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Proceedings of The Institute of Acoustics

PIEZOELECTRIC TRANSDUCERS FOR USE IN KNOCK DETECTION

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In these days where the supply of carbon based fuel seems to be literally drying up, it has become of paramount importance that we utilise the fuel we have remaining in a more efficient manner. To this end, major development programmes have been initiated to increase the efficiency of petrols use. The aerodynamic designing of car bodies to reduce drag, and the lightning of cars, are two of the main contributors to the future reduction of fuel wastage. Also in this field, research is being carried out into finding more efficient ways of burning the fuel in the engine itself, with advances in carburation and combustion chamber design. A major problem has been the adverse conditions in which any transducer has to operate when monitoring the pressure wave-forms inside a cylinder. These being, very high temperatures, severe conditions, and high atmospheric pressures. To overcome these problems, the instrumentation, to date, has been very expensive. There is now a system of PZT transducers on the market, which dramatically cut the cost, and ease the task, of trying to get these pressure wave-forms from the cylinder. These transducers can be used for the detection of incipient detonation through the associated high frequency cylinder oscillations, and, to aid in the determination of crank angle at peak cylinder pressure. Further development of this system, will allow a closed loop spark advance control, measuring cylinder pressures to determine the maximum torque (hence the best economy of fuel use) for spark timing. To be useful in the analysis of pressure time histories, a transducer must meet certain criteria:-

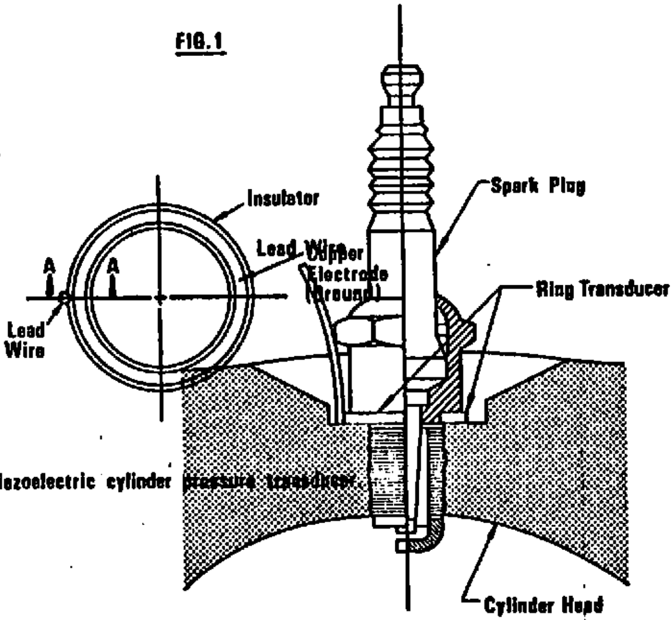
1. Generate a strong signal which is clearly distinguishable above the background vibration within the engine.
2. Have a band width of at least 15kHz to detect the characteristics of knock.
3. Be capable of surviving continuous exposure to temperatures of 250°C.
4. Be unaffected by temperature at the point where maximum cylinder pressure is detected.

Of prime consideration, it must be capable of being mass produced inexpensively and in automotive quantities.

This piezoelectric ring transducer meets all the above design criteria. The transducer itself is washer shaped, and has been designed for installation between the spark plug and cylinder head. Stress variations from the fluctuating cylinder pressures produce a voltage from the piezoelectric transducer. Referring to Figs. 1 and 2, we can look into the basic characteristics and formation of the transducer itself. The ceramic used to make the transducer is PZT 5A, a composition of lead, zirconia and titanium. PZT 5A has a Curie point of 365°C, well above the 250°C normal operating temperature. The washer shaped sensor uses copper as one of the electrodes

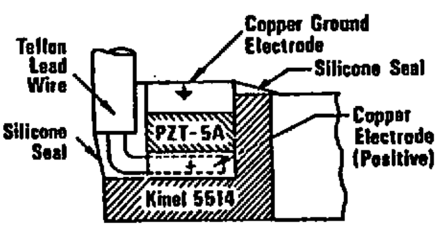
FIG.1

FIG. 2

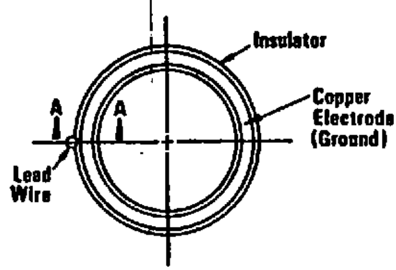


Piezoelectric cylinder pressure transducer.

