less wear than several light applications. Maximum carbon brake life can be achieved during taxi by using a small number of long, moderately firm brake applications instead of numerous light brake applications. This can be achieved by allowing taxi speed to increase from below target speed to above target speed, then using a single firm brake application to reduce speed below the target and repeating if required, rather than maintaining a constant taxi speed using numerous brake applications. Carbon brake wear is much less sensitive to airplane weight and speed than steel brake wear.

These recommendations are intended as general taxi guidelines only. Safety and passenger comfort should remain the primary considerations.