



Statistical analysis of wind turbine measurements at Hagshaw Hill Scotland

CREST
Loughborough University



Contents

1. Thermodynamics

- 
- (1) Bearing temperature vs electrical power*
 - (2) Gearbox temperature vs electrical power*

2. Measured data and curve fitting



3. Video examples



1. Thermodynamics

(1) Bearing temperature vs electrical power

- Power loss in a bearing

$$P_R = 1.05 \times 10^{-4} Mn$$



P_R =power loss, W

M =total frictional moment of the bearing, Nmm

n =rotational speed, r/min





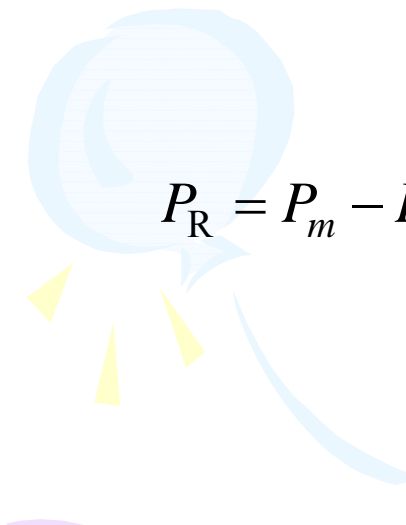
(2) Bearing temperature vs electrical power

$$\Delta T = P_R / W_S$$

ΔT = temperature increase, °C

P_R = power loss, W

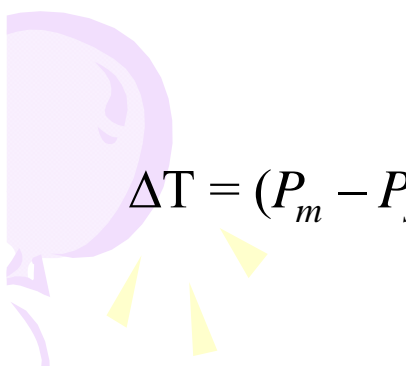
W_S = cooling factor, W/°C


$$P_R = P_m - P_s - \sum_{i=1}^n P_i$$

$\sum_{i=1}^n P_i$ Power loss including the iron loss, copper loss, windage loss, and etc.

P_m Mechanical power

P_s Stator electrical power


$$\Delta T = (P_m - P_s - \sum_{i=1}^n P_i) / W_S$$

2. Measured data and curve fitting

- Polynomial:

