

Experimental Analysis of Power Consumption in Ceiling Fan

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Abstract

Ceiling fans are one of the main power consuming sources. Total power consumption is multiple of fan rotation frequency. As India is facing the power crisis it is important to reduce the power consumption in every power consuming device. Hence Power reduction in ceiling fan is perhaps one of the most important parameter. Every power reduction process starts with identification of power consumption sources. Ceiling fans are extensively used to create an indoor breeze, improve the space air distribution and hence enhance the feeling of comfort. The fan speed, diameter, number of blades, blade angle and vibrations all play an important role in deciding the power consumption. Few previous studies have investigated fan induced flow and its characteristics under different geometric and operating conditions. In this study, response surface methodology is used to predict power consumption characteristics. The experiments were conducted based on the three different fans having three different blades, three room size, three different ceiling fan rod lengths three regulator knob positions and mathematical model was developed.

Keywords

Response Surface Method, Ceiling Fan Power Consumption, Optimization, MINTAB 16, L81 Array

I. Introduction

People feel discomfort when they get sweat in a space with a stagnant air. Therefore people try to Create air breeze around their bodies either naturally or mechanically to enhance body Convective heat transfer. Air motion helps sweat evaporation and accordingly brings body comfort feeling. Ceiling fans are used in offices; residences as an alternative in summer for comfort. The flow pattern features induced by ceiling fans are very helpful for people having interest working in this field. So knowing flow characteristics, as a result of ceiling fan rotation would help improving the fan design in addition to selecting its optimum placement to save energy. Therefore it is very important to select and control the input parameters for power saving. Various prediction methods can be applied to define the desired output variables through developing mathematical models to specify the relationship between the input parameters and output variables. The response surface methodology (RSM) is helpful in developing a suitable approximation for the true function relationship between the independent variables and the response variable that may characterize the power level for ceiling fan.[1] It has been proved by several researchers that efficient use of statistical design of experimental techniques, allow development of an empirical methodology, to incorporate a scientific approach in analysis of ceiling fan power consumption. Even though sufficient literature is available on analysis of ceiling fan power consumption, no systematic study has been reported so far to correlate the process parameters and power consumption. Hence, in this investigation, the design was used to conduct experiments for exploring the interdependence of the process parameters and second order

mathematical model for power consumption was developed from the data obtained by conducting the experiments.

II. Experimental Identification of Important Parameters

From the literature and previous work done among many independently controllable parameters affecting power consumption, the parameters viz. Fan Blades (A), Room volume (B), Downrod length (C) Fan speed (D) were selected as primary parameters for the study. These parameters are contributing to the power consumption in the ceiling fan. Different combinations of parameters were used to carry out the trial runs. This was carried out by varying one of the factors while keeping the rest of them at constant values.

Table 1: Parameters Level selected for the Experimentation

Parameters	Levels		
	Low (1)	Medium (2)	High (3)
Fan(A)	2	3	4
Room Size (m3) (B)	66.56	167.19	355.84
Rod Length (Inch)(C)	6.5	10.25	12
Speed Knob Position(D)	2	3	4

A. Conducting Experiments

For conducting experiments three different fans of various blades mainly (2, 3, 4), three different room size, three different rod length, and three different fan speed position were selected. Using clamp meter power consumption level in (kW) was recorded. Rod length for fan was measured. Reading in different room, using different rod at different regulator knob position were recorded as in observation table, (Table 1).

III. Development of Mathematical Model

A. Response Surface Methodology

Response Surface Methodology (RSM) is a collection of mathematical and statistical technique useful for analyzing problems in which several independent variables or responses are considered to optimize the desired output. In many experimental conditions, it is possible to represent independent factors in quantitative form as given in Eq. (1). Then these factors can be thought of as having a functional relationship or response as follows:

$$Y = \Phi(x_1, x_2, \dots, x_k) \quad \text{Eq. (1)}$$

Between the response Y and x_1, x_2, \dots, x_k of k quantitative factors, the function Φ is called response surface or response function. For a given set of independent variables, a characteristic surface is responded. In the present investigation, RSM has been applied for developing the mathematical model for characteristics of power. [7] In applying the response surface methodology, the independent variable was viewed as surface to which a mathematical model is fitted.

