CHAPTER IV

RESULTS AND DISCUSSION

GC-MS was employed for qualitative and quantitative analysis of selected polycyclic aromatic hydrocarbons (PAHs) in exhaust emission from a gasoline test engine. The selected PAHs, which are classified as the priority pollutants by U.S. EPA, are naphthalene, acenapthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, chrysene, benz(*a*)anthracene, benzo(*b*)fluoranthene, benzo(*k*)fluoranthene, benzo(*a*)pyrene, indeno(1,2,3-*cd*)pyrene, benzo(*ghi*)perylene, and dibenz(*a,h*)anthracene. A GC chromatogram of standard mixture PAHs is shown in Figure 4.1.

The computer software associated with the MS allows the output of the total ion chromatogram and background subtraction to yield mass spectra that are of individual peaks, or can take advantage of the SIM technique. Identification of individual peaks was performed by comparison of the mass spectra with the electronic library based on the Nation Bureau of Standard Library (NIST). The mass spectra and computerized searching results of individual selected PAHs in standard mixture are shown in Appendix C. Compounds identified in the standard mixture of PAHs from mass spectra are listed in Table 4.1.
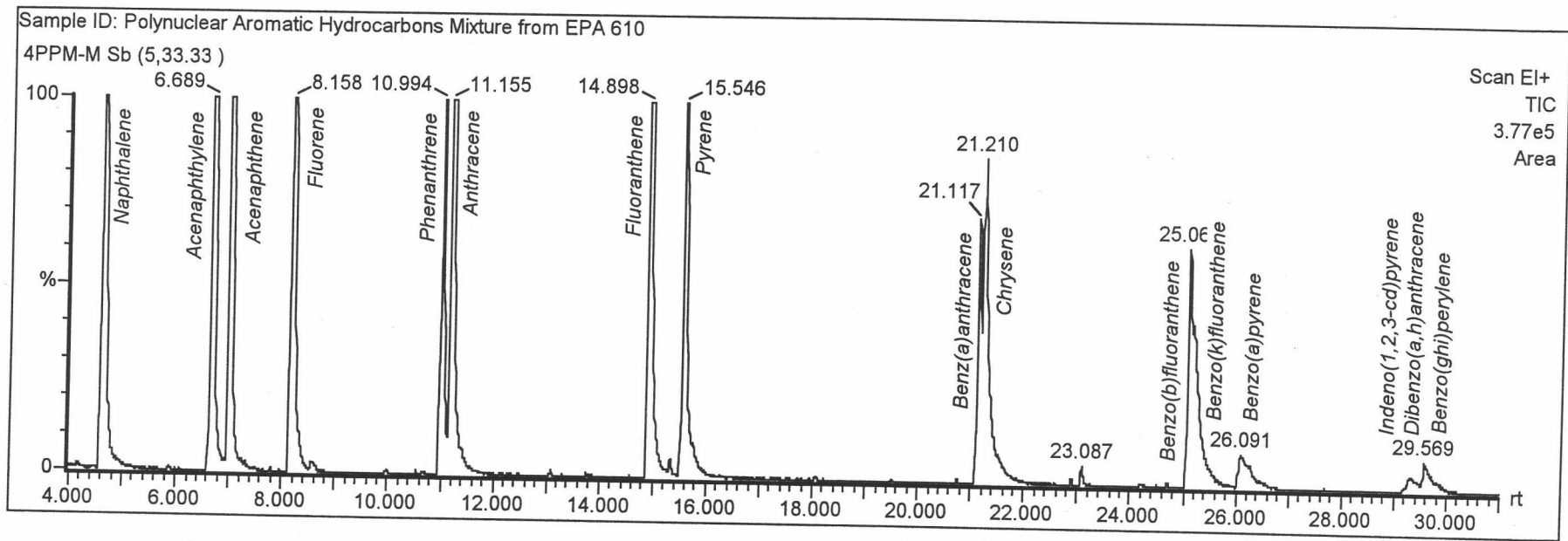
Figure 4.1 GC Chromatogram of Standard PAHs Mixture according to EPA 610

Table 4.1 List of Selected PAHs in Standard Mixture of PAHs according to EPA 610 including Retention Times and Detection limits

PAHs	MW	Retention time (min)	Detection limits (μg/ml)
Naphthalene	128	4.611	0.25
Acenaphthylene	152	6.689	0.25
Acenaphthene	154	7.026	0.25
Fluorene	166	8.158	0.25
Phenanthrene	178	10.994	0.25
Anthracene	178	11.155	0.25
Fluoranthene	202	14.898	0.25
Pyrene	202	15.546	0.25
Benz(*a*)anthracene	228	21.117	0.50
Chrysene	228	21.210	1.00
Benzo(*b*)fluoranthene	252	25.063	nd
Benzo(*k*)fluoranthene	252	25.157	nd
Benzo(*a*)pyrene	252	26.091	1.00
Indeno(1,2,3-*cd*)pyrene	276	29.189	2.00
Dibenzo(*a,h*)anthracene	278	29.309	2.00
Benzo(*ghi*)perylene	276	29.569	1.00

nd = not determined

The minimal detection limits of the GC-MS instrument used for analysis of selected PAHs [27] are also shown in Table 4.1.

