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Optimization of Process parameters for Single Cylinder Piston Type Compressed Air Engine Using Taguchi's Approach

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***Abstract:** This study presents a physical model of compressed air engines (CAEs) is established from existing 4 stroke petrol engine. A conventional 100CC four stroke internal combustion engine was modified to a two stroke compressed air engine To obtain performance on the CAEs, a setup is prepared with dynamometer. The output torque and brake power are obtained through experimental study. the investigation on piston type compressed air engine for different loading condition on a test bench and brake power has been examined with different loading condition by use of design of experiments. For design of experiments L_9 taguchi method is used for experimentation and parametric analysis. The results show that CAE has a good economic performance at pressure 5 kg/cm^2 provide maximum 0.9283 kW power output with varying load 1.5 kg to 2.5 kg for modified air engine from existing 4 stroke engine and 2 stroke engine. This research can be referred to in the optimization of air-powered engine.*

***Keywords:** Design Of Experiment, Compressed Air Engine, Piston Type, Different Loading Condition*

I. INTRODUCTION

Fossil fuel burning is considered to be the main cause of serious environmental issues, including greenhouse effect, ozone layer depletion and acid rain [1].Renewable fuels, such as wind, solar, compressed air, etc., are used as obvious solutions [2]. With respect to environmental protection, Shafiee and Topal believe that oil and gas reserves may be diminished in 2042; this enhances the competition in the field of renewable energy vehicles [3]. Because of its low cost, safe maintenance, easy access, recyclability, higher energy storage density and long lifespan, compressed air energy storage will be an advanced and rapidly developing field in the future. The flow characteristics of compressed air in equipment have been studied [4] to [6]. Most applications of compressed air engines focus on auxiliary systems or systems that assist IC engines [7,8,9]. Only a few studies or industrial projects have focused on the application of a compressed air engine as the main power system [10].India is one of the fastest developing countries with stable economic growth, which increases the demand for transport in many cases. Fuel consumption is relatively proportional to this demand. Due to shortage of fossil fuel reserves, India relies heavily on imported fuel and has a great effect on the economy. India has to find alternative to maintain growth rate. Compressed Air Engine is a better option to produce power to run automobile, generators etc. it does not required any of the known fossil fuels like petrol, diesel, CNG, LPG, hydrogen etc. this works using only compressed air. It works on high pressure air and hence is pollution free and 100% eco-friendly[11]. This study focuses on the experimental investigation of compressed air engines in vehicles as the main power system. These results can be used to evaluate the functional applications and efficiency of a compressed aerial engine and improve the scope of possible solutions. Choosing Piston Type Engine for Compressed Air Operations has the advantage of simple convenience in traditional internal combustion (IC) engines, considering the use of vehicles with zero pollution.

II. EXPERIMENTAL METHOD

4-Stroke internal combustion engine which is not suitable for Compressed air vehicles because Compressed air vehicles terminates its cycle in 2-stroke so the change is needed for the 4-Stroke to 2-Stroke engine, For current studies, the focus on a change in the valve timing mechanism. Cam profiling signifies the basic idea of converting the four strokes engine to the two strokes engine, here Fig. 1 and 2, shows Pictorial view of the Conventional cam and modified cam. Fig. 3 and 4 shows the Valve timing diagram for conventional cam and modified cam and Fig.5and 6 labels the dimension and Actual view of cam. For replacing the original cylinder head, a new set two flank cams has been designed for operating the inlet and exhaust valves of the modified engine. Both the exhaust and inlet cams are symmetric about the center line of the cam shaft. The cams are made of mild steels. The cam shaft

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originally had two cams with one lobe each which were mutually perpendicular to each other. The crank rotates due to the movement of the piston; the camshaft is attached with the crankshaft by a timing chain or a timing belt. And as the crank rotates the camshaft also rotates and hence the timing of the valves is managed. In the traditional camshaft the inlet and exhaust valve both functions [12]. Table (1) lists the specification of the 4-stroke IC engine, which was modified in the current study as a single cylinder piston type compressed air engine. Before the experiments, the 97.2 cc Internal Combustion engine was modified and connected to a compressed air tank. The cam profile was modified to be conjugate to change the engine from 4-stroke to 2-stroke operation. After the engine was installed, the intake and exhaust valves were examined for possible leakage under high-air-pressure operation.

