Faraday's Law PAG

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```r
library(ggplot2)
library(splines)

g <- 9.81

my_theme <- theme(panel.grid.minor = element_line(colour="gray", size=0.4),
                  panel.grid.major = element_line(colour="gray", size=1),
                  panel.background = element_blank())

area_df <- data.frame(displ=numeric(0), A1=numeric(0), A2=numeric(0),
                      A_t=numeric(0))
peak_df <- data.frame(displ=numeric(0), max=numeric(0), min=numeric(0),
                      vel=numeric(0))

for (file in Sys.glob("*.csv")) {
s_df <- read.table(file, sep=",", header=TRUE)
colnames(s_df) <- c("V1", "V2", "V3")
s_df$t <- seq_along(s_df$V1)
d_start = 1
d_stop = nrow(s_df)

spl <- strsplit(file, "[._]")[[1]]
displ <- abs(strtoi(spl[1]) - strtoi(spl[2]))

for (i in 1:3) {
    message(paste(file, "run", i))
    message(paste("Displacement:", displ))

    V <- s_df[,i]
    my_glm <- glm(V ~ ns(t, df = 100), data = s_df)

    pred_func <- function(t) predict(my_glm, data.frame(t=t))[1]

    min_opt <- optimize(pred_func, lower=d_start, upper=d_stop, maximum=FALSE)
    max_opt <- optimize(pred_func, lower=d_start, upper=d_stop, maximum=TRUE)
    mid_opt <- optimize(function(t) abs(pred_func(t)), upper=min_opt$minimum,
                                                        lower=max_opt$maximum)

    int_1 <- integrate(Vectorize(pred_func), d_start, mid_opt$minimum)
    int_2 <- integrate(Vectorize(pred_func), mid_opt$minimum, d_stop)
    int_t <- integrate(Vectorize(pred_func), d_start, d_stop)
```

```r

    peak_df[nrow(peak_df) + 1,] <-
        list(displ, max_opt$objective, min_opt$objective, sqrt(2 * g * displ))

    area_df[nrow(area_df) + 1,] <-
        list(displ, int_1$value, int_2$value, int_t$value)

    print(ggplot(s_df, aes(x = t, y = V)) +
          ggtitle(paste("Faraday's Law induced EMF", file, "run", i,
                        "Displacement", displ)) +
          labs(x="t / (s * k)", y="V / V") +
          geom_point(size=0.07, color="red") +
          my_theme +
          geom_line(aes(y = predict(my_glm)), color="steelblue",
                    size=2, alpha=0.5))
}}

my_theme2 <- function(ggp) ggp +  geom_point(color = "red") + my_theme +
             geom_smooth(method="lm", formula=y ~ x)

my_theme2(ggplot(area_df, aes(x = displ, y = A1)) +
    ggtitle("Area under first peak vs displacement") +
    labs(x="s / mm", y="A/(k * Wb)"))

my_theme2(ggplot(area_df, aes(x = displ, y = A2)) +
    ggtitle("Area under second peak vs displacement") +
    labs(x="s / mm", y="A/(k * Wb)"))

my_theme2(ggplot(area_df, aes(x = displ, y = A_t)) +
    ggtitle("Total area vs displacement") +
    labs(x="s / mm", y="A/(k * Wb)"))

my_theme2(ggplot(peak_df, aes(x = vel, y = max)) +
    ggtitle("First peak height vs velocity") +
    labs(x="v / (mm / s)", y="E/V"))

