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Response Surface Methodology (RSM) Models for Tandum Drive HPFM By Using 3 Independent Pie Terms

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***Abstract*— The goal of the current research article is to create three independent pi terms for three Response Surface Methodology (RSM) Models. Planned using the response surface methodology and carry out the tests (RSM). Utilizing the statistical programme MATLAB, the appropriate model was chosen and response surface models were developed. For the response characteristics, specifically Angular speed, the best fitting regression equations for the chosen model are discovered. Using the field data, the response surface equations are created and shown.**

***Index Terms*— HPFM, Optimization, Experimentation, Pi Terms, Dependant Variables, IndependentVariables, Human Power, Pedal Power, Flywheel Motor, Mathematical Modelling.**

I. INTRODUCTION

The process that led to the mathematical model began with the construction of some fundamental mathematical relations, which was followed by the production of a few single generalised equations [1-4]. To forecast the angular speed of the flywheel for various gear ratios, cycling mechanisms, and human energy, mathematical models have been devised [5-13] .Shende [4] investigated the mathematical modelling to determine the flywheel's angular speed in 2013.In order to further the work by constructing the RSM model, three independent terms—gear ratio, human energy, and mechanism effectiveness—are used in this paper. The Tandum human powered flywheel motor (HPFM) is a bicycle-driven energy unit that consists of a flywheel and speed-raising gears, while the mechanical power transmission system is made up of a clutch and torque-raising gears. Figure 1 depicts the machine's conceptual layout, whereas Figure 2 depicts the experimental setup for the HPFM that was actually built and made.

Proper experiment planning is crucial to achieving the study goals clearly, swiftly, with the right kind of data and a sufficient sample size. Numerous variables affect the tandum drive HPFM's performance. This study's objectives are to present the chosen experimental design in detail and to produce design information in the form of iterative models based on experimental data for various dependent and responsive variables of the human powered flywheel motor.

1.1. Experimental Setup

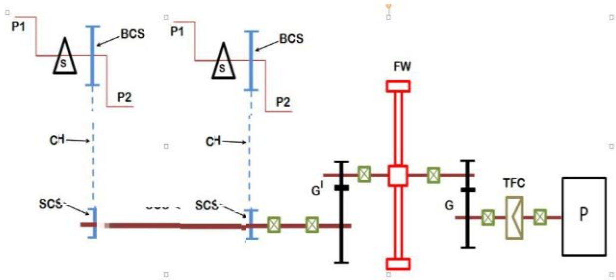

Figure 1: HPFM Tandum Drive [3]

S = Seat,
P1, P2 = Pedals,
BCS = Big Chain Sprocket,
SCS = Small Chain Sprocket,
CH = Bicycle Chain Drive,
GI = Speed increasing gear pair,
FW = Flywheel,
TFC/SJC = Torsionally Flexible Clutch / Spiral Jaw Clutch,
P = Process Unit,
G = Torque Amplification Gear pair

This novel machine system comprises of three subsystem viz
(1) Energy unit
(2) Transmission
(3) Process machine.

The Schematics of the system is shown in Fig 1.

Energy source: This consists of a flywheel FW, a speed-increasing gear pair G', and a pedalling system similar to that on a bicycle.The torque amplification gear pair G, the process unit, and TFC (the torsionally flexible clutch) make up the transmission.

Working:

Step 1: A young boy (20-25 years), slim stature, middle height peddles the bicycle like system for 1 minute and speeds up the flywheel FW to the speed of 500-1000 rpm. The FW is 0.8 m Rim diameter X 10.0 cm rim width X 2.0 cm rim thickness, The energy stored in the flywheel is 3500-4000kgf-m.

Step 2: The energy stored in the FW is made available to the process unit P once it reaches its rated speed thanks to the engagement of TFC. The energy stored in the FW is exhausted in 5 to 15 seconds depending on the process unit.

Figure 2: Experimental Setup-HPFM Tandum Drive

In the entire work done so far only one peddler is tried. As the system is introducing a new employment guarantee scheme with energy application or new process unit, it is worthwhile trying more than one peddler either two (i.e. tandum drive) schematically as shown in Fig.1 or three or even four. This innovation of the Energy unit may store more than 3000-4000 kgf-m energy in the flywheel [1,2,3,4,6,12,16 to 25,26 to 40]. This enhancement of stored energy in the flywheel during the same peddling time i.e. 60 seconds or 1 minute may prove to be worth for energizing other process units manufacturing other rural/village/interior based products/processes which are otherwise being energized by other conventional prime movers either electric Motor /Engine/Air motors etc. in the h.p. range 8 to 24 hp.