Table 1: Engine Specifications for 4-stroke engine

Parameter	Honda Sleek
Engine displacement	97.2 cc
Engine type	air cooled ,4 stroke
Number of cylinder	1
Valves per cylinder	2
Max power	7.0 ps @8000 rpm
Max torque	7.5 nm
Bore*Stroke	50 mm*49.5 mm
Fuel type	petrol
Starter	kick
Number of speed gear	4



Fig.1 Pictorial view of the Conventional cam

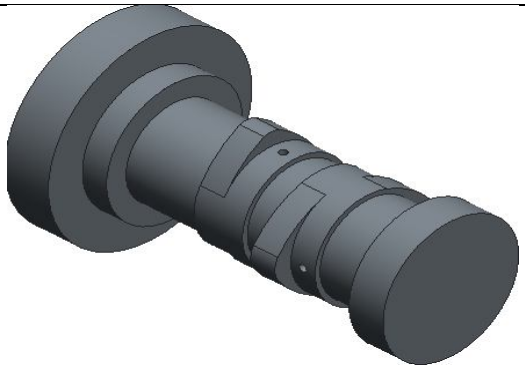


Fig.2 Pictorial view of the Modified cam

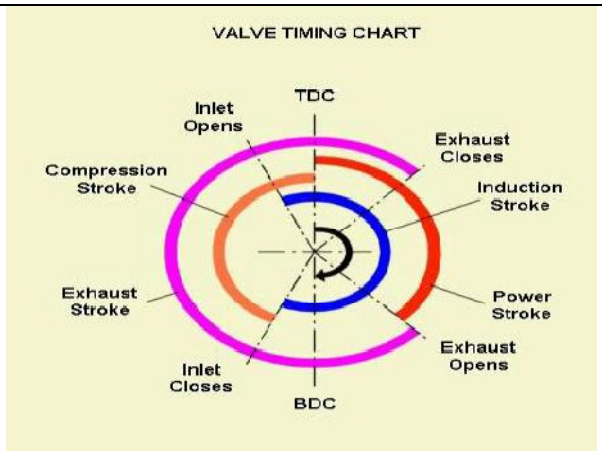


Fig.3 Valve timing diagram of the Conventional cam

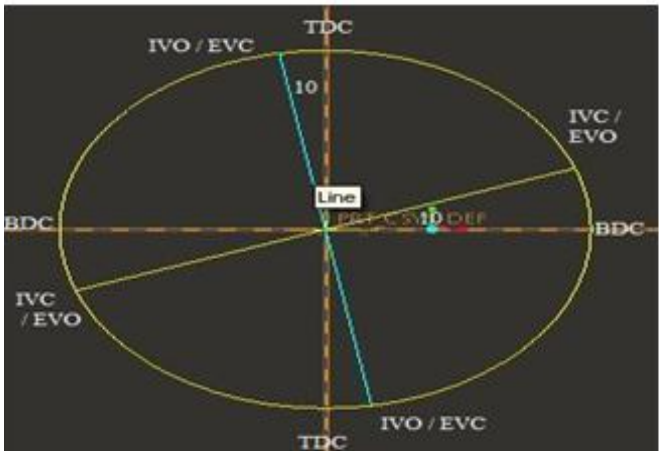


Fig.4 Valve timing diagram of the Modified cam

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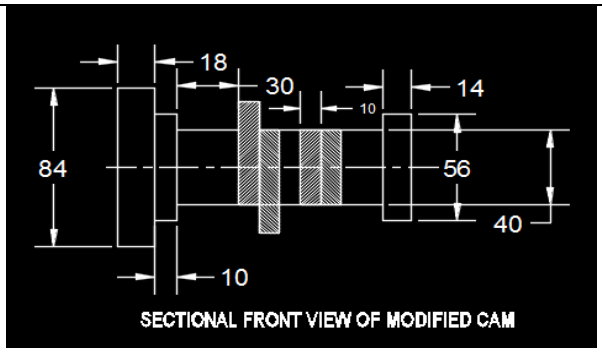