my_theme2(ggplot(peak_df, aes(x = vel, y = min)) +
    ggtitle("Second peak height vs velocity") +
    labs(x="s / (mm / s)", y="E/V"))
```

There seems to be a roughly linear relationship between max induced EMF and velocity (fig 8). This would make sense as Faraday's law states that EMF is proportional to rate of change of flux, which when the field is uniform is in turn proportional to velocity. However the data sample is probably much too closely spaces to make any conclusions, as any roughly analytic function of displacement would probably produce a similar plot.

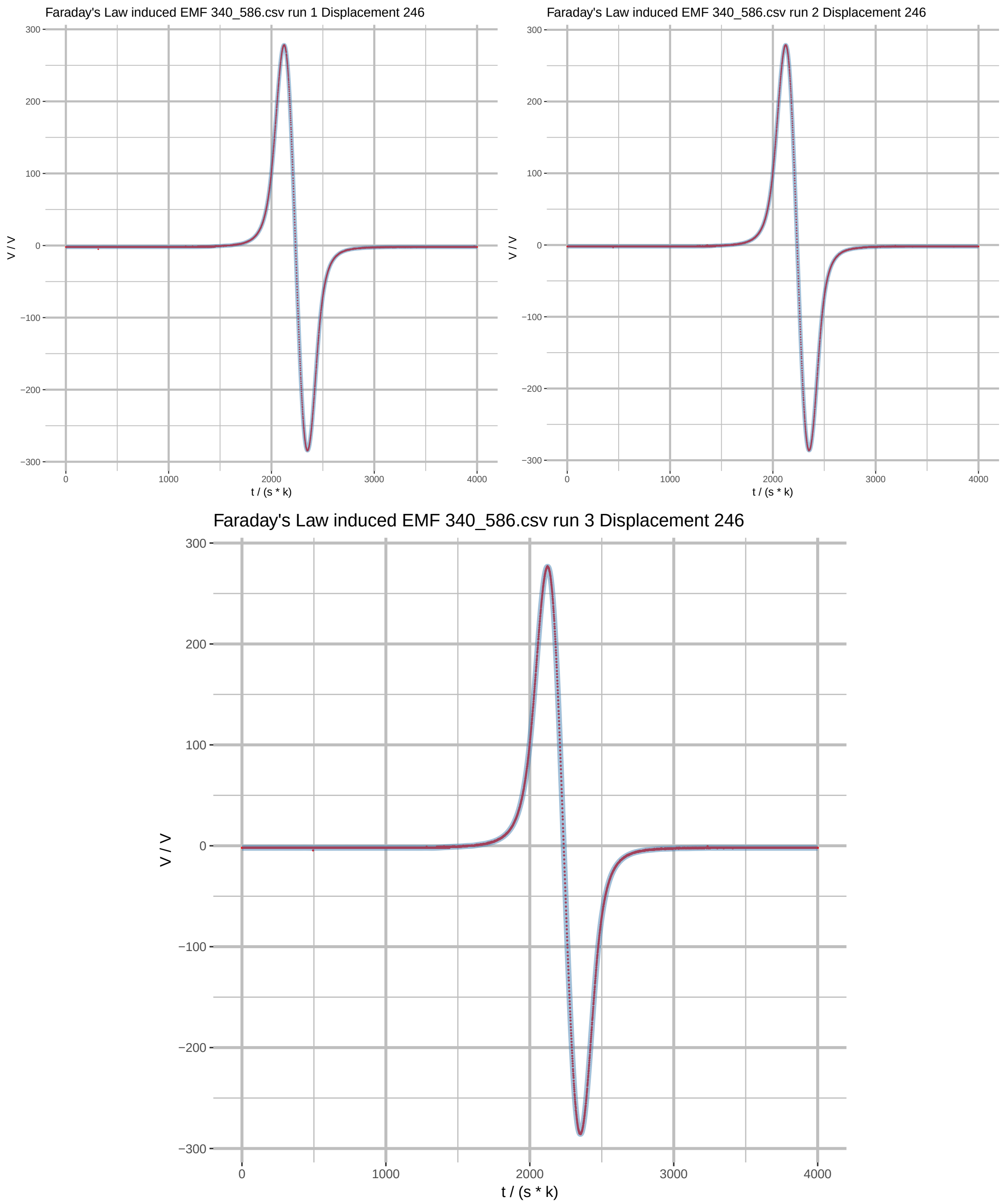


Figure 1: $d = 246\,\mathrm{mm}$

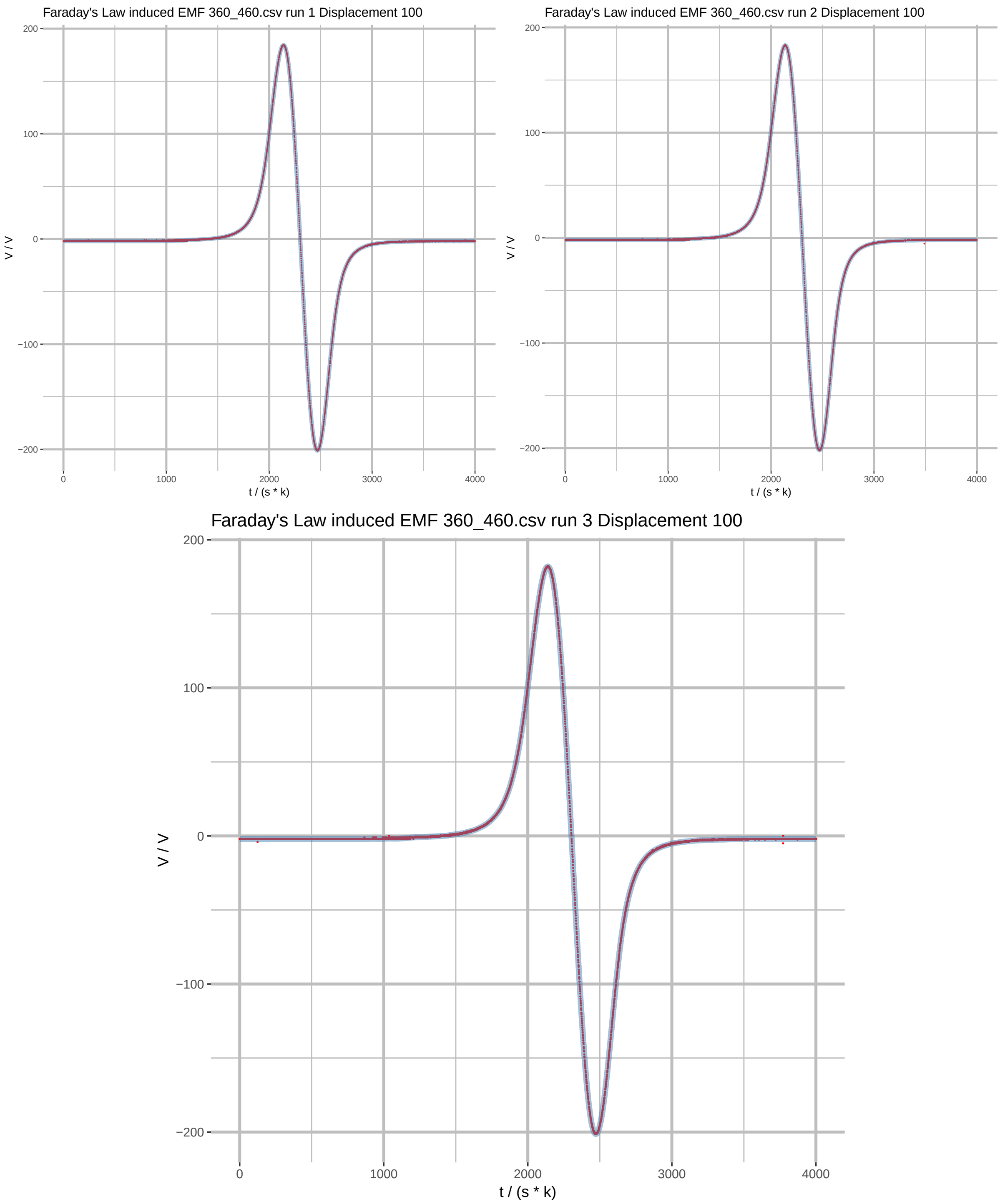
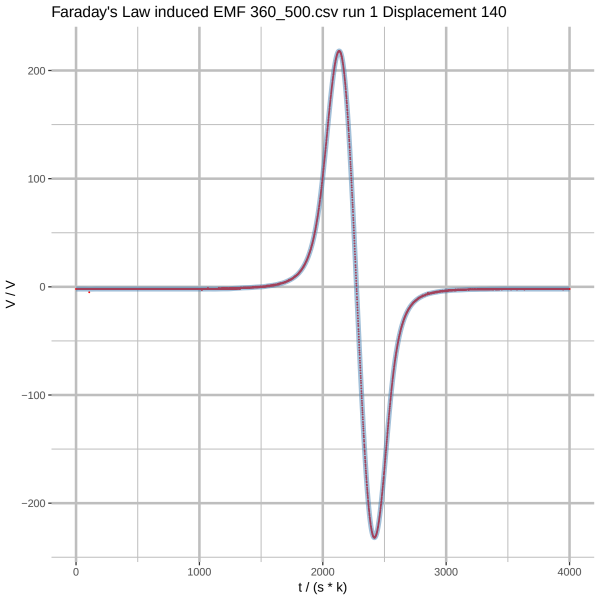
