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DESIGN FOR A DUAL PURPOSE LIQUID LEVEL SENSOR
(PATENT PENDING)

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ABSTRACT

Traditional engineering concerns such as lubrication and cooling are still present even as vehicle functions become more complex. The established solution to monitor fluid levels has been a sight glass or a dipstick. More complex machines demand continuous knowledge of fluid levels without adding to operator workload. Remote monitoring of vehicle health will become normal and expected by owners and operators of evolving vehicle designs. This dual function fluid level sensor provides both electronic and operator monitoring of vehicle fluids, as well as redundancy in the event of electronic failure. Grouping of sensor components that are considered more likely to fail into one group, aids replacement when necessary. By incorporating a traditional dipstick into a continuous electronic monitoring solution, either method of level monitoring is facilitated.

INTRODUCTION

As vehicles become more complex, functions such as monitoring lubricant levels in the engine and transmission need to be addressed without involving an operator. As more functionality is designed into vehicles, this drives the need to package more components like wiring harnesses, hoses, and electronics into ever smaller spaces. Space constraints and accessibility issues are becoming commonplace, and these issues can sometimes be solved with remotely monitored sensors. For example, the dipstick used to check transmission oil levels in most automobiles has been removed to make room for other components under the hood.

Several technologies have been adapted for sensing liquid levels over the years: floats, ultrasonic, radar, laser, and capacitive. The subject sensor was designed using traditional capacitive technology due to the lack of moving parts, cost, and reliability. One major advantage of this particular design is that is serves two purposes: remote electronic sensing or the traditional dipstick. It can be used in an electronic fashion by sending information to a central controller for displaying the fluid level (or sending a notice) or by the traditional “dipstick” method of reading the fluid level manually. Redundant functionality is important to success in many operating environments.

As more technology is applied to powertrain sub-systems, the cost of replacing and repairing them has risen as well. By carefully controlling the lubricant levels, operating efficiency increases, and the cost avoidance of catching failures before they are catastrophic becomes more important.

This sensor technology would apply to any type of vehicle that utilizes a "high value" powertrain. Lack of, or low levels of coolant, lubricants, or hydraulic oils can all produce a mobility failure and high repair costs. The situation becomes even more difficult if the operator is no longer present and the vehicle location is remote. Information is key in deciding if the vehicle can continue with its mission or needs to be parked to avoid further damage.

Autonomous Vehicles

Commercial and military vehicles are in the midst of a large transition from operator control to autonomous control. The sophistication of the vehicle ranges from small throw-away devices to expensive and powerful vehicles that have been converted away from operator control to remote. This means that there is no constant (or even occasional) monitoring of mechanical condition while the vehicle is being operated. The importance of sensors and remote monitoring is quickly apparent when operating these vehicles remotely. Some would argue that the level of attention given to a vehicle instrument panel, in the days of smart phones, is the same as not having an operator present.

Fighting For Space Claim

Modern engine compartments are full of items that enhance performance, reduce emissions, provide comfort to the occupants, cool the engine, and containers to store fluids. Traditionally, the first indication of a fluid leak has been a spot of oil on the garage floor. This is later traced back to its source, and the leak is fixed. For military vehicles this is not possible due to armor over and under the powerpack, which obscures the leak until more serious symptoms start to occur. Even in non-military vehicles, tracing a leak back to its source could entail taking apart most of the engine. The congestion under the hood also acts as a deterrent to regularly checking the oil level. Figure 1 shows the typical congestion in modern engine compartments.

Figure 1: Jeep Wrangler 3.6 L Engine Compartment

The situation gets worse when industrial designers try to dress up the looks of the engine with molded plastic covers. Figure 2 shows a typical engine cover used to dress up an engine bay.

Figure 2: Jeep Wrangler Engine Cover

Even though the engine bays of vehicles have been filled to capacity with essential equipment, the basic operating fundamentals of monitoring temperatures and providing lubrication cannot be ignored.

DUAL PURPOSE LIQUID LEVEL SENSOR

Having a remote sensor that continuously monitors lubrication fluid level in an area that is hard to access is extremely valuable. Running out of fluids can result in lack of mobility (potentially dangerous) and extensive damage (expensive). Having a vehicle out of service can have other more serious consequences in a tactical situation. Shown in Figure 3 is an electronic sensor that also allows users to manually check fluid levels in the normal fashion.

Figure 3: Dual Function Level Sensor

Operating Principles

The L3 fluid level sensor works by measuring capacitance as the fluid level travels up and down inside two co-axial elements. It also has a second ability to be used as a traditional dipstick by withdrawing the bayonet from the tube and observing the level of oil visually. A built in circuit card converts the capacitance into a frequency sent to the vehicle that varies from 100-160 kilohertz (kHz). This frequency can, with software logic, be used to drive warning lights or audible tones for the operator. The “bayonet” portion of the dipstick (anode) is coated in a polymer that will both insulate the internal metal and prevent contact with the outside tube (cathode). The handle of the dipstick is also insulated from vehicle electrical ground to prevent the body of the maintainer having an effect on the measured capacitance. Electrical signals from the anode are passed to the circuit card through spring contacts and a radial metallic band that functions as a form of stationary slip ring.