Fig.5 Sectional front view of Modified cam

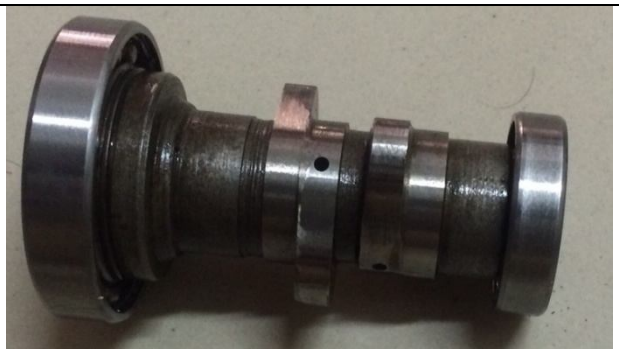

Fig.6 Actual view of the Modified cam



Fig.7 Experimental set up for single cylinder piston type air engine

The seepage of the intake valve was consequently close to the flow rate in the experiments, and it seriously affected the performance of the compressed air engine. The exhaust valve leakage was examined when the engine was locked in the intake process, and no leakage was observed. The experimental set up for 4 stroke single cylinder air engine is shown in Fig.7[12].

III. EXPERIMENTAL DESIGN

The purpose of the formation of the experiment is to determine the critical parameters and their target values[13]. On the basis of selected parameters, experimental design is carried out. The Taguchi experimental design is done for L_9 OA for two parameters which are air pressure and different load condition.

A. Process parameters

Process parameters are one of the most important factors for any experimental work. In the current case, the process parameters are selected based on the reviews of various literature. The different levels for process parameters are shown in table 2below.

Table 2 Levels for process parameters

Factor	Symbol	Unit	-1	0	+1
AIR PRESSURE	p	kg/cm^2	4	5	6
LOAD	L	KG	1.5	2	2.5

B. Output Process Parameters

In present study parameter taken as a response is brake power.

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IV. RESULT AND DISCUSSION

For load testing of air engine, it is connected with the rope brake dynamometer with brake drum, spring balance, belt and holding frame. During testing, brake power were measured to determine effective parameters of air pressure with loading condition by using taguchi design of experiments L_9

A. Taguchi Analysis of brake power of air engine versus pressure, load

Table 3 shows the Experimental Readings For Taguchi L_9 Orthogonal Array for brake power. The response tables 4 and 5 show the average of the selected characteristic for each level of the factors. The response tables include ranks based on Delta statistics, which compare the relative magnitude of effects. The Delta statistic is the highest average for each factor minus the lowest average for each factor.

Table 4 Response Table for Signal to Noise Ratios

Level	pressure	load
1	48.29	48.59
2	46.15	48.05
3	50.53	48.33
Delta	0.54	4.37
Rank	2	1

Table 5 Response Table for Means

Level	pressure	load
1	0.7289	0.5938
2	0.7574	0.7600
3	0.7663	0.8988
Delta	0.0374	0.3049
Rank	2	1

Ranks are assigned based on Delta values; Rank 1 is assigned to the highest Delta value, Rank 2 to the second highest Delta value, and so on. The main effects plot provides a graph of the averages in the response table. Based on the taguchi design analysis, from the table 4 and 5, it can be seen that for, the factor with the biggest impact on the S/N ratio is load (delta =4.37,Rank =1) so load is given more impact for brake power. and also it can be seen that at the response table and main effect plots for S/N ratio from figure 5,9 , for 2 kg and 2.5 kg of load have almost the same average S/N ratio (48.05 and 48.33).