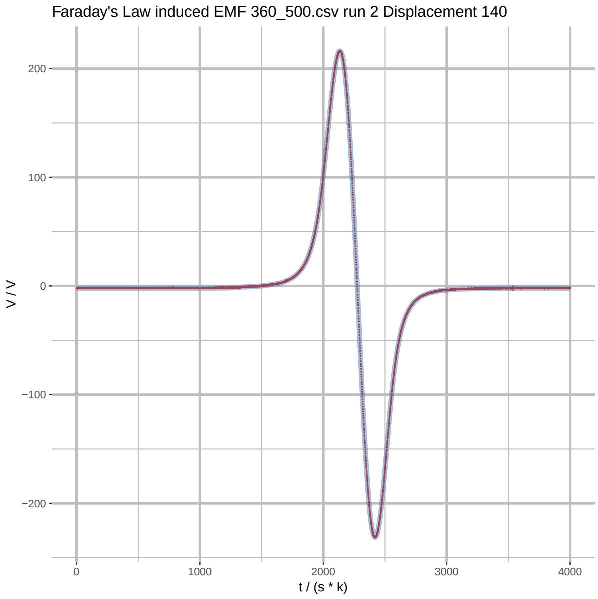


Figure 2: $d = 100\,\mathrm{mm}$





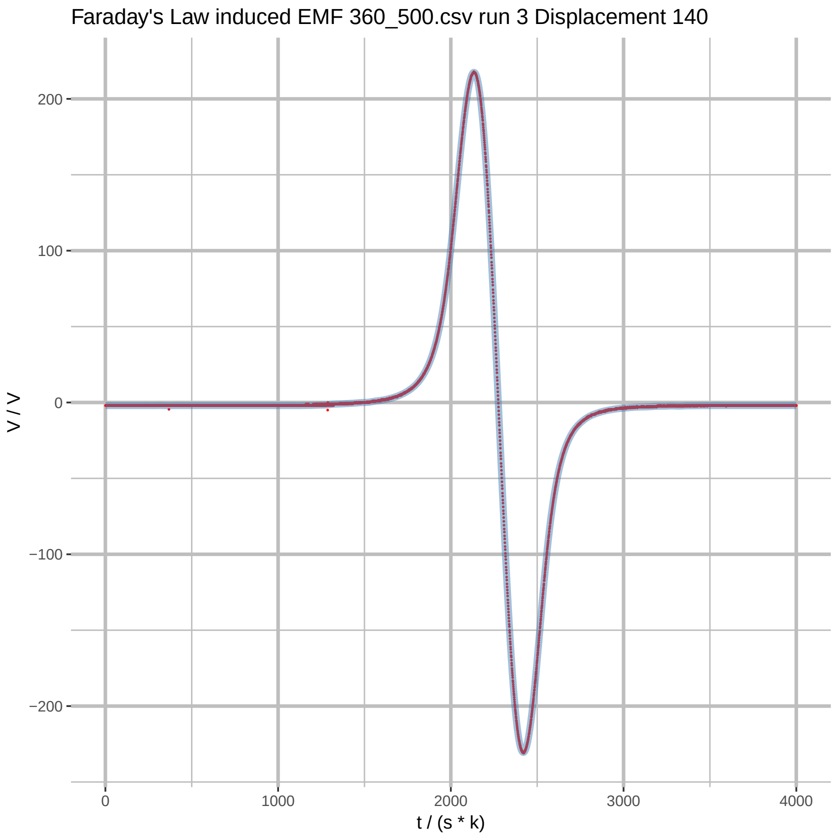


Figure 3: $d = 140\,\mathrm{mm}$