$$p(x) = p_1x^n + p_2x^{n-1} + \dots + p_nx + p_{n+1}$$

x : Measurements

$$\hat{x} = \frac{x - \mu_1}{\mu_2}$$

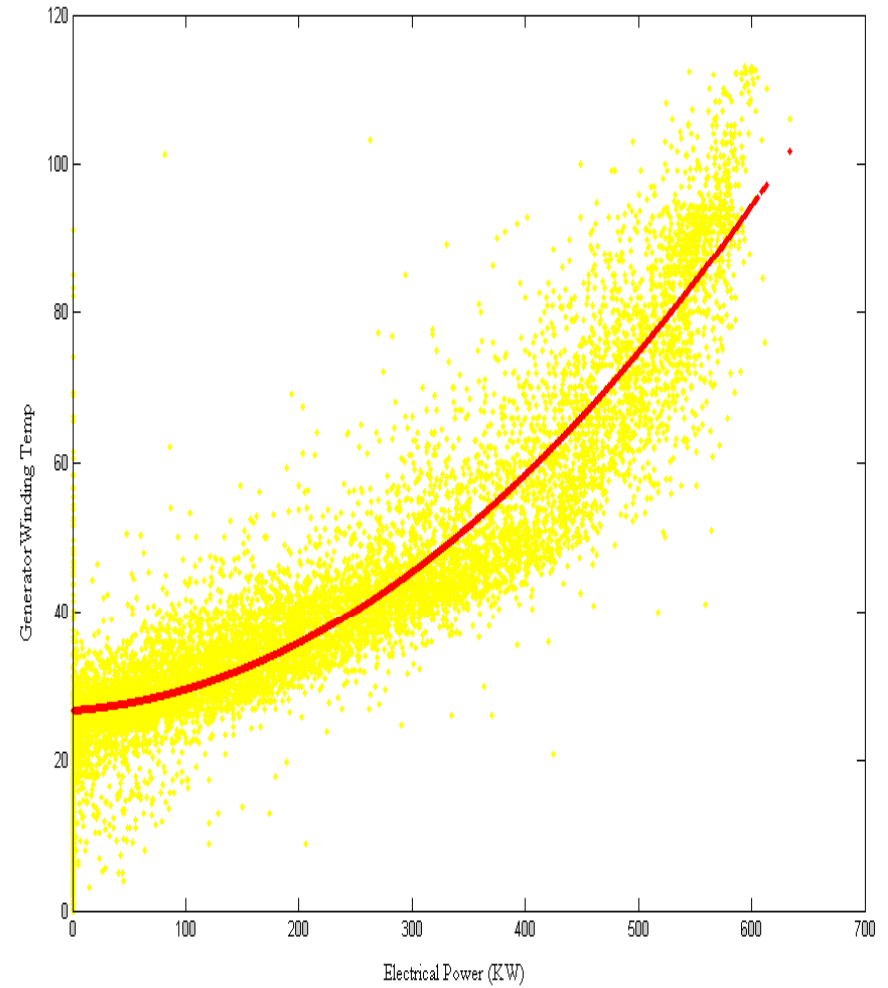
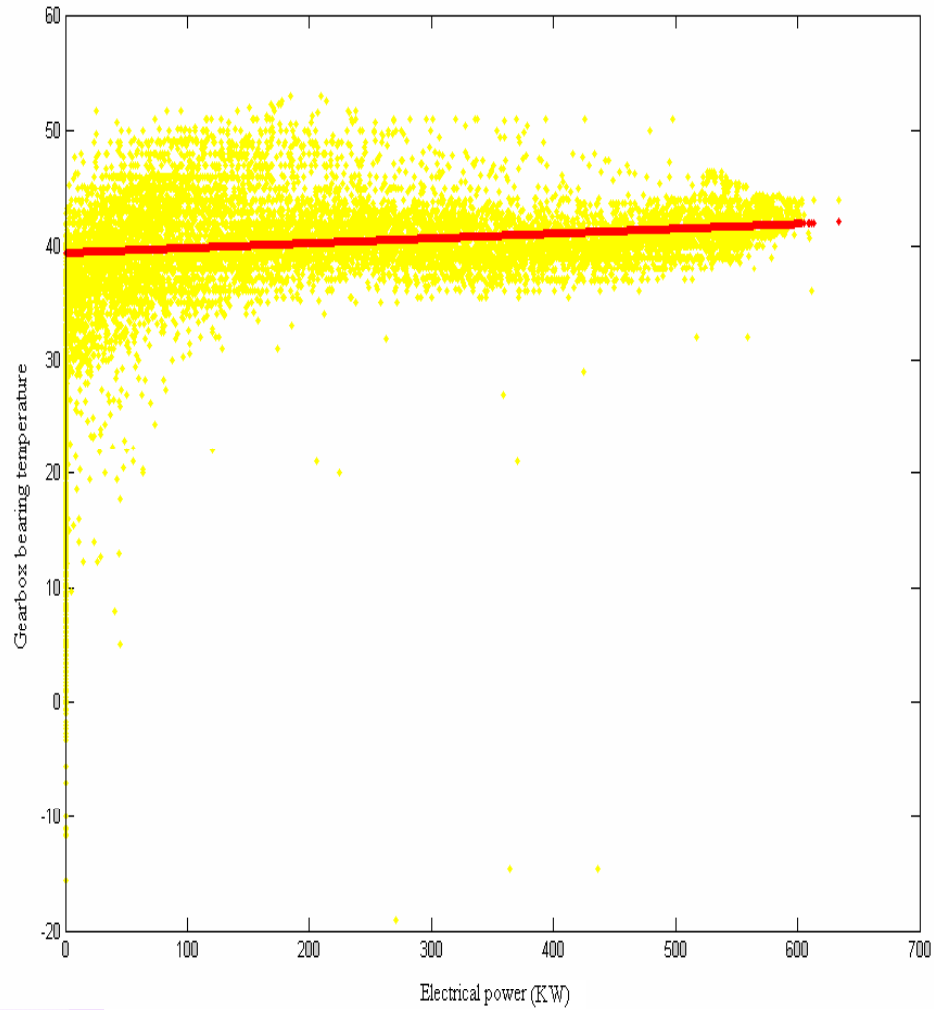
μ_1 : mean

μ_2 : standard deviation

- Centering and scaling transformation

$$p(x) = p_1^*\hat{x}^n + p_2^*\hat{x}^{n-1} + \dots + p_n^*\hat{x} + p_{n+1}^*$$