- To enhance the power range of so far developed HPFM energized process Machines [14-15]
- To establish an expression for ωT.
- To define an expression for the flywheel's maximal energy storage.
- To establish an expression for maximum efficiency of the system

II. CONCERNS RESPONSE SURFACE METHODOLOGY (RSM) MODELS

Response surface methodology (RSM), a set of mathematical and statistical tools used for modelling and analysing problems where a response of interest is influenced by several variables, aims to maximise a response. Answering the question, "How is a certain response affected by a given set of input elements over some specified region of interest?" is the major objective of the Response Surface Methodology. •What input values will result in a maximum (or minimum) for a particular response?

What is the nature of the link between the response-factors near this maximum (or minimum)?

For instance, let's say we want to determine the values of two factors—x1, x2—that will maximise the process's response variable y:

$y = f(x1, x2) + \varepsilon$ (Noise)

A response surface is the surface denoted by = f(x1, x2) and graphically depicted as a solid surface in three dimensions. In order to depict the contour of the response surface, lines of constant response are drawn in the x1, x2 plane. The response surface's response surface heights are matched to each contour. Such a plot is useful for examining the values of x1 and x2 that lead to modifications in the response surface's form or height.

A collection of mathematical and statistical techniques that are useful for the modelling and analysis of problems where a response of interest is influenced by multiple variables and the goal is to optimise this response make up the Response Surface Methodology (RSM), a crucial topic in statistical design of experiments (Montgomery 2005). The dimensional study led to the creation of the following terminology. These phrases are easily divided into three groups because they don't have any dimensions. These groups are translated into three spatial dimensions [1-3] to produce a response surface.

2.2 STEPS IN RESPONSE SURFACE METHODOLOGY

•To estimate the functional relationship between y and the set of independent variables as closely as possible (usually, a low-order polynomial in some region of the independent variables: first-order model, or second-order model if there is curvature in the system).

•To establish the parameters of the approximation polynomials (to find the maximum response, for instance).

•To do the response surface analysis using the fitted surface.

If the fitted surface is a good approximation of the underlying response function, then analysis of the fitted surface will be roughly equal to analysis of the actual system.

2.3 RESPONSE SURFACE DESIGN

Six words are created in accordance with the dimensional analysis. Since these terms have no dimensions, splitting them into three groups is quite simple. To create a response surface, these three groups are translated into three dimensions of space. Hence,

X = Pi 1 x Pi2 x Pi 3

Y = Pi 4 x Pi 5

Z = Pi 01

The ranges of input X, Y and output Z are more variant. Hence by using scaling principle, the above

X, Y and Z values are scaled as follows:

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x = X / max (X), y = Y / max (Y), and z = Z / max (Z)

2.4 RSM MODEL DEVELOPMENT

To explore how process parameters affect output parameters, experimental data are gathered with process parameter levels set as indicated in the observation table.

Response surface methodology is used to plan and carry out the tests (RSM).

Utilizing statistical software called "MATLAB R2009a," response surface models were developed and the right model was chosen. For the response characteristics, specifically the prediction of angular velocity, the best fit regression equations for the chosen model are obtained. The response surface equations are created using experimental data and displayed (figure to) to examine how different response characteristics are impacted by process variables. Sample RSM model computations are shown in the table.

LINEAR MODEL POLY55:

f(x,y) = p00 + p10*x + p01*y + p20*x^2 + p11*x*y + p02*y^2 + p30*x^3 + p21*x^2*y + p12*x*y^2 + p03*y^3 + p40*x^4 + p31*x^3*y + p22*x^2*y^2 + p13*x*y^3 + p04*y^4 + p50*x^5 + p41*x^4*y + p32*x^3*y^2 + p23*x^2*y^3 + p14*x*y^4 + p05*y^5

where x is normalized by mean 3.442e-05 and std 1.51e-05
and where y is normalized by mean 2.484 and std 1.324
Coefficients (with 95% confidence bounds):

p00 = 2.663e+04 (2.467e+04, 2.859e+04)
p10 = -336.5 (-2635, 1962)
p01 = 1620 (-1445, 4685)
p20 = -2425 (-6018, 1167)
p11 = 981.6 (-3379, 5342)
p02 = -2525 (-7221, 2171)
p30 = 927.5 (-2202, 4057)
p21 = -1840 (-7584, 3904)
p12 = 1942 (-1440, 5324)
p03 = 1199 (-1535, 3934)
p40 = 1008 (-93.39, 2110)
p31 = -976.1 (-2589, 636.9)
p22 = 554.2 (-1400, 2508)
p13 = 702.5 (-2110, 3516)
p04 = -419.4 (-3461, 2622)
p50 = -413.6 (-1305, 477.8)
p41 = 891.6 (-622.8, 2406)
p32 = -702.7 (-2461, 1056)
p23 = 313.6 (-2083, 2710)
p14 = -655 (-1934, 623.5)
p05 = 155 (-1075, 1385)