The contaminants from materials used for sampling, and the recovery and repeatability of the analytical method are described in Appendix D [27].
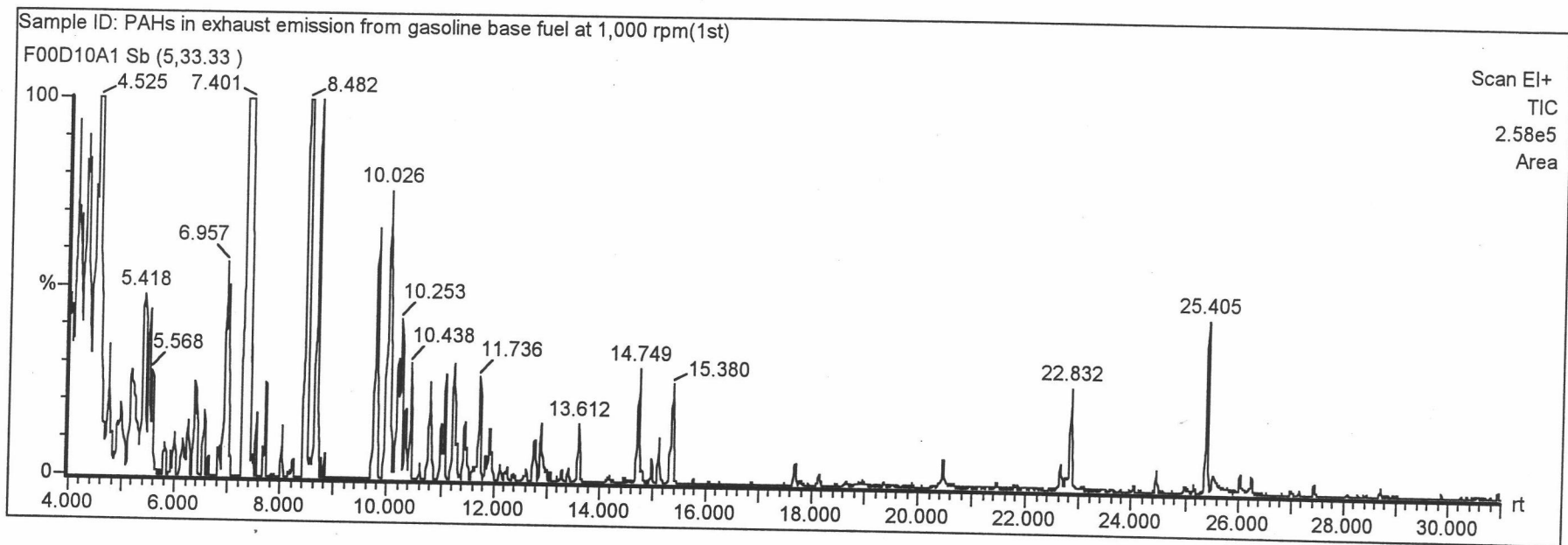
Figure 4.2 GC Chromatogram of an Extract from Gasoline Test Engine Exhaust at 1,000 rpm powered by Gasoline Base Fuel

The study of GC chromatrogram of an extract from gasoline test engine exhaust, as illustrated in Figure 4.2, for example, shows that the emission consisted of different levels of naphthalene, acenapthylene, fluorene, phenanthrene, anthracene, fluoranthene, and pyrene. SIM technique and computerized library searching were employed to support the identification. Appendix E illustrates the total ion chromatogram of a representative exhaust sample, including ion chromatograms, mass spectra, and computerized searching results of individual selected PAHs found in the exhaust samples. The patterns of total ion chromatogram of exhaust samples are similar even with different engine conditions or fuels.

The recovery of these PAHs is believed to account for the emission of PAHs already in the gasoline fuel or storage in the engine deposit and the pyrosynthetic reactions involving aromatic species or pyrosynthetic transformation of the aliphatic components of the fuel.

4.1 Effect of Engine Speeds on Emission of PAHs

Engine speed affects the swirl characteristics, ignition timing, and combustion temperature of the engine. At low engine speed, there is less swirl and lower combustion chamber temperature. At mid engine speed, the optimum swirl dynamics and optimum combustion timing develop the maximum power band for the engine. High engine speed generates over-swirl and shortens the period over which combustion proceeds [15].