Table 3Experimental Readings For Taguchi L_9 Orthogonal Array (brake power)

Pressure	Load	BP 1	B P 2	SNRA6	MEAN6
4	1.5	0.5628	0.5662	47.4140	0.56450
4	2.0	0.7319	0.7365	47.0714	0.73420
4	2.5	0.8860	0.8898	50.3819	0.88790
5	1.5	0.5847	0.5894	44.9418	0.58705
5	2.0	0.7550	0.7626	42.9966	0.75880
5	2.5	0.9283	0.9244	50.5245	0.92635
6	1.5	0.6309	0.6290	53.4213	0.62995
6	2.0	0.7858	0.7880	54.0802	0.78690
6	2.5	0.8782	0.8860	44.0788	0.88210

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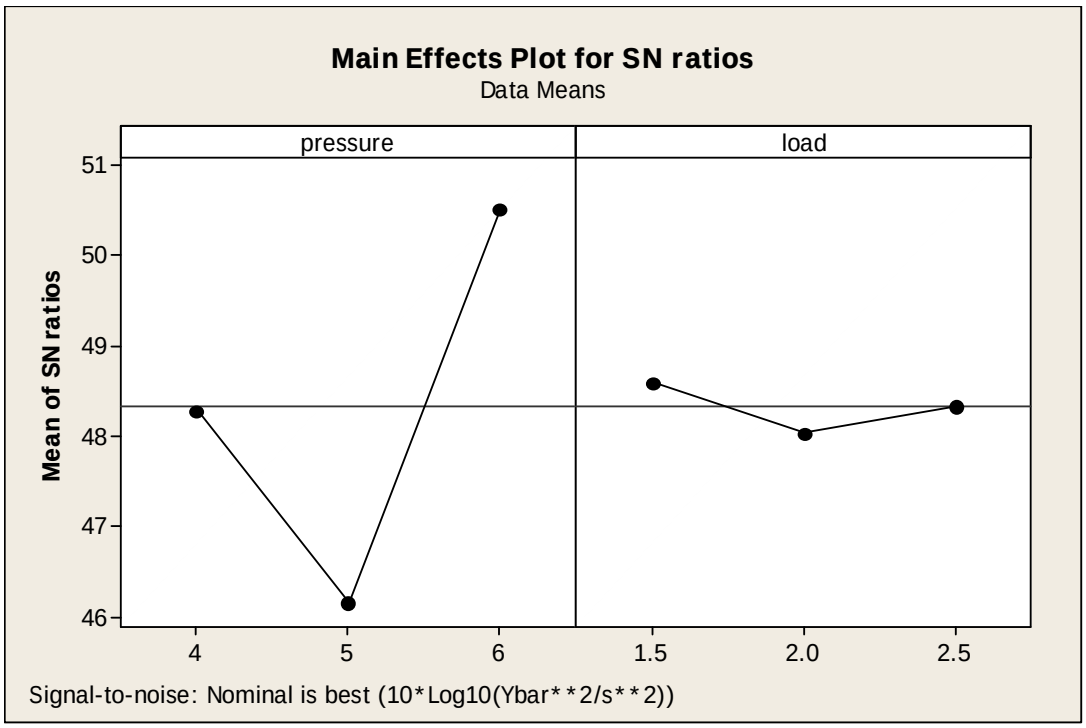


Fig. 8 Main effects Plot for SN ratio (Brake Power)

