

Liquidmetal alloys in automotive pressure sensors

Challenge

Meet growing demand while maintaining product innovation, with price sensitivity as a priority.

Based on current forecasts the global pressure sensor market could amount to \$9.36 billion by 2020, according to a report published by Transparency Market Research. Automotive is the largest revenue generating segment in the pressure sensor market, but many others including aircraft, oil and gas, consumer electronics, heavy machinery, industrial, and medical are experiencing a similar demand. This novel application acts as a transducer, generally measuring gas and liquid pressure. When a gas or liquid expands, the sensor generates a signal as a function of the pressure imposed. There is a wide range of applications and technology surrounding the pressure sensor market including, but not limited to: altitude, flow, depth, pressure, system leak, and radiometric correction of transducer output sensors. This case study will analyze how Liquidmetal technology could be an economic and engineering advantage in the automotive pressure sensor market.

The challenge

In addition to technology advancements, changing laws and regulations are major reasons why pressure sensors are a growing product in the automotive market. The sensor collects and relays valuable information about engine performance, energy efficiency, and an object's environment. For example, in the United States, European Union, and other countries, tire pressure sensors are required by law in registered motor vehicles. These sensors must be capable of detecting when one or more of the vehicle's tires is 25% or more below the manufacturer's recommended inflation pressure.

Current tire pressure laws in the US have been in place for over eight years, resulting in improved vehicle safety and fuel efficiency. Unfortunately, these products are expensive and can fail easily due to environmental changes or minor manufacturing flaws. Some forecasts suggest demand for tire pressure monitoring systems will triple in size over the next five years, resulting in substantial market opportunity for manufacturers. Increased volume will undoubtedly ramp up expectations for manufacturers to improve the product and their yield rates.

\$1.69 billion

2014 automotive pressure sensor market size.

3x

Projected pressure sensor market growth by 2020.

Typical materials used to form pressure sensors include 17-4PH and 316L stainless steels. These materials are subject to physical deformation, embrittlement, and property changes over time. Whether or not it is liquid or gas being measured, along with the temperature applied, can have an impact on the different steels. Burst failure, caused by pressure spikes, along with corrosion are common causes of failure. 17-4PH withstands pressure spikes better than 316L, but is less corrosion resistant, forcing a trade-off. Stainless steels used today also have to protect the electronics from the damaging effects of exposure to the liquids and/or gases for which they are monitoring. Both are challenging requirements because these materials experience cyclical stress, which can lead to micro-fractures thus allowing fluids and gases to penetrate the sensing device.

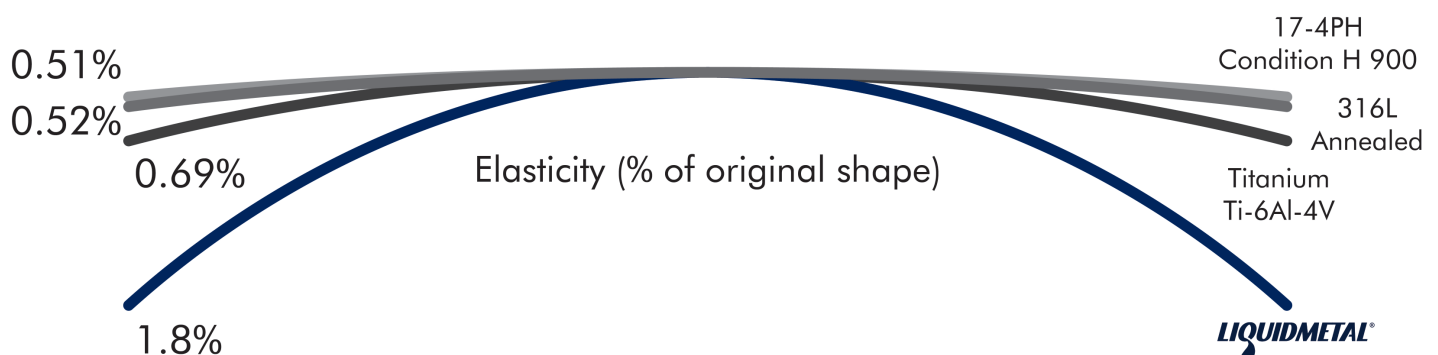
The solution

For the first time, the same concept seen in plastic injection molding is available with metal. The result is the capability to mold complex metal shapes in one step, with a

resulting alloy that is strong, hard, light, and corrosion resistant. Different pressure sensor technologies contain many different components, but when considering the general technology, Liquidmetal alloy offers several viable manufacturing options when compared to traditional manufacturing methods.

