

Dynamic Vehicle Weight Reduction and Safety Enhancement

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ABSTRACT

The rising cost of fuel, global warming and the economy in general has increased awareness about the importance of vehicle weight as it relates to consumer cost savings at the gas pump. However, vehicle safety cannot be compromised at the expense of reduced weight, making it necessary to find a proper balance to satisfy all requirements. The *Ultra brake rotor*™ reduces weight by as much as 40% for each wheel which translates to significant improvements as defined by CAFE regulations. Fully compatible with original calipers and other wheel components, these rotors additionally provide enhanced vehicle reliability and performance. Independent laboratory tests demonstrate compliance to FMVSS 135, and a 40% increase in rotor and brake pad wear life. Weight reduction is achieved by casting an aluminum core structure around steel wear inserts to form a strong mechanical bond. The 2007 GM Yukon front rotor cast from traditional grey iron steel weighs 26 pounds, while an equivalent *Ultra brake rotor* part contains 8 pounds of steel and 9 pounds of aluminum for a total weight of 17 pounds. Since aluminum has thermal conductivity properties superior to that of grey iron steel, performance improvements result from expected operation as friction heat is rapidly transferred from the steel inserts into the aluminum and then dissipated to air.

This paper details the test results to support 20 - 30% longer pad life, less rotor wear, with 40% reduction in weight when compared to conventional steel rotors.

OBJECTIVE

The primary goals of the *Ultra brake rotor* are to:

1. Provide wheel assembly weight reduction for improved fuel economy
2. Provide a rotor component that is compatible with current OEM mating parts
3. Improve heat transfer performance during brake operations
4. Improved handling and braking

A front version of the *Ultra brake rotor* for a 2007 GM Yukon is shown in Figure 1

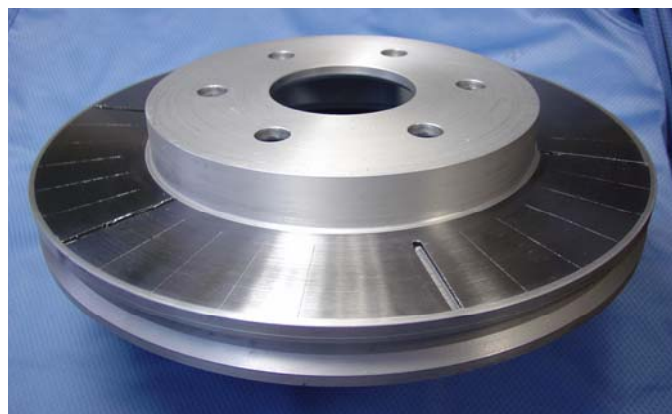


Fig. 1 – the *Ultra brake rotor*

PROBLEM DEFINITION

Fuel economy in vehicles is impacted by many factors, such as engine efficiency and mass weight. Efforts are constantly being made to improve on these and other factors to provide consumers with affordable solutions to the rising cost of gas. There is also a heightened awareness of conservation concerns as a result of topics such as global warming, environmental preservation, and reliance on foreign oil.

Developing ways to reduce weight in a vehicle are realized by replacing typical automotive steel with alternative materials such as engineering plastics, composites, and common metal alloy. Many material choices weigh substantially less than conventional steel. But since many of the available materials are either still unproven or cannot yet be economically produced, there is reluctance to implement them as a weight reduction solution. Changes effected by use of certain new materials often require a paradigm shift within the automotive industry.

Such may be the case when applied to a vehicle component where safety considerations are paramount. Brake rotors have traditionally been manufactured from grey cast iron for decades, and performance expectations are well known.



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APPROACH

The *Ultra brake rotor* accomplishes the goal of providing weight reduction by casting conventional aluminum alloy to form the main rotor structure around steel wear inserts. As shown in Figure 2, each wear insert is configured with steel beads that provide the means of physically joining the parts together.