Figure 4.3 shows the effect of engine speeds on total selected PAHs emission from gasoline test engine. When the engine speed was changed from 1,000 rpm to 1,500 rpm the total PAHs concentrations in exhaust emission was decreased. At 1,500 rpm there was greater turbulence and swirl, higher flame speed, and optimum combustion timing. Consequently, the fuel and air were mixed more homogeneously and burnt

more completely. At the engine speeds of 2,000 and 2,500 rpm, the total concentrations of PAHs increased because the higher speed may restrict the kinetics of the reaction in such a way that there is insufficient time for complete combustion, so that the pyrosynthetic reactions are more favoured.
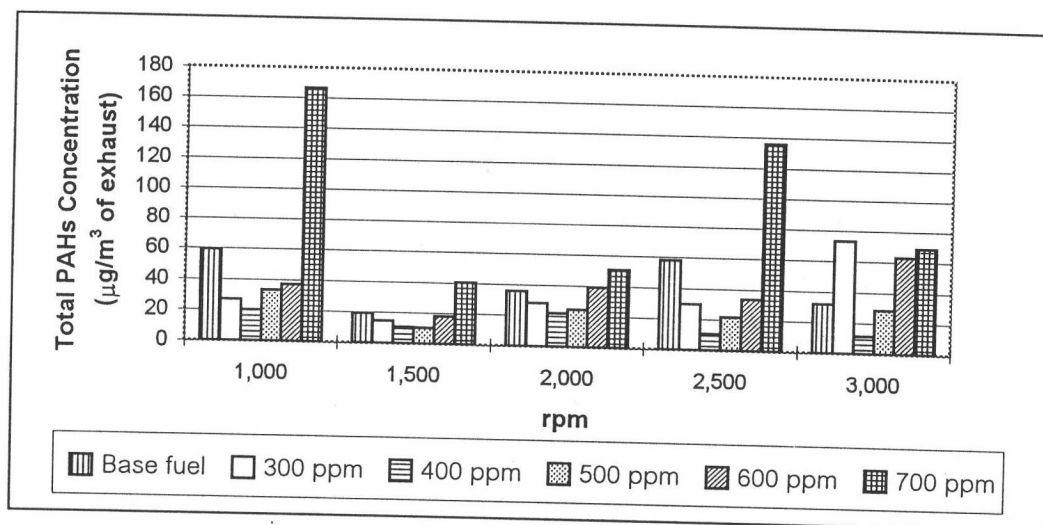

Figure 4.3 Effect of Engine Speed on Total PAHs in Gasoline Test Engine Exhaust Emission

At the highest speed of 3,000 rpm, the concentration of total PAHs decreased due to the over-swirl characteristic and heat loss of combustion chamber by the rich air-fuel mixture favouring neither complete combustion nor complete pyrosynthetic reaction.

4.2 Effect of Dispersant on Emission of PAHs

The total PAHs emission tended to decrease when a dispersant was blended into the gasoline base fuel, as shown in Figure 4.4. With the operation of dispersant, the deposits were removed from fuel injector or carburetor, valves and cylinder wall. The engine was cleaned up and kept-cleaned. The combustion process was more complete and consequently PAHs formed in the combustion process decreased.
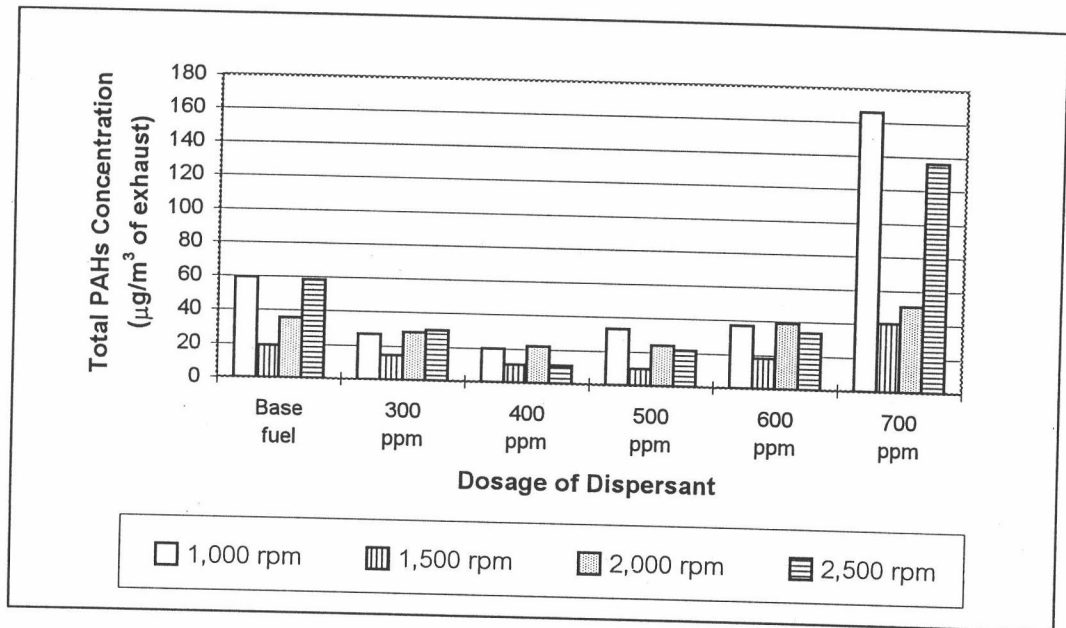
Figure 4.4 Effect of Dispersant on Total PAHs in Exhaust Emissions

The results of this study show that the effective quantity of dispersant for decreasing PAHs in exhaust emission is 400 ppm (v/v). PAHs in exhaust emission will increase if more dispersant is employed. The reason of this increment is that the dispersant used in this study is relatively high molecular weight polymeric material, therefore more addition in fuel may cause the higher incomplete combustion products that can pyrosynthesize to PAHs.