TIG
TITANIUM
INFORMATION
GROUP

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Automotive Applications

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Increasing demand for more fuel-efficient and environmentally friendly road vehicles has focused interest on weight reduction and improved performance. Automotive applications of titanium follow logically from the high strength, low density and, in select applications, low modulus of titanium alloys, and their excellent resistance to corrosion and oxidation. Titanium has a long record of success in performance and racing cars. Applications include:

- Valve Springs
- Valves
- Valve retainers
- Rocker arms
- Gudgeon (wrist) pins
- Cam belt wheels
- Connecting rods
- Clutch discs, springs and housings
- Gear box housings
- Drive shafts
- Exhaust systems
- Steering gear
- Suspension linkages
- Torsion bars
- Suspension springs
- Wheels
- High strength fasteners
- Brake calliper pistons
- Bumper supports
- Damage tolerant underpanels

Reducing the weight of motor vehicles, private cars in particular, is just one aspect of the complex challenge which today's automotive designers are facing. Making cars smaller, - an apparently obvious strategy, creates problems in providing acceptable free space inside the vehicle for passengers and their effects. Small, lighter weight cars are unlikely to satisfy the aspirations of every owner or driver. Weight reduction in this class of car, - without compromise to space, contributes to the reduction of fuel consumption, and the ‘green’ image of the manufacturer. Cost represents a particular challenge for fundamentally more expensive materials such as titanium. A recent check in the US and Europe suggests the following levels of cost are affordable for weight saving.

Type of Vehicle	**£/car/ kilo of weight saved**	**$/car/lb of weight saved**
Mass production	£1.50 - £2.00	$1.00 - $1.33
CAFE *limited	£3.00 – £15.00	$2.00 - $10.00
Speciality and Luxury	£5.50 plus	$3.66 plus

**CAFE = Corporate Average Fuel Economy (USA)*

Design Concepts

Overall, a vehicle weight reduction of 1% is claimed to give a reduction in fuel consumption of some 0.7%. Weight reduction in the moving parts of the engine is however likely to be much more effective in achieving improved fuel economy than body weight reduction. Titanium alloy density is some 60% that of steel, and the elastic modulus is about half that of steel. Direct substitution of steel parts with titanium is rarely the best way to proceed, but in practice should produce an immediate weight reduction of at least 40%. The low modulus of titanium is beneficial for springs, but component redesign may be necessary in stiffness limited applications. Specific strength, and likewise specific toughness and fatigue limits of titanium compare very favourably to both steel and aluminium alloys.

Comparison of specific strength of engineering alloys

Material	Density kg/l	Young's Modulus	Yield Strength	Specific Strength
CP Titanium	4.51	105 GPa	250 - 450 MPa	50 - 100
Ti-6Al-4V	4.43	112 GPa	900 – 1100 MPa	200 - 250
Ti - LCB®	4.79	110 GPa	950 – 1400 MPa	200 - 290
Carbon Steel	7.8	200 GPa	350 - 450 MPa	45 - 60
Aluminium Alloy	2.8	70 GPa	100 - 350 MPa	35 - 125

SPRINGS

Uniquely among engineering alloys, titanium possesses the strength, density and modulus to make the 'ideal' spring for almost every application. The key to successful spring design is to optimise the saving of weight and space. Correctly designed titanium springs can be typically three quarters the height and 60 - 70% lighter than steel equivalents. The aerospace industry has long used titanium alloy springs in a wide range of applications.

How does titanium permit such competitive spring designs? Two equations govern the weight and the deflection under load of coil compression springs. In the first equation for spring weight, the load L and the spring rate R are fixed by the designer for the application, the low shear modulus and low density of titanium are in the numerator of the equation, and high allowable stress in the denominator. Weight is therefore minimised when titanium is used. In the second equation, the low shear modulus of titanium is in the denominator, thus deflection is increased. As a consequence the number of active coils may be reduced, this in turn permitting a reduction of the free height of the spring (50- 80% that of a comparable steel spring), with further weight reduction, and a higher natural frequency.

The TIMETAL LCB™ monoshock coil spring on the 2006 Yamaha YZ250 MX bike is 30% lighter than an equivalent steel spring

Equation 1

$$\text{Spring Weight} = \frac{Gr \times 2L^2}{T^2R}$$

G = Shear Modulus
r = Density
T = Allowable Stress
L = Load
R = Spring Rate

Equation 2

$$\text{Spring Deflection} = \frac{L \times 8ND^3}{Gd^4}$$

N = Number of Coils
D = Diameter of Coils
d = Diameter of Wire

Titanium springs can be produced by hot or cold coiling and should be finished by shot peening, typically to .16 - .18A intensity. Beta alloys such as Beta-C™, LCB® (Low Cost Beta), as a class offer designers many options to select a final combination of properties for specific application e.g. as valve or suspension springs. Consultation with the alloy producer and the spring manufacturer is recommended in order that the appropriate method of manufacture and finishing is used.

Most of the commonly available titanium alloys have been used in automotive applications. You are advised to consult with alloy producers and suppliers among the member companies of the Titanium Information Group. They will be pleased to advise on the most suitable or available alloy for any specific application.

FOR FURTHER INFORMATION CONTACT

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