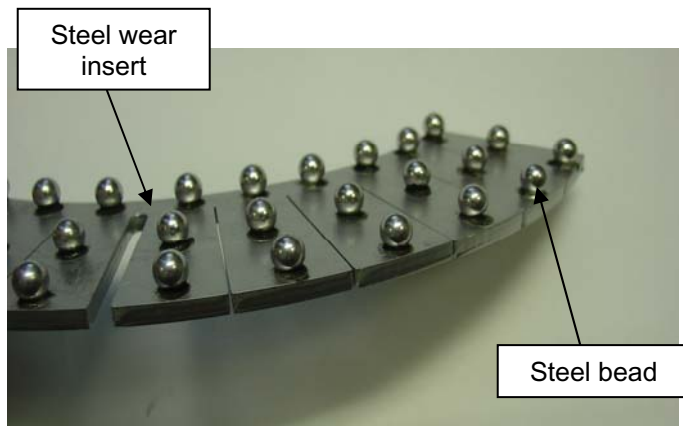


Fig. 2 – Steel Wear Insert

In the casting process, molten aluminum flows around each steel bead creating a strong mechanical bond to the aluminum. Figure 3 shows a section view model of a machine finished rotor with the steel wear inserts and aluminum casting as a unitary component. The resulting rotor product weighs far less than a rotor cast entirely in iron, providing vehicle performance benefits that allow faster acceleration, shorter stopping distance, fuel savings, and improved emissions.

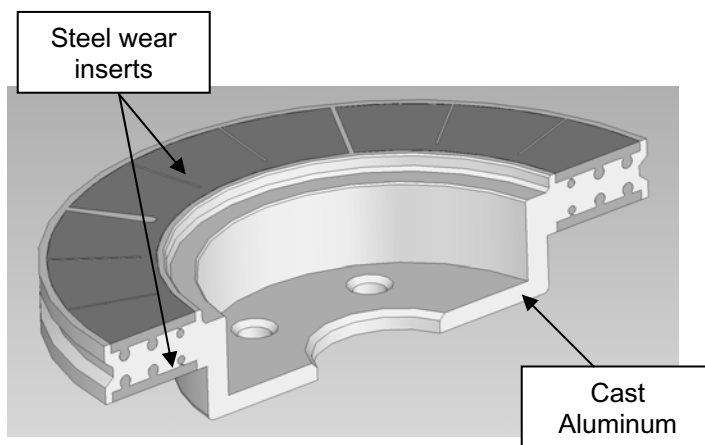


Fig. 3 – Sectioned rotor model

The use of steel inserts ensures that rotor wear surfaces in contact with brake pads remain consistent with existing cast iron rotors. However, while wear performance characteristics are not changed when compared to current OEM rotors, marked performance improvements benefit from the cast aluminum core structure. Aluminum alloy has thermal conductivity properties far superior to that of conventional grey iron steel, allowing for friction heat in a braking operation to be rapidly transferred from the steel inserts into the

aluminum body where it can then be dissipated to air. This translates into advantages that enable longer pad wear life and improved brake fade performance. Aluminum also offers superior corrosion resistance.

METHODOLOGY

From a weight reduction standpoint, casting aluminum alloy A356, the alloy used to produce the 2007 GM Yukon rotor shown in Figure 1, has a density of 0.097 lbs/in³ versus ASTM A-48 grey cast iron which compares at 0.25 lbs/in³. The current OEM Yukon front rotor weighs 26 pounds, while an equivalent *Ultra brake rotor* weighs 17 pounds; 9 pounds of aluminum and 8 pounds of steel wear insert components.

Considering now the comparative thermal properties of the different materials, A356 aluminum has a thermal conductivity of 92 Btu•ft/hr•ft²•F, far superior in comparison to 28-30 Btu•ft/hr•ft²•F for typical ASTM A-48 cast iron.

It is well known that the basic principle for braking a vehicle involves a driver increasing pressure on the brake pedal to slow down or stop, and that brake response declines, or “fades” as a result of overheated brake components. The rotors and pads reach a point where they become unable to absorb additional heat and therefore cannot generate the friction required to perform effectively. Physics dictates that all brakes will eventually fade once a certain temperature has been reached. In an effort to reduce the heat build-up and lessen the effects, many different techniques have been used to produce brake components that operate as cool as possible. For example, better heat resistance can be achieved by using semi-metallic linings in place of non-asbestos organic or low-met linings, and heat can be dissipated faster by venting the brake rotor.

In the OEM brake rotor, the elevated temperature of surfaces in friction contact with the brake pads is transferred throughout the mass of cast iron where it is then very slow to dissipate. Brake pad components degrade faster the longer they are exposed to the elevated rotor temperature.

Since aluminum is a better heat exchanger than steel, it is capable of pulling the heat away from the steel wear insert surfaces where friction is occurring. Again because of the greater thermal properties available in aluminum, the equivalent stored heat mass can be rapidly dissipated to air.

Relative to both weight reduction and thermal performance improvements, the design and manufacturing process for the *Ultra brake rotor* allows additional opportunities in these areas. The thickness of a cast iron rotor is dictated by design and processing constraints based on minimum wall sections that can be reliably cast to produce a part that meets strength and performance requirements. In addition, many automotive rotors, especially front mounted ones, also require cored