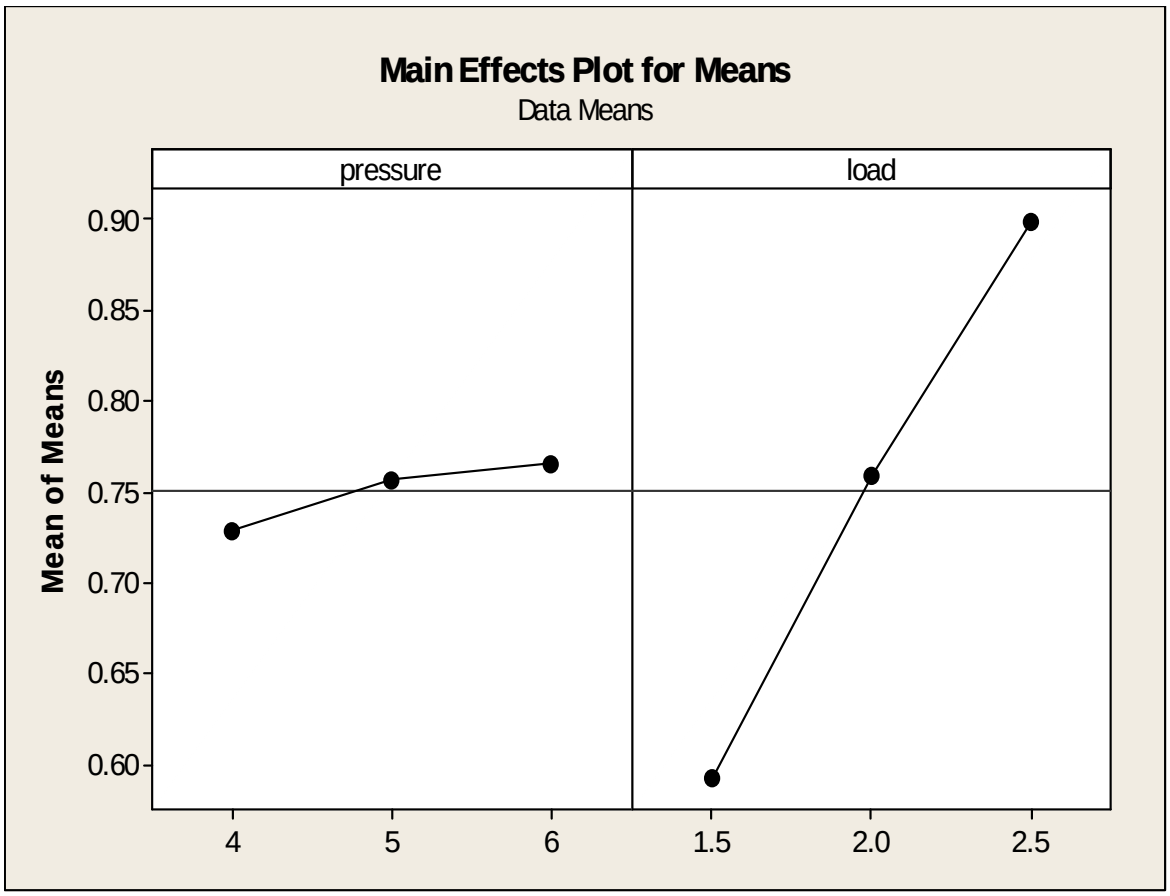


Fig.9Main Effect plot for Means (Brake Power)

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From the response diagrams in fig 8 and 9,it can be seen that with increase the pressure of the compressed air then brake power of the engine would increase. also from the response diagram and experimental taguchi design array combination, it can be seen that at 5 bar pressure and 2.5kg load , achieved maximum mean of brake power.