FIG. 2



Cross section A-A of pressure transducer.



Piezoelectric cylinder pressure transducer.

and, for insulating mold material, a fibreglass reinforced polyimide plastic able to withstand high temperatures and corrosive environments. This type of plastic was selected for its precision machining qualities, high compressive strength, and high heat distortion temperature, which at 350°C is, again, well above the operating temperature of normal engines. The cross section shows the placement of the two copper electrodes in relation to the PZT 5A ceramic. Pick up from the PZT itself is via a PTFE covered wire able to operate at high working temperatures of up to 205°C continuous operation. The washer transducer is placed on the end of the spark plug and replaces the gas seal washer which is normally there. Changes of thermal conductivity, by the use of washers and transducers, cause a temperature change on the end of the centre electrode of the ignition plug of about +5°C. Data for this was obtained from NGK Company, in Japan. The voltage from this transducer, when stressed, is fed into a voltage follower circuit whose output is proportional to cylinder pressure. Initial calibration of the transducer washer can be obtained by pressurising the cylinders, with a known pressure, and formulating a calibration curve from these absolute results.

Experimental verification has been carried out, on these transducers, by working on a single cylinder engine, using a Champion 183 spark plug. The engine has a 6:1 compression ratio and at 1200 RPM, wide open throttle, the maximum cylinder pressure was 3.1 MPa, or 450 psi. Comparisons were made with a laboratory grade Kistler quartz piezoelectric pressure transducer, which tended to verify that the PZT sensor is sufficiently sensitive to detect detonation frequencies and valve timing events, marked by high frequency noise. The pyro electric effect of all piezoelectric sensors does generate a voltage, but the transducer temperature change is slow in comparison to the cylinder pressure. This voltage appears as a DC bias and is bolcked by the low frequency break point of the voltage follower circuit. The pyro electric voltage does not impede the sensors' efficiency in measuring cylinder pressure. The PZT measures cylinder pressure, without an appreciable phase shift, compared to the Kistler quartz transducer. The ability of the PZT sensor to detect knock is similar to the Kistler sensor, which can be seen from Fig 3.

Further development of the PZT would imply that a fairly simple electrical circuit, connected to the output signal, could be used for a closed loop control for automatic spark advance, by positioning the peak cylinder pressure desired during the power stroke of the engine. The experimental verification was from a paper by Kent W Randall of Systems Control Inc. and Prof. J David Powell of Stanford University.

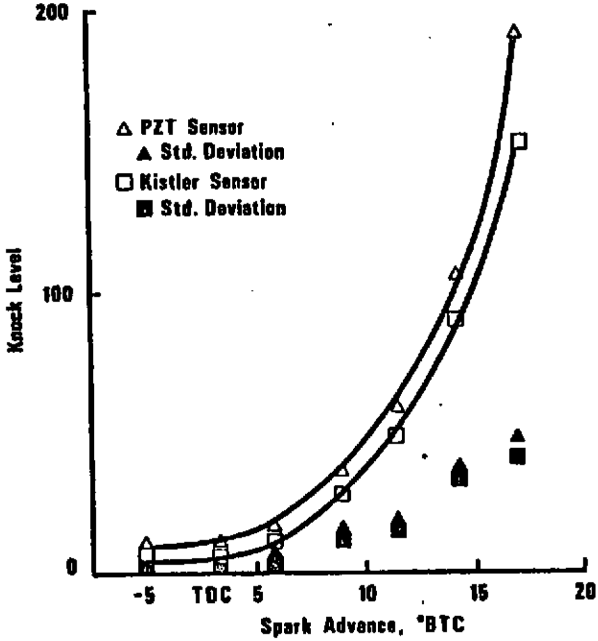


FIG. 3 Comparison of PZT and Kistler transducers knock level response at 900 rpm.