3. Video example: Three-month measurements and data fitting

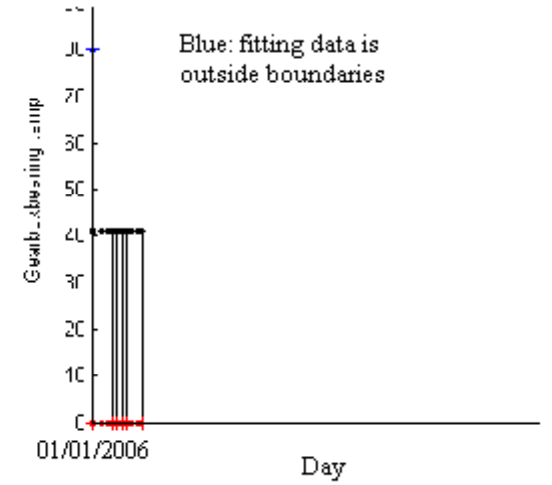
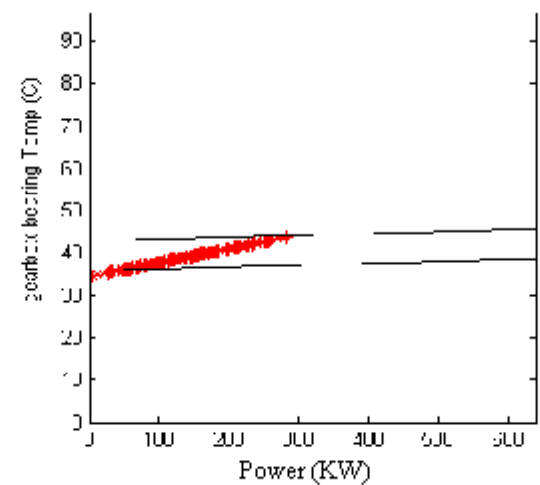
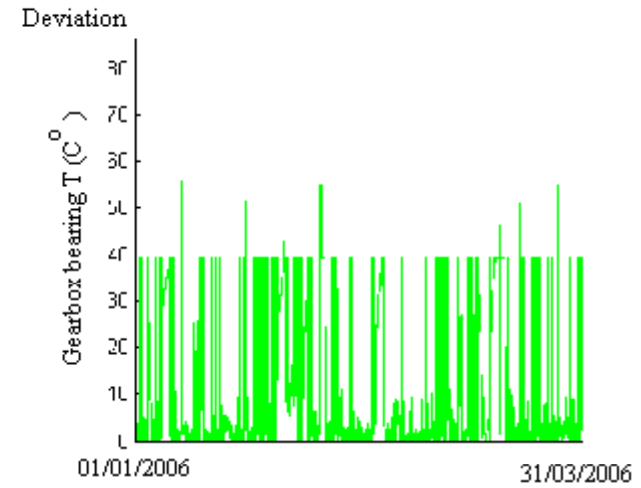
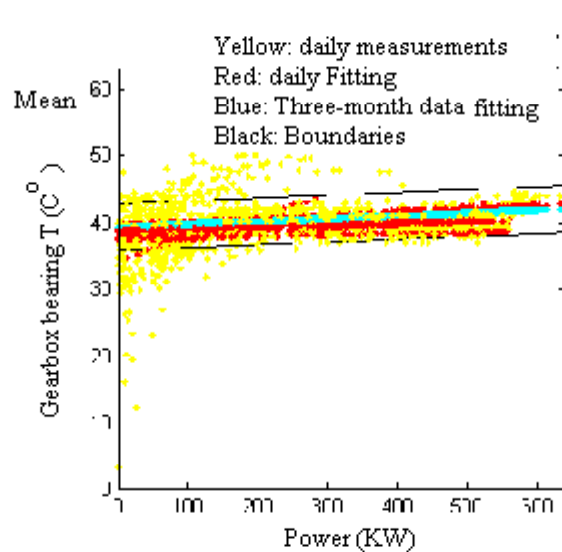


3. Video example: daily monitoring

```
116 - subplot(2,2,2)
117 - >plot(date_line_NUH,P_Ge
118 - %hold on
119 - >plot(date_line_NUH,dlv_
120 - %hold on
121 - plot(date_line_NUH,dlv_a
122 - legend('time on a ten m
123 - ylabel,'detrended gearbu
124 -
125 - datetick('x',1,'keep_lin
126 - pause(1)
127 - axes([732678 732767 0 10
128 - datetick('x',1,'keep_lin
129 - pause(1)
130 - axis([732678 732767 0 10
131 - hold on
132 - %%%%%%%%%%%%%%%%%%%%%%%%%
133 - subplot(2,2,4)
134 - >plot(ACTIVE_POWER_xy_UU
135 - >hold on
136 - >plot(ACTIVE_POWER_xy_UU
137 - >hold on
```

Command Window

```
l_s_ = 72.4
l_s_ = 72.5
l_s_ = 72.6
l_s_ = 72.7
l_s_ = 72.0
K_s_ = 504
K_s_ = 72.0
date_info =
--Jan-2006
date_time_num =
732600.99005556
```



A decorative graphic on the left side of the slide features three balloons: a light green one at the top, a light blue one in the middle, and a light purple one at the bottom. Each balloon is connected to a streamer that extends downwards. Small yellow triangular shapes are scattered around the streamers, resembling confetti or streamer tassels.

4. Conclusions and Suggestions for Future Research

- Daily trend and deviation of power curve, vibration and temperatures in turbine components are useful for the condition monitoring of a whole turbine and turbine components.
- Lower and upper boundaries defining the acceptable range of statistical parameters of measurements is determined according to common practices. Residual analysis will be conducted on measurements to determine the levels of significance and therefore set up the boundaries.
- Apply both frequency analysis and statistical analysis to available long time data sets.