MEMS-based Handy Fuel Adulteration Detection Device

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Introduction: Adulteration of petrol and other automobile fuels is a rampant malpractice in India. With the rising prices of fuel and subsidy on kerosene, getting away with even 10-15% adulteration is immensely profitable. To check adulteration effectively, it is necessary to monitor the fuel quality at the distribution point itself. The equipment for this purpose must be handy and the measurement method quick. It should also preferably be economic and easy to use.

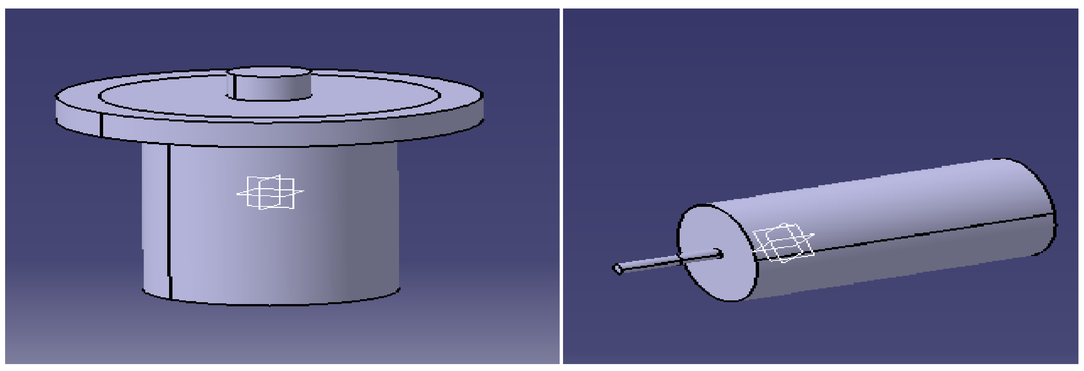

Figure 1. Sample holder with attachment

Computational Methods: A combined density and viscosity measurement is the best way to determine the % adulteration in a sample. As the aim is to keep the device as handy as possible, the use of a miniaturized sensor becomes imperative. MEMS-based AT-cut Quartz BAW (Bulk Acoustic Wave) Resonator proves to be the ideal choice for this purpose.

Physics involved – Structural Mechanics → piezoelectric device (pzd)

Crystal cut angles for AT and SC set using Rotated System Euler angles in Geometry.

Piezoelectric coupling relations for the resonator are as follows:

$$D_i = e_{ijk}S_{jk} + \varepsilon_{ij}E_j$$

$$T_{ij} = c_{ijkl}S_{kl} - e_{kij}E_k$$

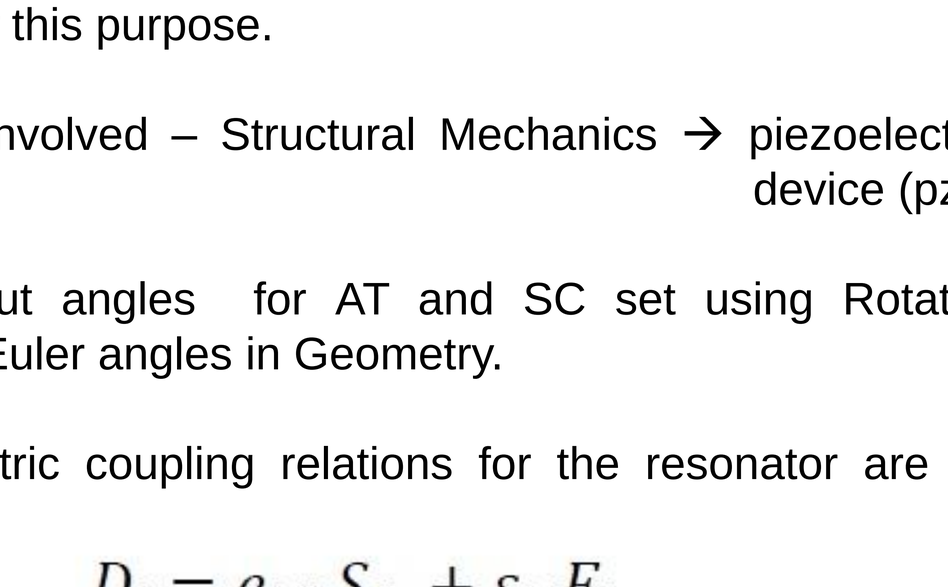

Figure 2. Basic geometry of quartz crystal

Results: Upon doing eigenfrequency study for AT and SC cut crystals, following results were obtained:

Gasoline/ Diesel Ratio (%vol)	Density of Mixture (g/ml)	Eigenfrequency Response AT -cut (Hz)	Eigenfrequency Response SC -cut (Hz)
100/0	0.76473	4.620583e5	3.676332e5
80/20	0.78334	4.60804785	3.666358e5
67/33	0.79835	4.5980185	3.658372e5
57/43	0.80754	4.5918978	3.653509e5
50/50	0.81482	4.587072e5	3.649669e5