Table 2: Observation Table

Run Order	Fan blades	Room Volume	Down rod Length	Fan speed	Energy Consumption
1	1	1	1	1	0.386604
2	1	1	1	2	0.447822
3	1	1	1	3	0.522816
4	1	1	2	1	0.379848
5	1	1	2	2	0.44478
6	1	1	2	3	0.513646
7	1	1	3	1	0.38173
8	1	1	3	2	0.443813
9	1	1	3	3	0.518221
10	1	2	1	1	0.366597
11	1	2	1	2	0.426765
12	1	2	1	3	0.481712
13	1	2	2	1	0.377185
14	1	2	2	2	0.439589
15	1	2	2	3	0.508561
16	1	2	3	1	0.374164
17	1	2	3	2	0.428505
18	1	2	3	3	0.494278
19	1	3	1	1	0.379691
20	1	3	1	2	0.442081
21	1	3	1	3	0.514178
22	1	3	2	1	0.375094
23	1	3	2	2	0.434157
24	1	3	2	3	0.497448
25	1	3	3	1	0.355169
26	1	3	3	2	0.416342
27	1	3	3	3	0.483553
28	2	1	1	1	0.332564
29	2	1	1	2	0.393652
30	2	1	1	3	0.486167
31	2	1	2	1	0.34351
32	2	1	2	2	0.412415
33	2	1	2	3	0.521486
34	2	1	3	1	0.347231
35	2	1	3	2	0.423069
36	2	1	3	3	0.539721
37	2	2	1	1	0.331019
38	2	2	1	2	0.404062
39	2	2	1	3	0.509884
40	2	2	2	1	0.316716
41	2	2	2	2	0.376953
42	2	2	2	3	0.454104
43	2	2	3	1	0.341376
44	2	2	3	2	0.406711
45	2	2	3	3	0.513912
46	2	3	1	1	0.341376

47	2	3	1	2	0.405748
48	2	3	1	3	0.510413
49	2	3	2	1	0.31456
50	2	3	2	2	0.374396
51	2	3	2	3	0.461948
52	2	3	3	1	0.334897
53	2	3	3	2	0.400037
54	2	3	3	3	0.505121
55	3	1	1	1	0.33479
56	3	1	1	2	0.403581
57	3	1	1	3	0.478373
58	3	1	2	1	0.335458
59	3	1	2	2	0.40045
60	3	1	2	3	0.467309
61	3	1	3	1	0.340704
62	3	1	3	2	0.410222
63	3	1	3	3	0.47915
64	3	2	1	1	0.334233
65	3	2	1	2	0.398412
66	3	2	1	3	0.471664
67	3	2	2	1	0.328381
68	3	2	2	2	0.394842
69	3	2	2	3	0.454356
70	3	2	3	1	0.328601
71	3	2	3	2	0.395556
72	3	2	3	3	0.447321
73	3	3	1	1	0.332906
74	3	3	1	2	0.400756
75	3	3	1	3	0.468077
76	3	3	2	1	0.328381
77	3	3	2	2	0.39181
78	3	3	2	3	0.45764
79	3	3	3	1	0.341152
80	3	3	3	2	0.40623
81	3	3	3	3	0.470896

The mathematical equations for energy consumption by using Response Surface Method (RSM) is,

$$\text{Energy Consumption} = 0.41653 - 0.01913 * A - 0.00639 * B + 0.00040 * C + 0.07126 * D + 0.00248 * AB + 0.00193 * AC + 0.00088 * AD - 0.00499 * BC - 0.00218 * BD + 0.00010 * CD + 0.00294 * ABC - 0.00007 * ABD - 0.00119 * ACD - 0.00185 * BCD + 0.00038 * ABCD$$

Where,

A=Fan blades level

B=Room Volume

C=Down rod length

D=Fan speed

B. Optimizing Parameters

Contour plots show distinctive circular shape indicative of possible independence of factors with response [7]. Contour plots play a very important role in the study of the response surface. By

generating contour plots using software for response surface analysis, the optimum is located with reasonable accuracy by characterizing the shape of the surface. If a contour patterning of circular shaped contours occurs, it tends to suggest independence of factor effects while elliptical contours as may indicate factor interactions. Response surfaces have been developed for both the models, taking two parameters in the middle level and two parameters in the X and Y axis and response in Z axis. The response surfaces clearly reveal the optimal response point. RSM is used to find the optimal set of process parameters that produce a maximum or minimum value of the response. In the present investigation the process parameters corresponding to the power consumption are considered as optimum. Hence, when these optimized process parameters are used, then it will be possible to attain the minimum power consumption. Figure 1 presents three dimensional response surface plots for the power consumption. The surface plots generated are almost circular which reveals that there is least dependency of the parameters on the power consumption.