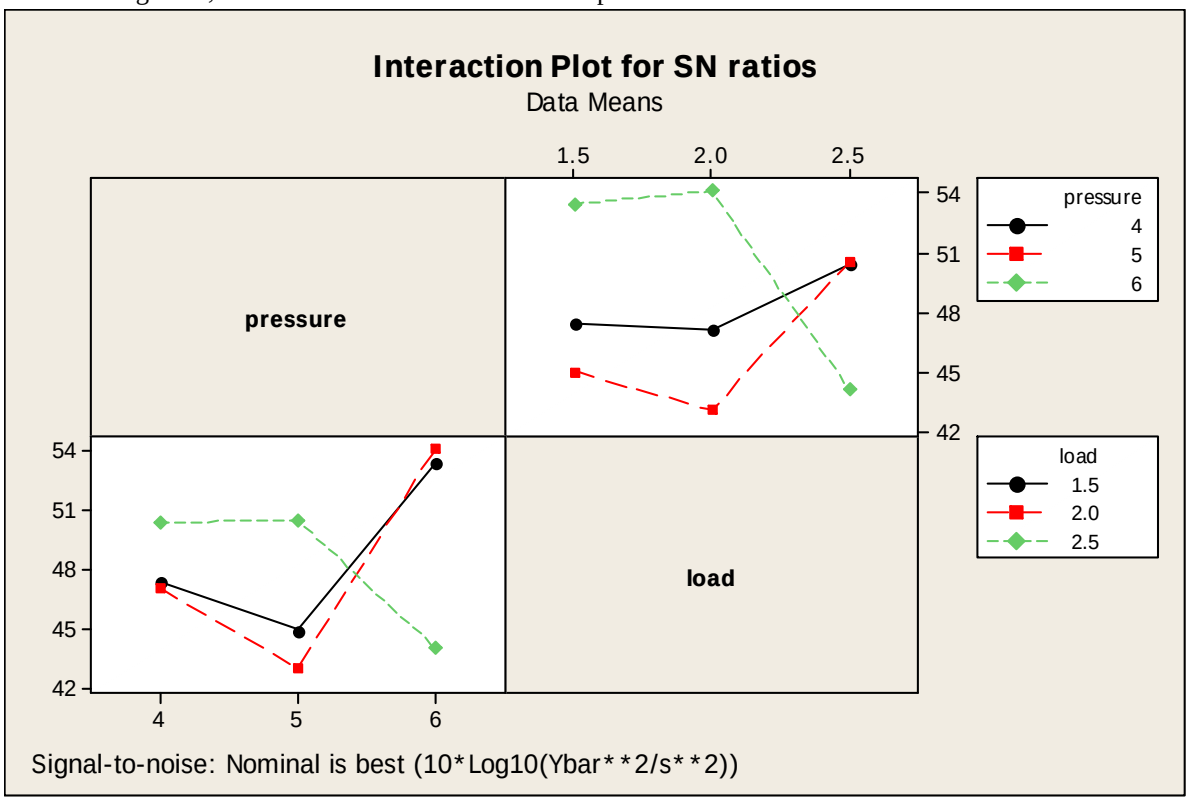


Fig.10.Interaction Plot for SN ratio (Brake Power)

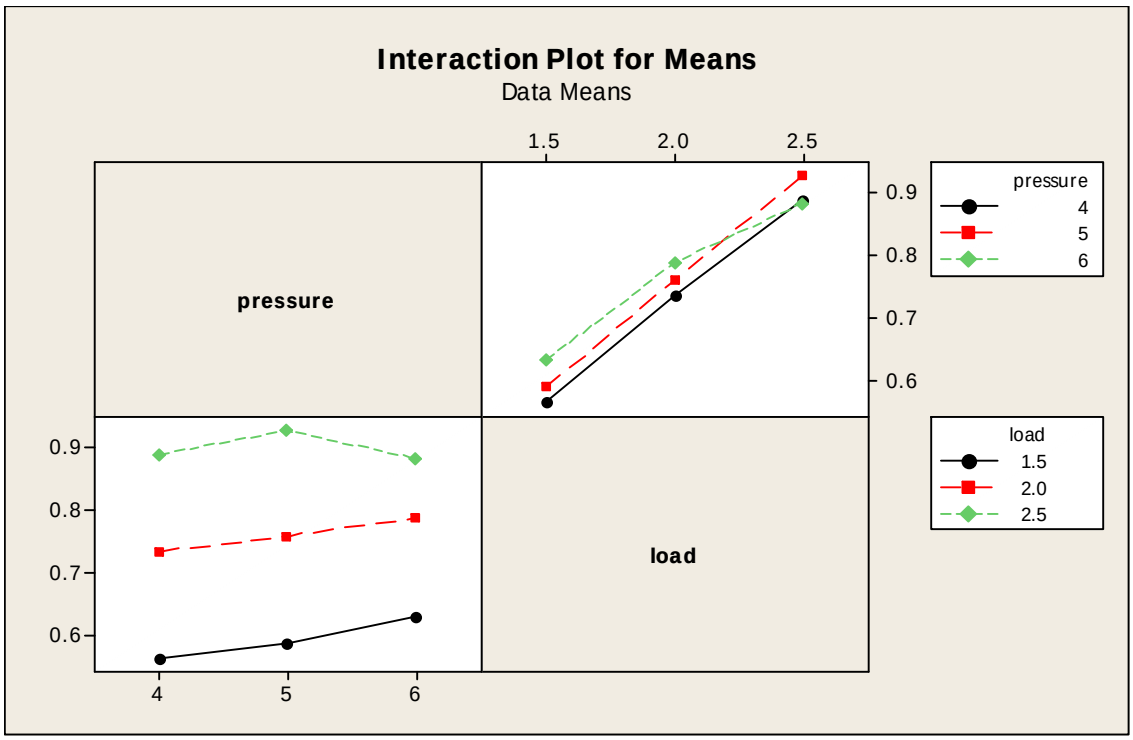


Fig.11 Interaction plot for Means (Brake Power)