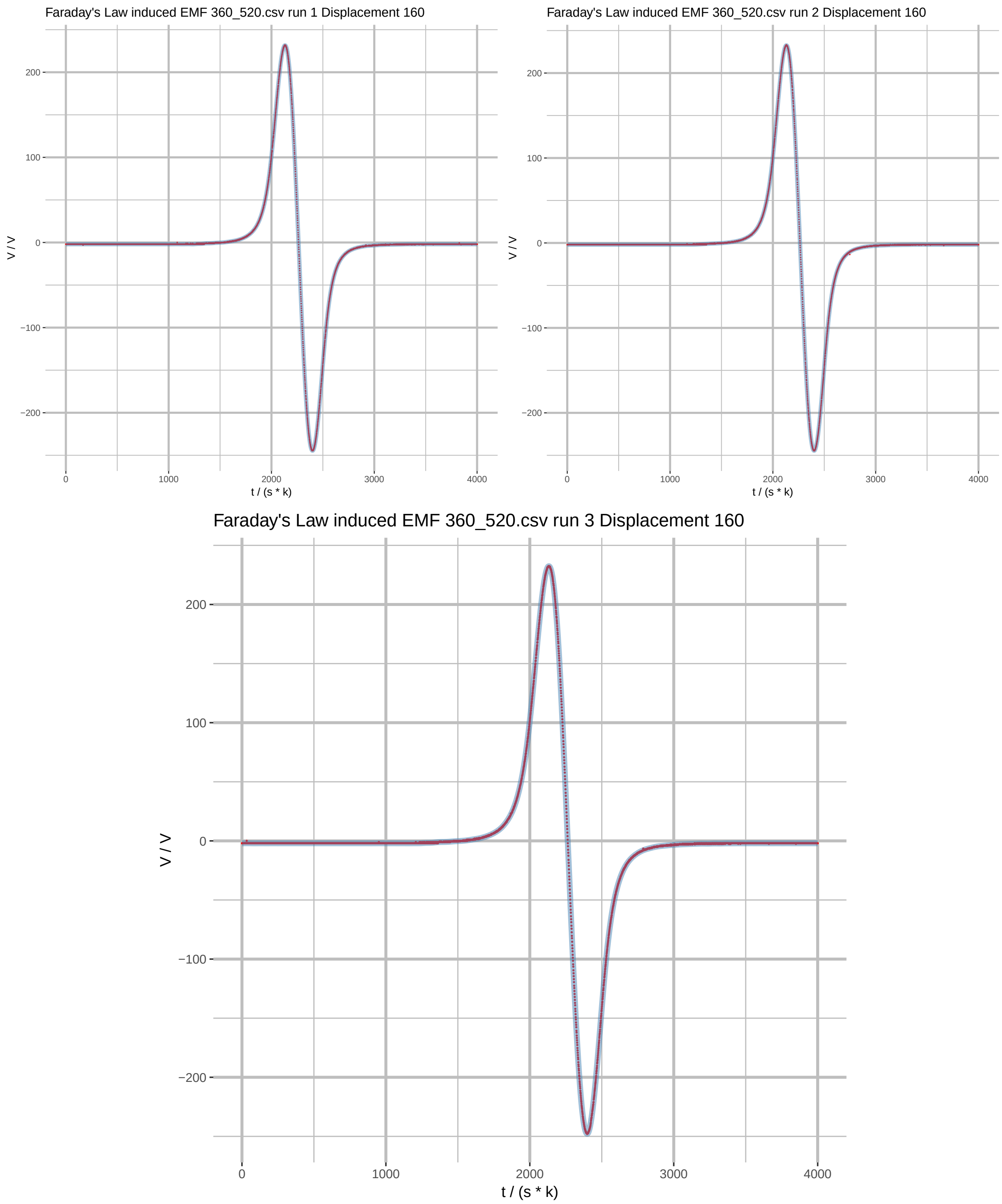


Figure 4: $d = 160\,\mathrm{mm}$

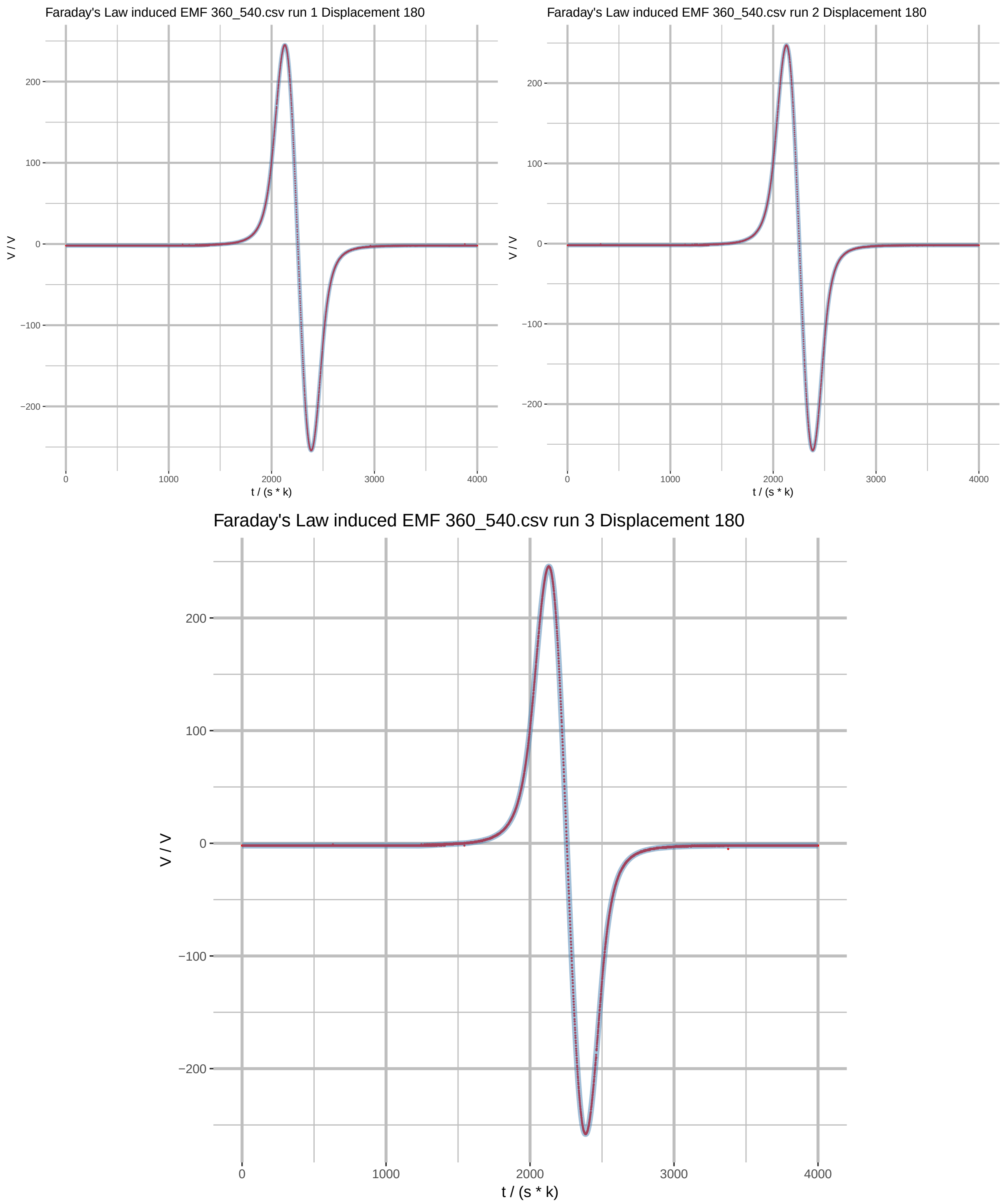


Figure 5: $d = 180\,\mathrm{mm}$

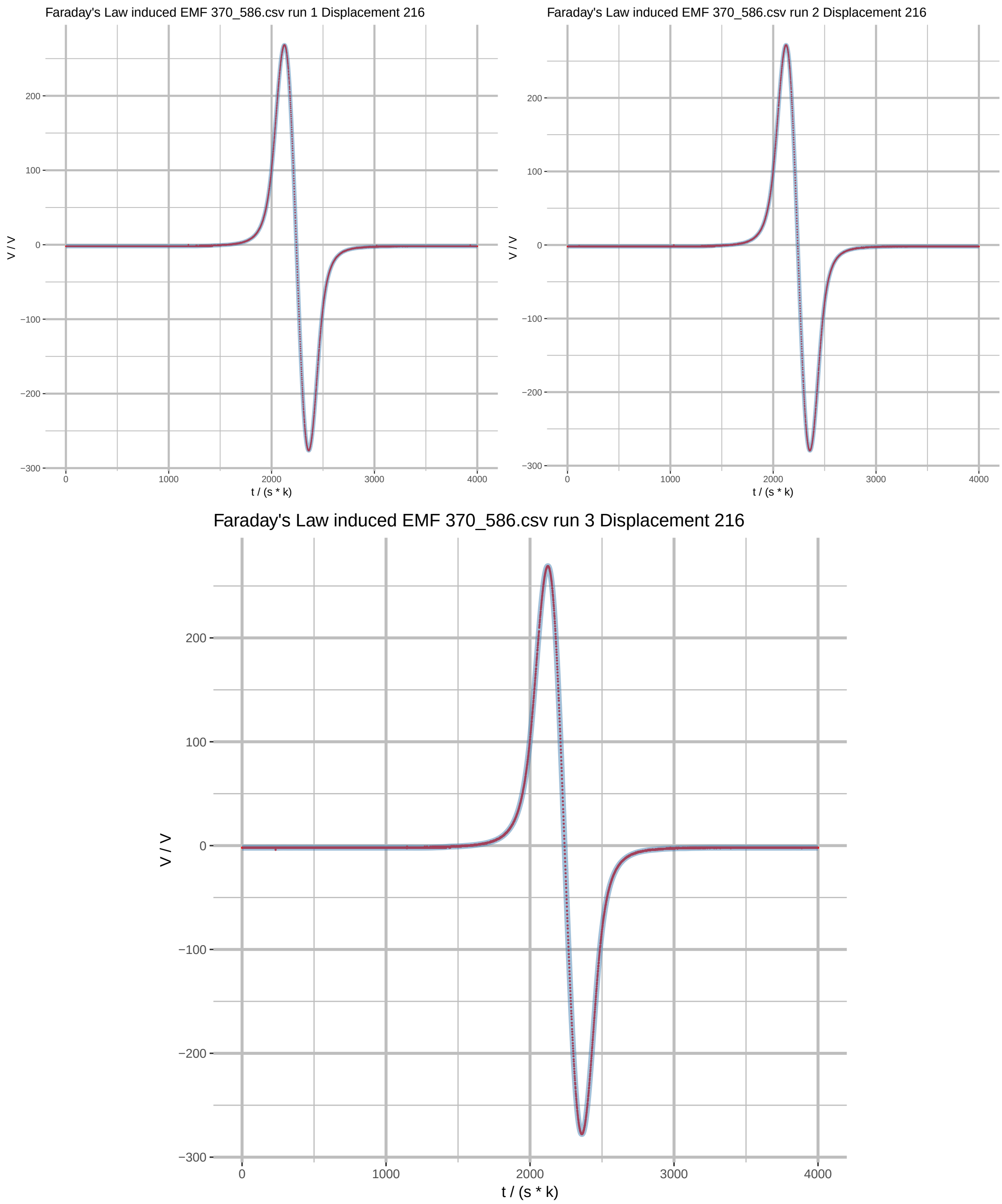