C. Surface Plots

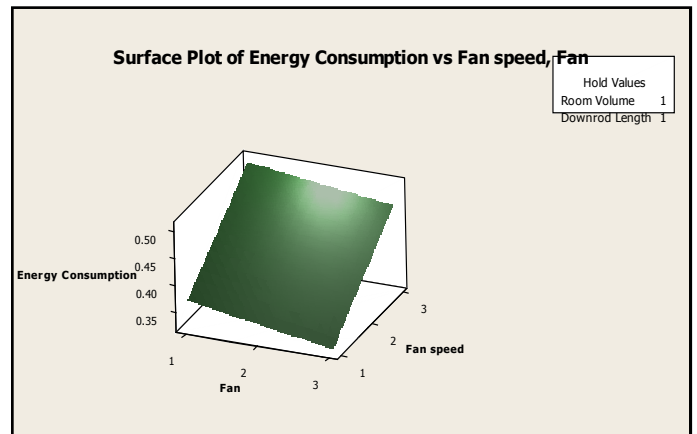
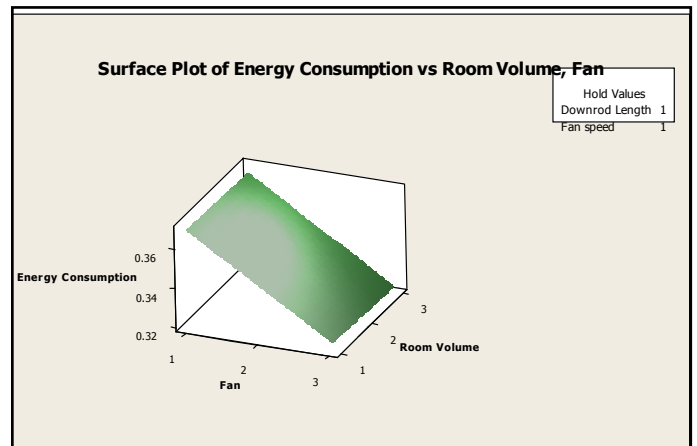
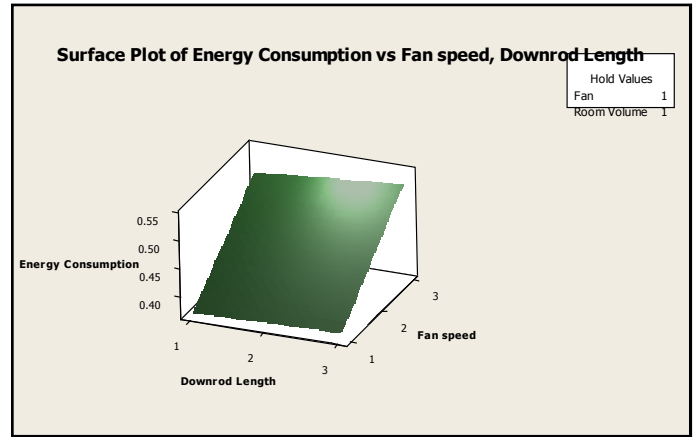