Dual Function

What makes this sensor different from all other dipsticks is that maintainers are able to read the fluid level without electronic assistance or by allowing the vehicle to monitor and alert the operator when necessary. This also provides redundancy in the case of malfunctioning electronics or software. It also provides the ability to access fluid level without powering up the vehicle. Figure 4 shows the dipstick being used in the traditional fashion with the bayonet being removed from the tube to inspect the oil level. The main part of the sensor remains attached to the housing.

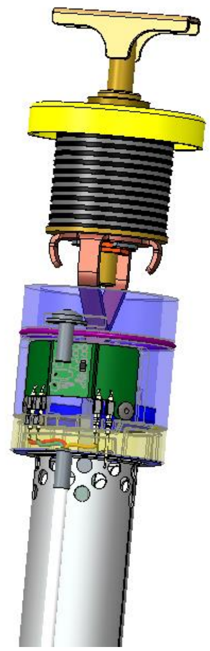

Figure 4: Removing Dipstick from Housing

On the Fly Measurement

Measuring oil levels while the vehicle is in motion can be an advantage by detecting leaks before damage occurs. As the vehicle moves across hills and corners, the liquid level in the sump is affected by gravity and centrifugal forces. This in turn affects measured levels. In the future, it will be possible to simultaneously measure vehicle roll and pitch and mathematically modify the measured oil level based on vehicle attitude. Mathematic functions can also be used to smooth response in order to filter out transient conditions.

Easily Replaced Electronics

The sensor has been designed to make important components such as a circuit board and the dipstick field replaceable by a technician with minimal skills. The upper and lower portions of the housing function as an electrical connector that allows the hard wiring of the vehicle/sensor to be separated from the electronics of the sensor. This also means that all functions that would traditionally be associated with low failure rates have been put into a group that remains wired into the machine's main wiring harness. Higher failure rate items have been grouped into a replaceable housing that is more easily accessed and replaced in the engine bay if required. Figure 5 shows how the electronics housing can be removed by loosening a screw, while the lower housing remains in place, with no wires removed.

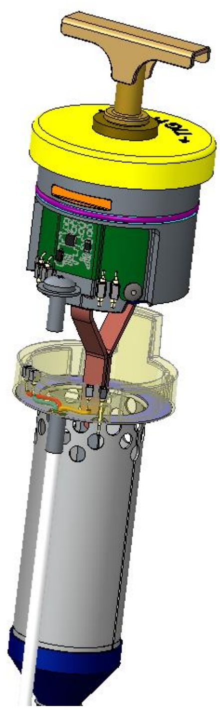

Figure 5: Replacement of the Electronics Housing

TESTING

Prototype sensors were tested in a transmission housing with clear sides. Oil was added from the top and the level was read with a steel ruler while at the same time capacitance was measured with bench instruments. Figure 6 shows one of the calibration curves produced in this manner.

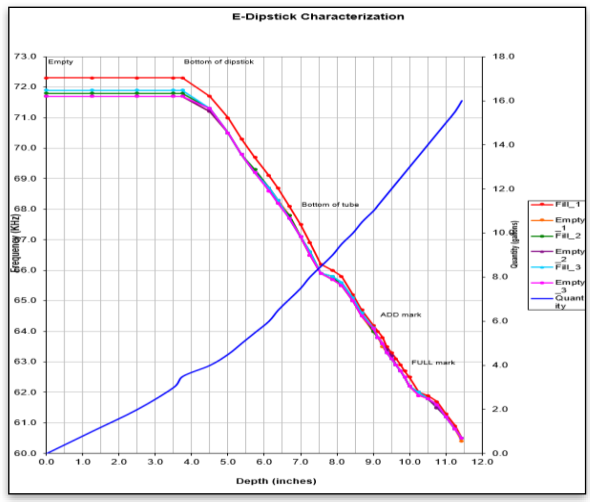

Figure 6: Fluid Level Characterization Curve

Without any statistical basis, initial testing has shown that this sensor is repeatable to approximately .50 inches at the lower fluid levels that were tested and approximately .13 inches at the higher fluid levels. This is particularly suited to this type of sensor because low fluid levels are typically gross problems like leaks and higher levels are controlled for efficiency. This sensor provides more than adequate functionality in the vehicle but it is not capable as a laboratory instrument.

Testing was also performed on a functioning transmission where oil foaming has been noted as a problem. Oil inside the sensor near the measured level does not experience much flow. This results in the measured level being much more consistent than readings taken visually with a dipstick.

Oil quality was also considered as a source of measurement variation. New oil and oil contaminated with brake dust were tested, and no change in accuracy was found. More testing is planned, but any “reasonable” level of oil contamination, either metallic or non-metallic, is not expected to adversely impact sensor functionality. Using different fluids other than the oil tested may impact the frequency response of the sensor. This would be addressed when setting up the indicator levels in the software. Other planned changes are expected to increase repeatability.

SUMMARY

The low technology dipstick of the past can now evolve and be used in the world of mechatronics and autonomous vehicles. This design is capable of providing the data needed to verify correct vehicle operation and still be useful to normal maintainers. The accuracy is not a laboratory instrument but is far superior to discrete level indicator. Redundancy is provided in case of electronic failure and can be quickly repaired without interaction with the vehicle wire harness.