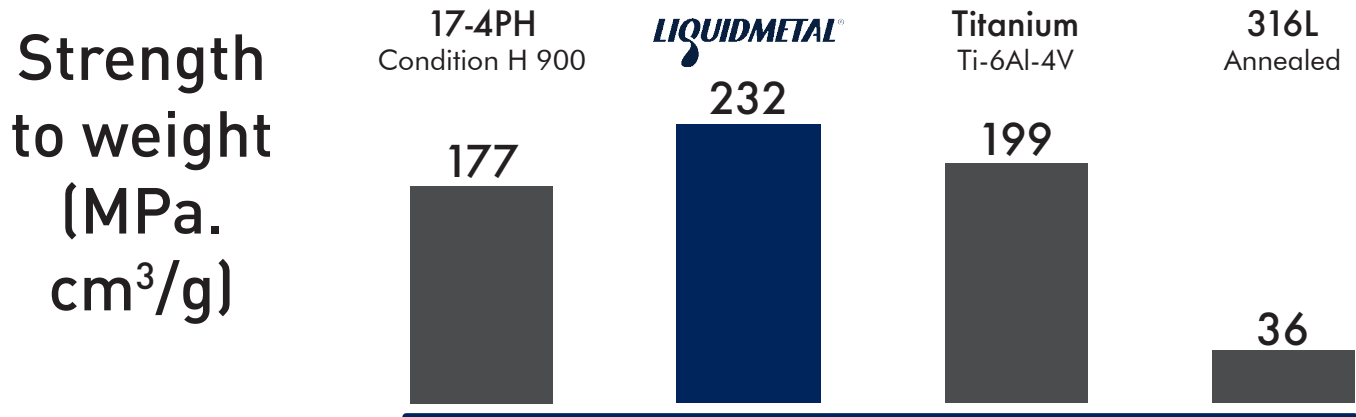
Accuracy over time

A well built pressure sensor requires the mechanical properties of its diaphragm to be maintained over hundreds of millions of cycles and decades of use to achieve accurate results over the lifetime of the sensor. Recalibration for drift due to aging is possible but undesirable. Membranes made from Liquidmetal are extremely stable, exhibiting consistent elastic deflection with extensive use. Previous success highlighted by this property came in the form of a medical clamp that improved cycle fatigue by over 1000%. More information about this specific application is available on the Liquidmetal blog.



Size and Weight

Many applications require the overall volume and mass of sensors to be minimized. Liquidmetal alloys are stronger than titanium, allowing smaller, lightweight membranes to withstand higher pressures than conventional metals.



Pressure spikes

The high strength of Liquidmetal parts also allows highly sensitive sensors to withstand extreme spikes in pressure. In combination with its elasticity, Liquidmetal represents a rare combination of mechanical properties that cannot be found in traditional materials.

Yield strength (MPa)