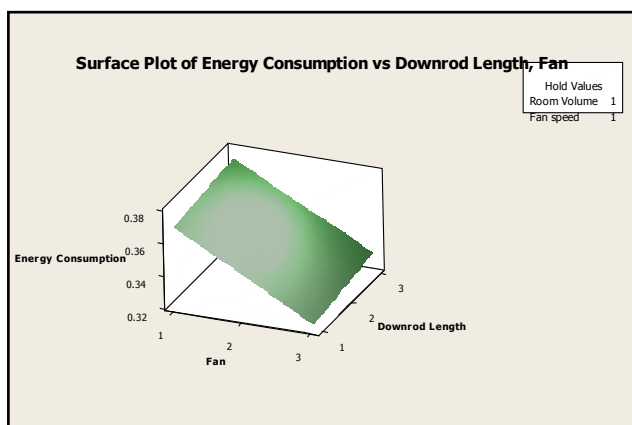
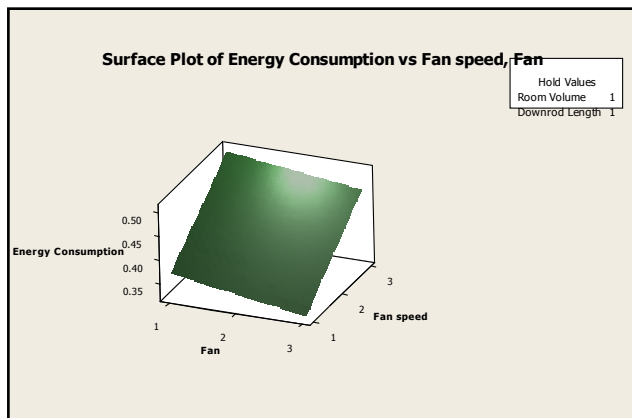
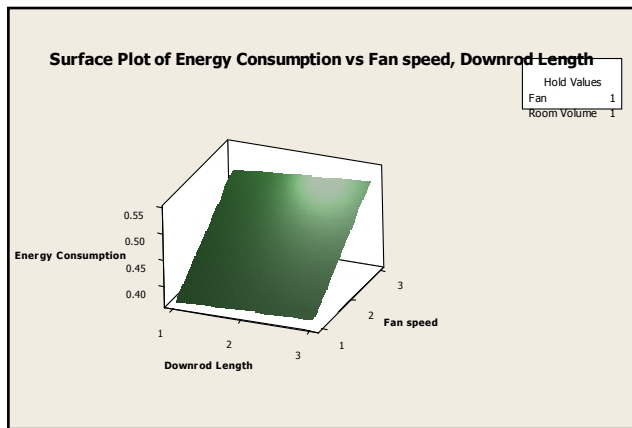
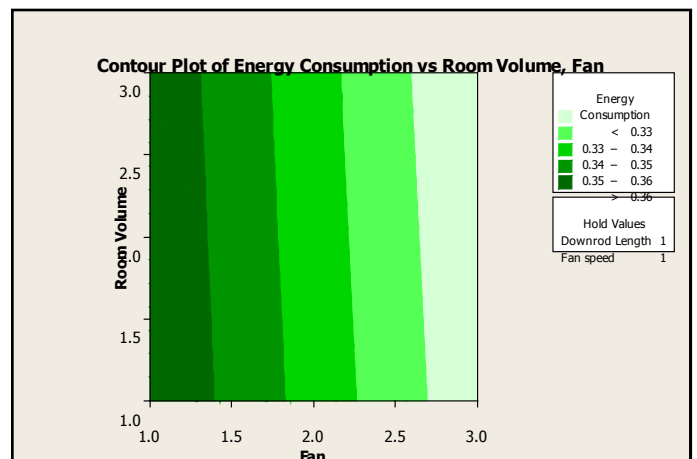


