3106.41 cm$^{-1}$ for $\text{C}=$H alkene. These observations have been summarized in Table 5.

### 3.1.3. Nuclear Magnetic Resonance (NMR)

Analysis of the $^1$H NMR spectrum of polymer retarder additive (see Fig. 5) showed eight protons with four different peaks. The most shielded peaks with singlet signals resonated at $\delta$ 6.09 and $\delta$ 5.55 represented to terminal methylene of H-3a and H-3b. A singlet signal which integrated three protons and resonated at $\delta$ 3.74 belonged to the methoxyl protons (OCH$_3$) for ester functionality. Another singlet signal resonated at $\delta$ 1.93 represented the three protons of methyl group attached to C-2.

A total of five carbon signals were observed in the $^{13}$C NMR spectrum of retarder additive (see Fig. 6). The spectrum detected carbonyl carbon at $\delta$ 167.88 (C=O); a quaternary carbon at $\delta$ 136.20 (C-2); and a methoxyl carbon at $\delta$ 51.73 (OCH$_3$). The carbon signal at $\delta$ 18.27 corresponded to methyl carbon while methylene carbon (C-3) appeared at $\delta$ 125.36. The presence of a carbonyl, quaternary, methylene, methyl, and methoxyl carbons in $^{13}$C NMR spectrum is in agreement with the structure of polymer retarder additive of methyl methacrylate (MMA). Fig. 7 shows the structure of retarder additive while Table 6 tabulates the chemical shifts.

### 3.2. Effect of retarder additive on physical properties of fresh and hardened polymer resin

#### 3.2.1. Fresh working life of fresh polymer resin

The fresh working life of fresh polyester resin was visually observed to record the duration taken to become viscous before the curing process was complete. Fig. 8 shows the duration of fresh working life of polyester resins with different retarder additive contents. Results demonstrated that the overall fresh working life of polyester resins had gradually increased when the retarder additive was used.