1379

17-4PH
Condition H 900

1524

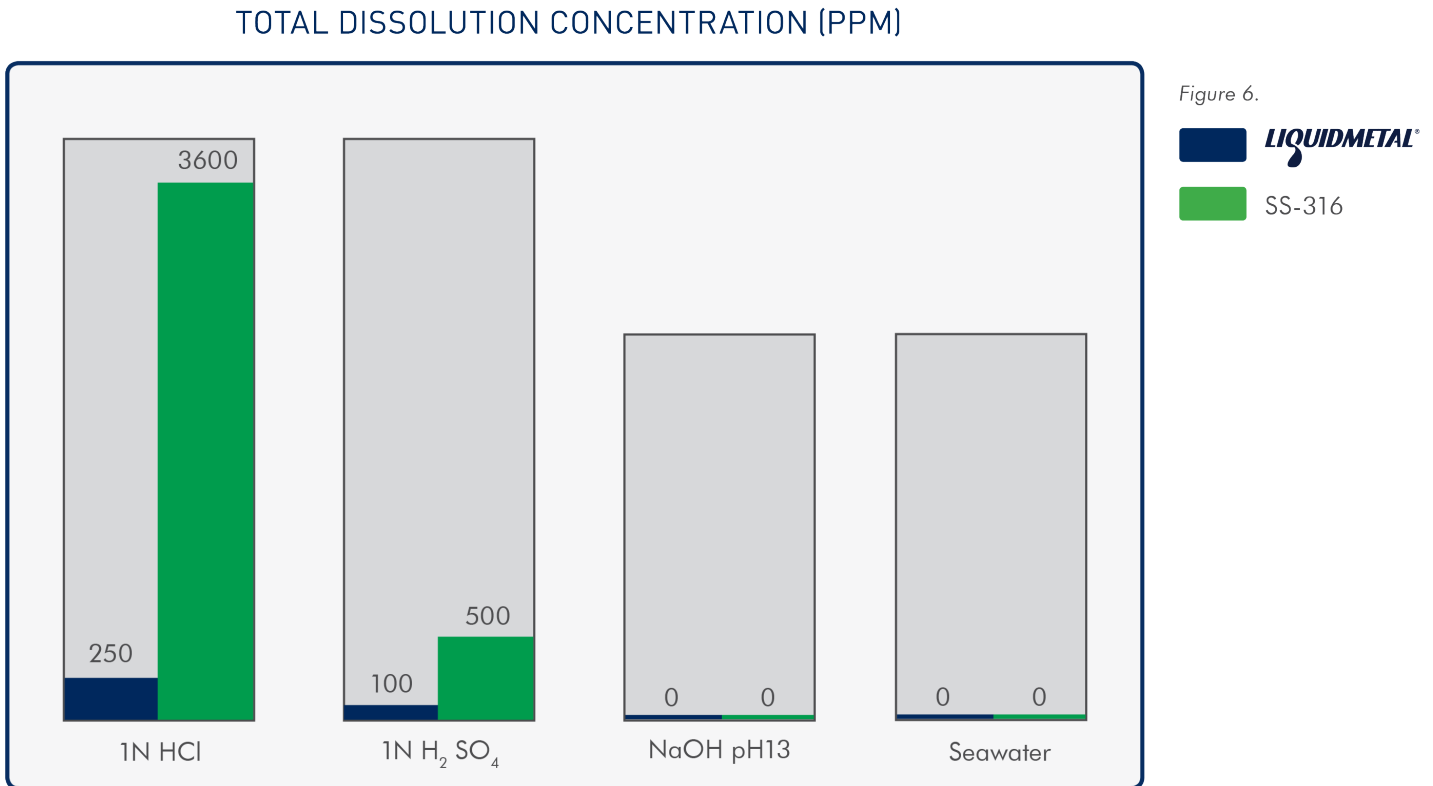
LIQUIDMETAL[®]

880

Titanium
Ti-6Al-4V

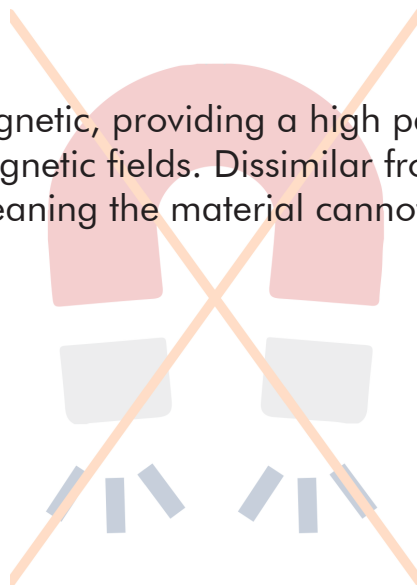
Harsh environments

Liquidmetal alloys are highly resistant to corrosion from water, saline solutions and many acids, making them suitable for many harsh-environment applications. The chart on the right demonstrates the superior performance of Liquidmetal alloys over 316 stainless steel in both hydrochloric acid and sulfuric acid.



Non-magnetic

Liquidmetal alloys are non-magnetic, providing a high performance option for applications sensitive to magnetic fields. Dissimilar from stainless steels, Liquidmetal is diamagnetic, meaning the material cannot become magnetic over time.



Burst-valve

Unlike conventional metals, Liquidmetal parts do not plastically deform, meaning that they will break when pushed past their elastic limit, but will not bend. This property may be incorporated into pressure sensor designs to achieve a binary failure mode (working or not working, rather than incorrect readings) or burst valve functionality for protection against pressure spikes in the rest of the system.

Unified package

The Liquidmetal process allows the sensor housing and membrane to be molded as a single part, eliminating performance issues that may result from an imperfect seal between both parts.

PRESSURE SENSOR FACTORS	LIQUIDMETAL PERFORMANCE
MEDIA COMPATIBILITY	Highly resistant to most corrosive environments and chemicals
THERMAL STRESS	Lower Young's modulus and linear thermal expansion coefficient than titanium or steel
MECHANICAL STRESS	Entirely elastic deformation up to 2% strain
RESISTANT TO OVERLOADING	Liquidmetal alloys are roughly twice the UTS of titanium
ELECTROMAGNETIC INTERFERENCE (EMI)	Transparent to magnetic fields (similar to copper), and low electrical conductivity (similar to titanium)
PACKAGING	Liquidmetal sensor housing and membrane can be molded as a unified part

What manufacturing difficulties are keeping you up at night?

Precise

$\pm 0.0008''$

Complex shapes

1
molding step

Elasticity

1.8%





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