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As shown in Fig.10 and fig.11, these interaction plot lines are not parallel .This interaction effect between load and brake power depends on the value of the pressure. for example, as per the plot at 2.5 kg load and 5bar pressure this combination is associated with the higher brake power.

B. Contour Plot Analysis

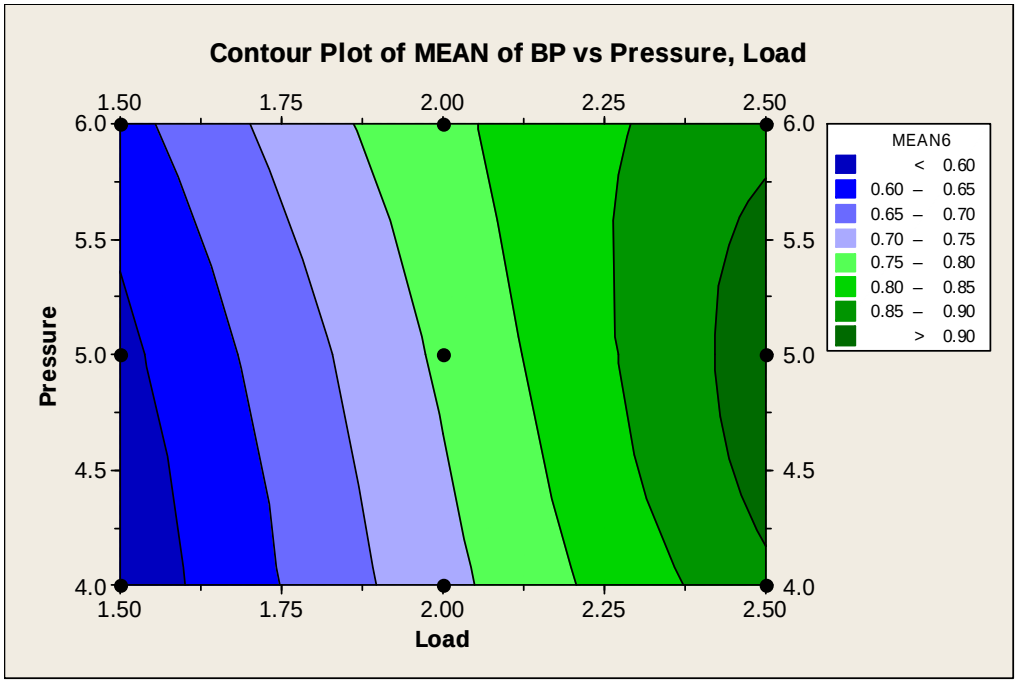


Fig.12 Contour plot of Mean of brake power vs Pressure & load

Fig.12 shows how pressure (y) and load (x) affect the contours of a brake power. The darker green regions indicate higher brake power. From the figure12 it can be seen that the combination of 5 bar pressure and 2.5 kg load gives maximum brake power i.e darker green area in convex shape. This graph gives the means of brake power range so prediction of compressed air pressure on different loading condition for air engine will be very easy to predict.

V. CONCLUSIONS

Present work based on DOE L_9 three different values of pressure viz; 4bar ,5bar and 6 bar and three different values of load i.e 1.5 kg ,2kg and 2.5kg are experimentally investigated on air engine test rig i.e modified from the existing 4 stroke internal combustion engine. Based on experimental observation, graphs are plotted and results are critically discussed for the different responses. Here, Load is given more impact on brake power as compare to pressure.. At 2.5 kg load and 5bar pressure this combination is associated with the higher brake power. In this study, the taguchi method gives effective methodology in order to find out the effective performance output for any machines. The results are very useful for adopting conventional internal combustion engine to convert to the air engine, and there is also the forecast of the process parameters to use the compressed air engine with zero pollution.