Table 1. Data for Gasoline-Diesel mixture

Diesel/ Kerosene Ratio (%vol)	Density of Mixture (g/ml)	Eigenfrequency Response AT -cut (Hz)	Eigenfrequency Response SC -cut (Hz)
100/0	0.85204	4.562638e5	3.630229e5
80/20	0.84374	4.56805385	3.634533785
67/33	0.83893	4.5712e5	3.63704185
57/43	0.83526	4.573605e5	3.638955e5
50/50	0.83201	4.575738e5	3.640652e5

Table 2. Data for Diesel-Kerosene mixture

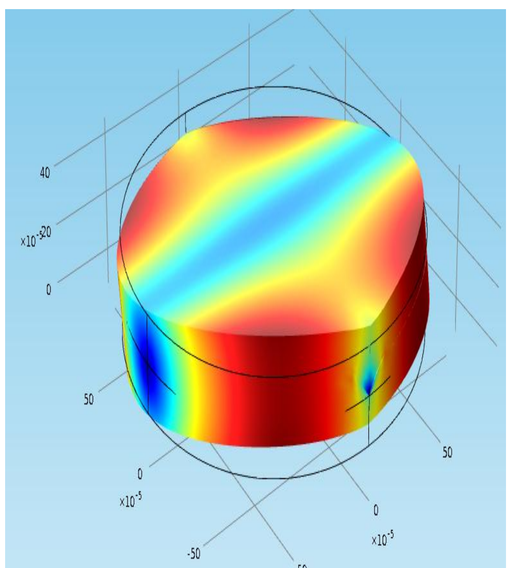

Figure 3. Loaded AT crystal

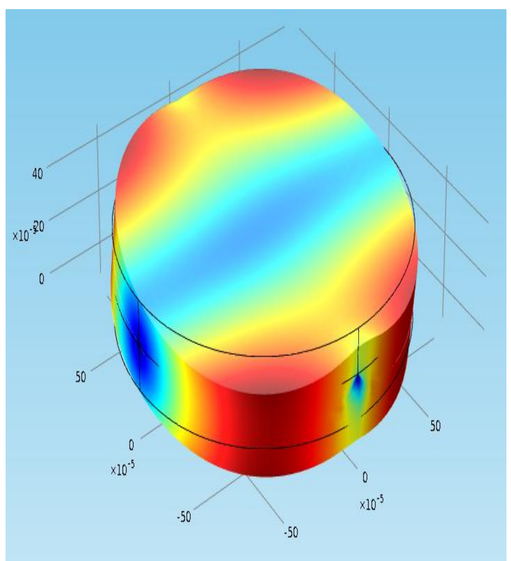

Figure 4. Loaded SC crystal

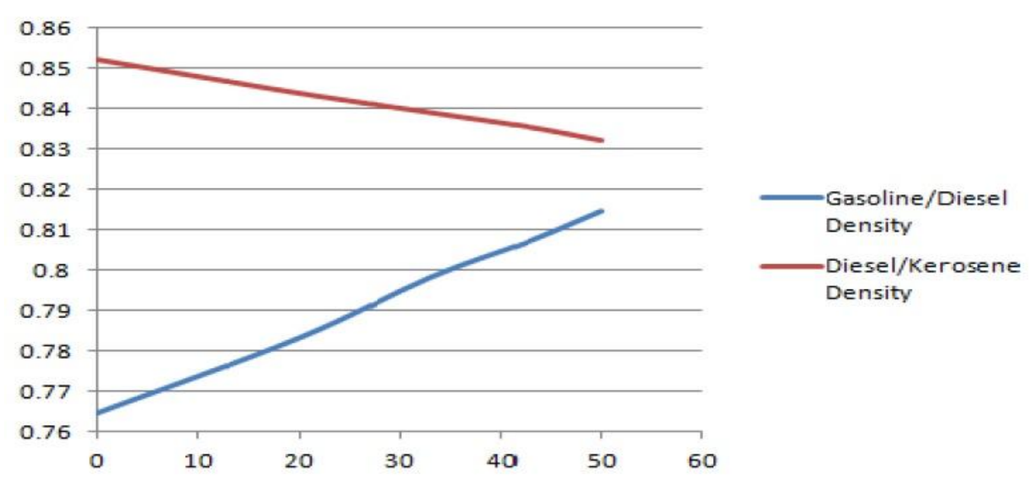

Figure 5. Density (g/ml) vs. % adulteration values

Conclusions: Sensitivity to fuel density changes of an AT-cut crystal is better than that of a SC-cut one and hence AT-cut TSM (Thickness Shear Mode) Quartz Resonator is better suited for such liquid sensing applications.

Reference:

Sh. R. Yadav, K. Murthy, D. Mishra and B. Baral, “Estimation of petrol and diesel adulteration with kerosene and assessment of usefulness of selected automobile fuel quality test parameters”, International Journal of Environmental Science and Technology, Vol. 1, No. 4, pp. 253-255, Winter 2005

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