Fig. 1: Surface Plots for Power Consumption

D. Contour Plots



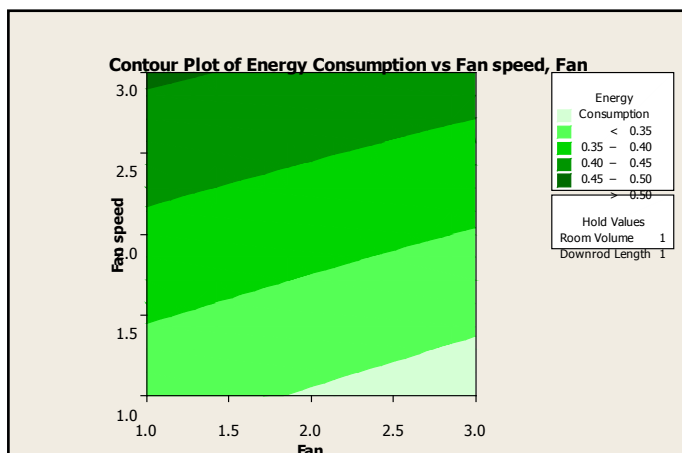
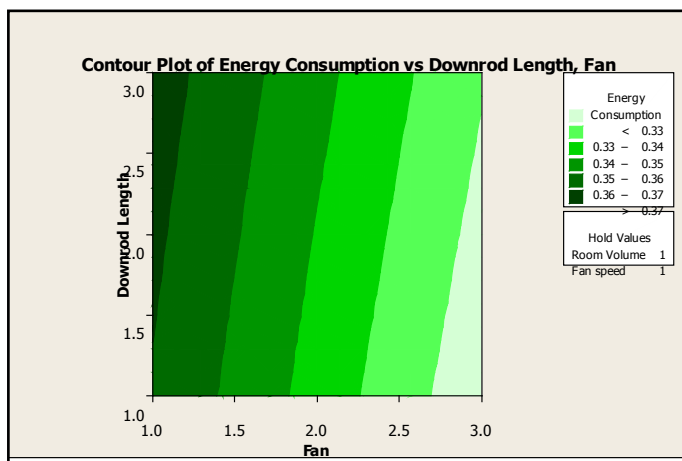
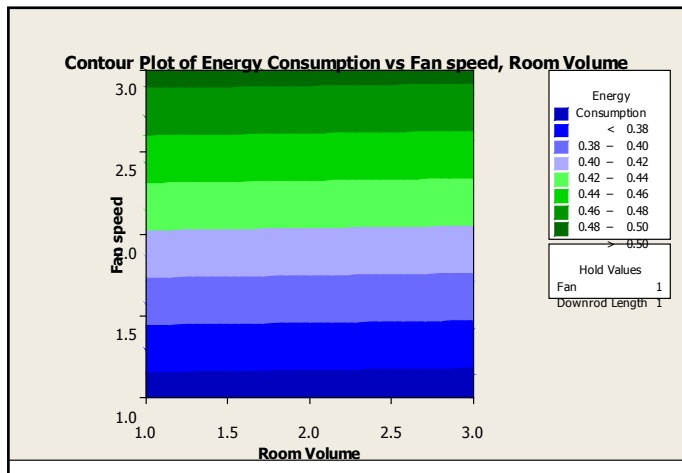


Fig. 2: Contour Plots for Power Consumption

E. Response Optimization

Table 3: Parameters for Optimization

parameter	goal	Lower	Target	Upper	Weight	Import
Energy Consumption	Minimum	0.315	0.315	0.53	1	1 1

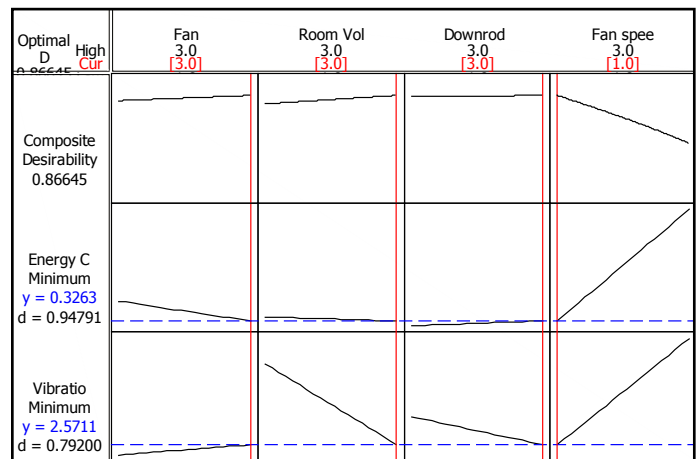


Fig. 3: Optimization Plot

F. Global Solution

Fan blades level = 3
 Room Volume = 3
 Down rod Length = 1
 Fan speed = 1

Energy Consumption = 0.320608,
 Desirability = 0.974156
 Composite Desirability = 0.974156

IV. Conclusion

From the experimentation we got the global value of power consumption 0.315 kW with the set up of Fan having four blades, 355.84 m3 Room Volume, 12 inch Downrod length and Desirability function of 0.947912 which is the Probability of achieving power consumption.

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