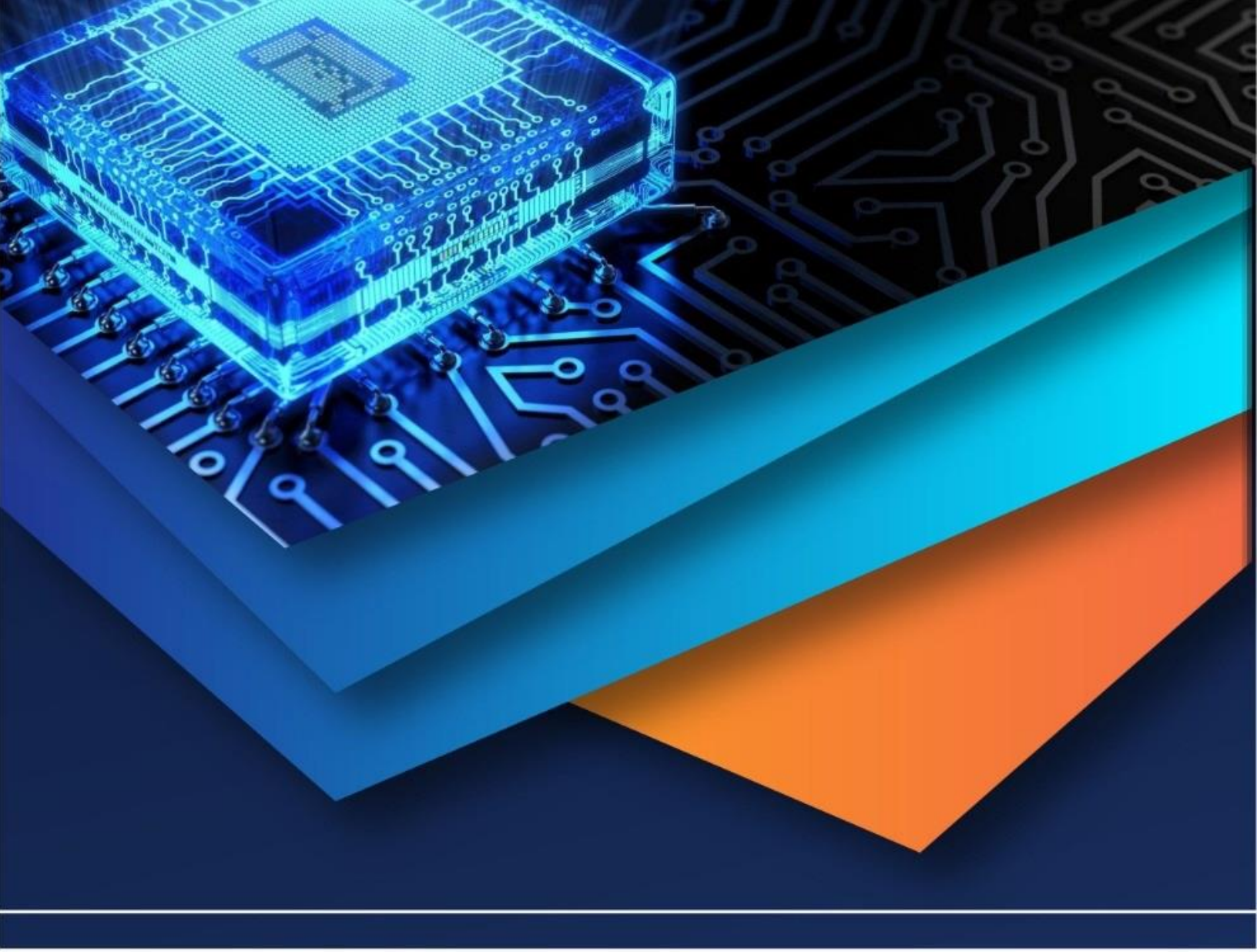
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