Goodness of fit:
SSE: 1.382e+07
R-square: 0.9438
Adjusted R-square: 0.8688
RMSE: 960

Predicted SFRC Strength By Using RSM

f(x,y) = 2.663e+04 -336.5*x + 1620*y -2425*x^2 + 981.6*x*y -2525*y^2 + 927.5*x^3 -1840*x^2*y + 1942*x*y^2 + 1199*y^3 +1008*x^4 -976.1*x^3*y +554.2*x^2*y^2 + 702.5*x*y^3 -419.4*y^4 -413.6*x^5 + 891.6*x^4*y -702.7*x^3*y^2 + 313.6*x^2*y^3 -655*x*y^4 + 155*y^5

3D Plots and RSM Plots for all dependent models for 3D Model Pi01:

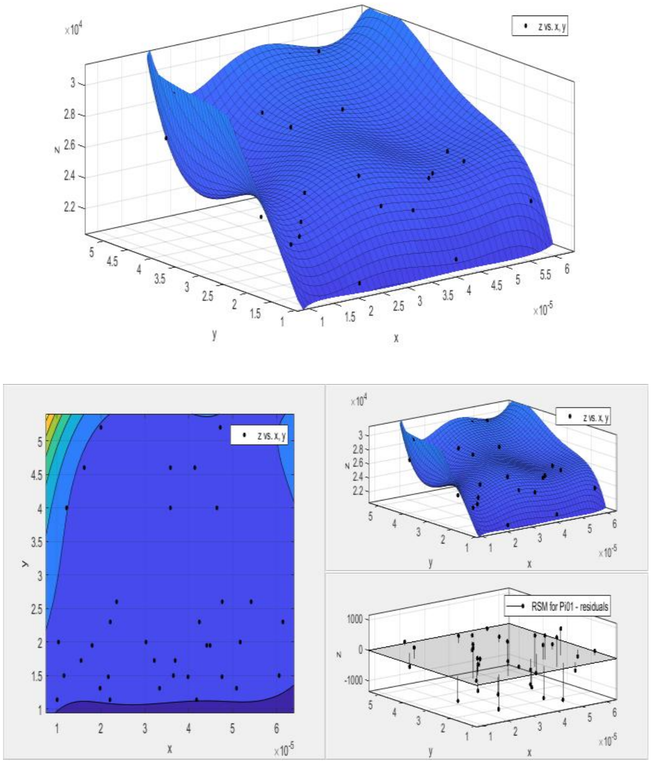

Figure3: RSM Model for Pi01Angular speed)

Table 1: Sample Calculations of RSM Model for angular velocity [4]

X= П1	Y= П2*П3	Z= Pi01
1.00155E-05	1.14	20881
4.17763E-05	1.14	21195
2.20642E-05	1.14	20985.67
1.15875E-05	1.5	23811.67
6.05811E-05	1.5	23288.33
3.64946E-05	1.5	24335
1.03383E-05	2	25120
5.17291E-05	2	25905
3.02633E-05	2	26428.33
1.21774E-05	4	30876.67

DISCUSSIONS OF 3D GRAPHS

In order to demonstrate how real phenomena function due to the proper interaction of independent components, it is possible to assess the behavior of any model using graphical representation. There has been an attempt to anticipate angular velocity.

In order to create an exact 3D graph, dependent terms are placed on the Z-axis, whilst from three independent terms, two are merged to create a product that is displayed on the Y-axis.

On the X-axis is a representation of the final independent pi term.

III. CONCLUSION

Using the gear ratio, the effectiveness of the mechanism, and human energy, the RSM model was designed to forecast the strength of the angular velocity. The data shown in column experimental strength and the anticipated RSM strength clearly show the importance of this model. The error vs. frequency graph for anticipated angular speed clearly illustrates the importance of this approach.RSM model for angular speed prediction created.

Comparing strength to one's own observed experimental strength

Predicted strengths and observed experimental strengths are determined to be within 90% of the confidence limit and to be relatively close to one another. It amply demonstrates the accuracy of RSM models created to determine anticipated strength.

For the response characteristics, the best-fitting regression equations for the chosen model are found.

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