Temperature measurement by using RTD

OBJECTIVE

- To perform the temperature measurement of heated body.
- To gain a basic knowledge of Temperature measurement device (RTD).
- To perform the data analysis of two samples (Z-Test).

APPARATUS REQUIRED

- Electric heater
- RTD sensor
- Temperature Indicator
- Stop watch

ASSUMPTIONS

- Internal Resistance of the specimen is negligible (Infinite thermal conductivity)

EXPERIMENTAL – FINDINGS

- The temperature measurement experiment and its analysis can be done with given technology.
- The data can be taken with an electric temperature probe (RTD) and the correlation of Resistance with temperature can be understood.
- The data analysis can be done using “Z” Test.

THEORY BACKGROUND

Temperature is a principle parameter that needs to be monitored and controlled in most engineering operations such as heating, cooling, drying and wetting. Temperature sensors have been developed based on different temperature-dependent physical phenomena including thermal expansion, thermoelectricity, electrical resistance, and thermal radiation. RTD is one of the temperature sensor based on electrical resistance. RTDs are manufactured from metals whose resistance increases with temperature. Within a limited temperature range, the resistivity increases linearly with temperature. A general relationship is used to convert electrical resistance R to temperature T:

$$R_T = R_0\,(1 + aT + bT^2 + cT^3 + \cdots)$$

Where,

R_T - is the electrical resistance at temperature T,

R_0 - is the electrical resistance at a reference temperature, usually $0^{O}C$,

a, b, and c - are material constants.

For Platinium

$$R_T / R_o = \alpha T + 1$$

Temperature Coefficient of Resistance (α) = 0.00392 ($1/^{O}C$)

Advantages of RTDs:

- A wide temperature range. (-50 to 500°C for thin-film and -200 to 850°C for wire-wound)
- Good accuracy. (better than thermocouples)
- Good interchangeability.
- Long-term stability.

A Z-test is any statistical test for which the distribution of the test statistic under the null hypothesis can be approximated by a normal distribution. Because of the central limit theorem, many test statistics are approximately normally distributed for large samples. For each significance level, the Z-test has a single critical value (for example, 1.96 for 5% two tailed) which makes it more convenient than the Student's t-test which has separate critical values for each sample size. Therefore, many statistical tests can be conveniently performed as approximate Z-tests if the sample size is large or the population variance known.

The term "Z-test" is often used to refer specifically to the one-sample location test comparing the mean of a set of measurements to a given constant. If the observed data X1, ..., Xn are (i) uncorrelated, (ii) have a common mean μ, and (iii) have a common variance σ2, then the sample average X has mean μ and variance σ2 / n. If our null hypothesis is that the mean value of the population is a given number μ0, we can use X −μ0 as a test-statistic, rejecting the null hypothesis if X −μ0 is large.

Tabulation:

S.No	Time (t) in Sec	Temperature (RTD 1) (T₁) in °C	Temperature (RTD 2) (T₂) in °C	S.No	Time (t) in Sec	Temperature (RTD 1) (T₁) in °C	Temperature (RTD 2) (T₂) in °C
1	30			51	1530		
2	60			52	1560		
3	90			53	1590		
4	120			54	1620		
5	150			55	1650		
6	180			56	1680		
7	210			57	1710		
8	240			58	1740		
9	270			59	1770		
10	300			60	1800		
11	330			61	1830		
12	360			62	1860		
13	390			63	1890		
14	420			64	1920		
15	450			65	1950		
16	480			66	1980		
17	510			67	2010		
18	540			68	2040		
19	570			69	2070		
20	600			70	2100		
21	630			71	2130		
22	660			72	2160		
23	690			73	2190		
24	720			74	2220		

25	750			75	2250		
26	780			76	2280		
27	810			77	2310		
28	840			78	2340		
29	870			79	2370		
30	900			80	2400		
31	930			81	2430		
32	960			82	2460		
33	990			83	2490		
34	1020			84	2520		
35	1050			85	2550		
36	1080			86	2580		
37	1110			87	2610		
38	1140			88	2640		
39	1170			89	2670		
40	1200			90	2700		
41	1230			91	2730		
42	1260			92	2760		
43	1290			93	2790		
44	1320			94	2820		
45	1350			95	2850		
46	1380			96	2880		
47	1410			97	2910		
48	1440			98	2940		
49	1470			99	2970		
50	1500			100	3000		

Procedure:

1. Place the given specimen on heater plate.
2. Place two RTDs on specimen.
3. Switch on the heater plate and Temperature indicator.
4. Fix the temperature (say 60°C,90 °C) and power (900W).
5. Press the lock button.
6. Measure the temperature after steady state for every 30 sec (Use stop watch) for time measurement.
7. Process the data in MS EXCEL®.
8. Calculate $\overline{X}_1, \overline{X}_2, \sigma_{x1}, \sigma_{x2}$.
9. Calculate Z parameter.
10. Calculate $\dfrac{\Delta X_{peak}}{X^{+}_{peak} + X^{-}_{peak}}$ for each sample.

Calculation : (Comparing two sample means)

For comparing two samples directly, we need to compute the Z statistic

$$z = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\sigma^2_{x1} + \sigma^2_{x2}}}$$

Where,

$\overline{X}_1$ - Mean value of sample 1.

$\overline{X}_2$ - Mean value of sample 2.

σ_{x1} - Standard deviation of sample 1 divided by the square root of the number of data points. (Standard Error of mean 1)

σ_{x2} - Standard deviation of sample 2 divided by the square root of the number of data points. (Standard Error of mean 2)

- If the Z-statistic is less than 2, the two samples are the same.
- If the Z-statistic is between 2.0 and 2.5, the two samples are marginally different.
- If the Z-statistic is between 2.5 and 3.0, the two samples are significantly different.

- If the Z-statistic is more then 3.0, the two samples are highly significantly different.
- X_{peak} is the peak value of temperature at any instant of time.
- $\Delta X_{peak} = \left| X^{+}_{peak} - X^{-}_{peak} \right|$

Result:

Analyze and interpret the data using Z test.

Reference:

1. S. Wang, Juming Tang and F. Younce "Temperature Measurement" Washington State University, Pullman, Washington, U.S.A.
2. http://en.wikipedia.org/wiki/Z-test
3. http://homework.uoregon.edu/pub/class/es202/ztest.html