Figure 6: $d = 216\,\mathrm{mm}$

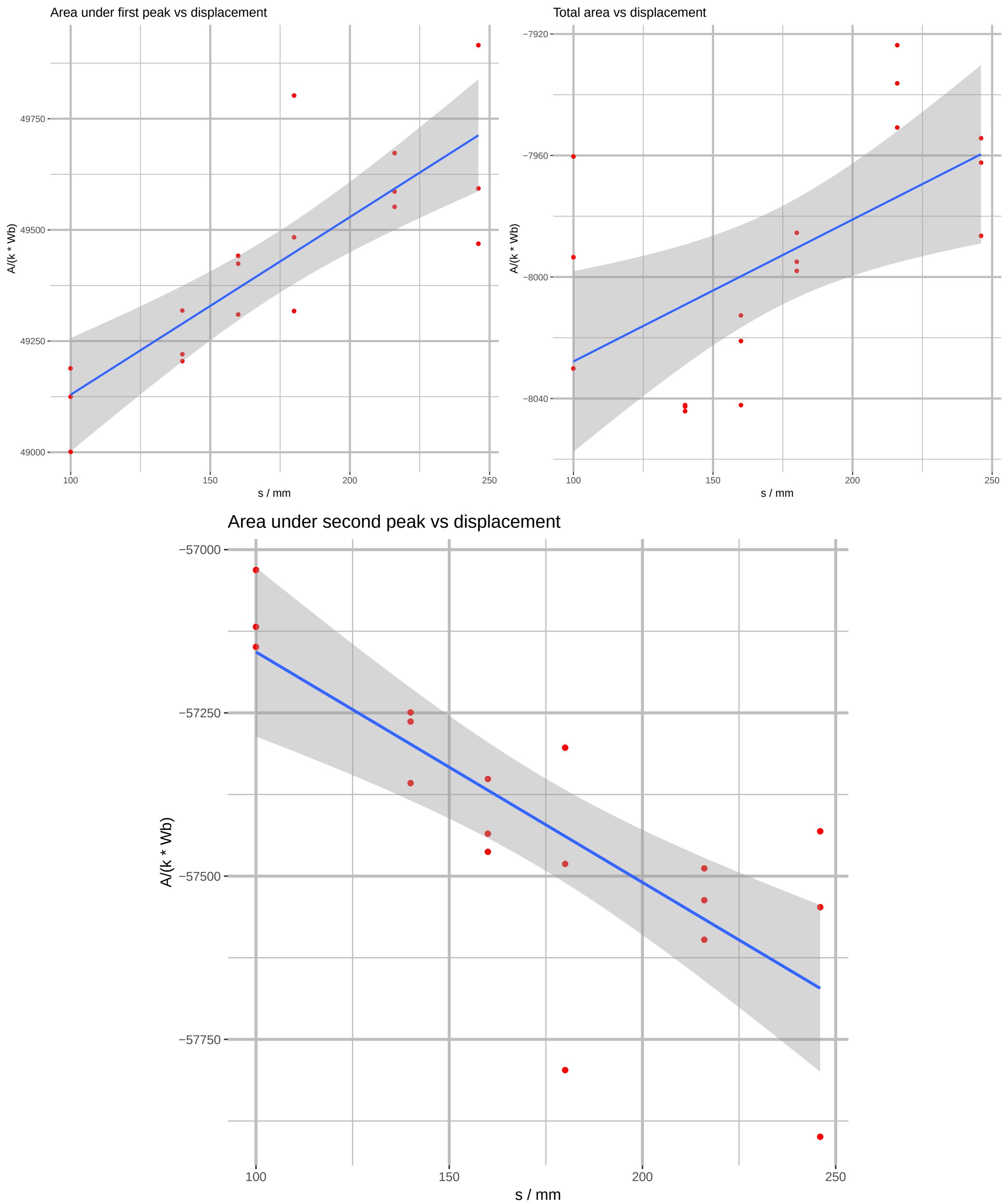


Figure 7: Area plots

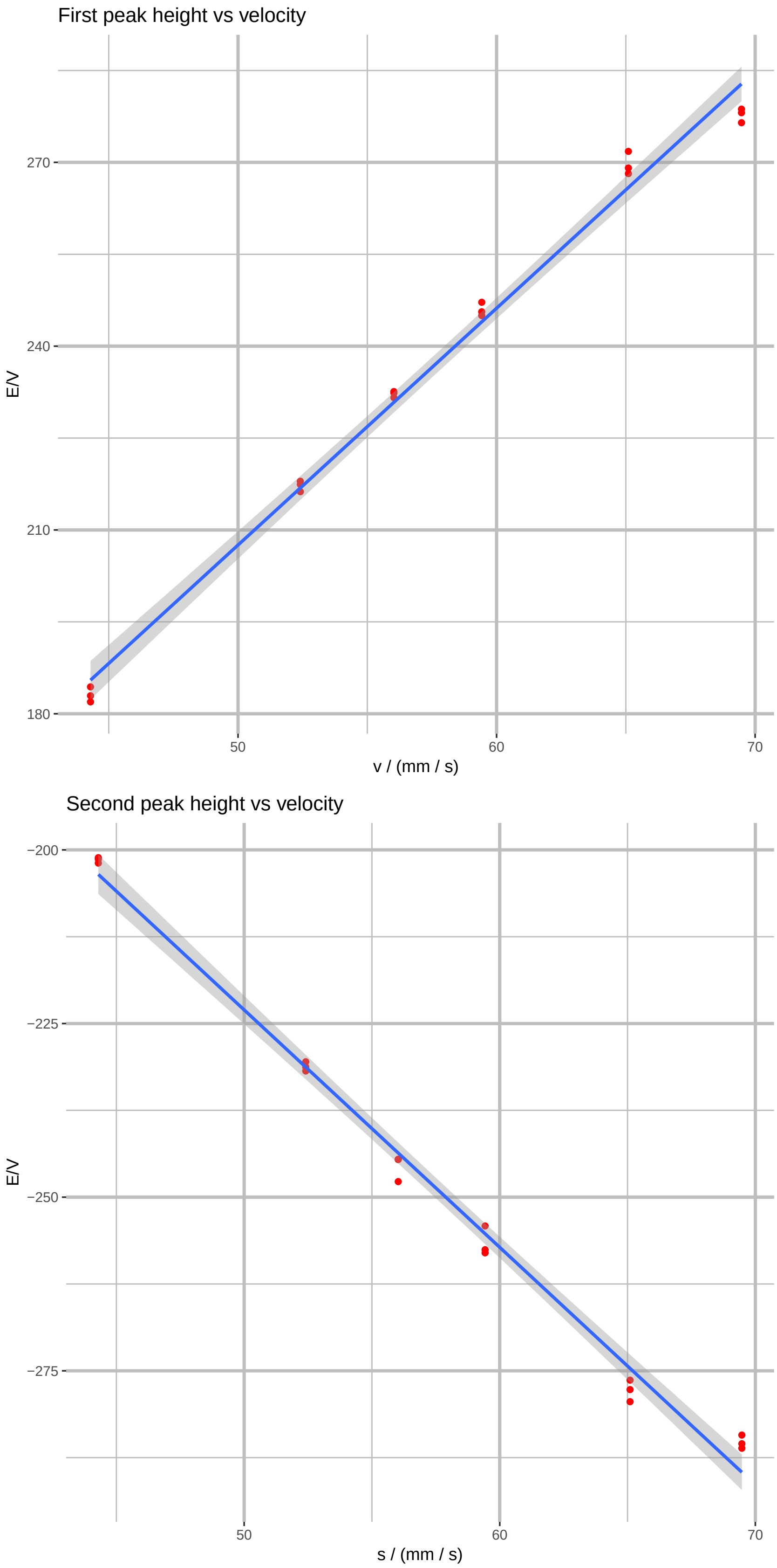


Figure 8: Peak plots