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DESIGN AND EVALUATION OF INTERNAEL COMBUSTION ENGINES PERFORMANCE

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ABSTRACT:-Operating an internal combustion engines with different values of time, Speed, Compression ratio and temperature needs a lot of work & effort. To have best evaluation of operating processes and engine performance DOE – 9 Expert is used. In designing process time, Number of cycles per minute and compression ratio were input as variable factors and the calculated results of fuel consumption rate, Torque is the response and brake power, the brake thermal efficiency, brake specific fuel consumption, the brake mean effective pressure, the volumetric and mechanical efficiency and the indicated power are the theoretically calculated factors .The first designed experimental work was for combustion engine which worked with gasoline only. Then a 10% of methanol added to gasoline is considered as mixture operating fuel. The DOE – 9 obtained predicted results were compared with the results and showed a good agreement. DOE – 9 perturbation plot show that as speed and mechanical efficiency and brake power increased (10 %).
Key words: Torque, Speed, Compression ratio, Gasoline, Methanol, DOE.

1. INTRODUCTION

Operating an internal combustion engines with high performance required accuracy in operating variables. These variables include choosing torque, speed and the operating fluid. A trend of mixing the fuel with different amount of another component and compare the results is an important issue to be studied and evaluated.

Fuel properties related to the content, and viscosity and distillation temperature. As for oxygen content or oxygenates, the addition of lower alcohols such as methanol and ethanol to Gasoline was effective in reducing particulate emissions without sacrificing other emission components(1).

Practically, adding some oxygenated compounds to fuels to reduce engine emissions without engine modification seems to be a more attractive proposition.

Methanol is regarded as one of the promising alternative fuels or oxygen additives for gasoline engines with its advantages of low price and high oxygen content. However, due to the difficulty in forming a stabilized gasoline/methanol blend. Few reports found on this topic and previous work was mainly concentrated on the application of diesel/methanol blends in a compression ignition engine (2). Therefore, much work is needed in the application of diesel/methanol blends in compression-ignition engine for clarifying the basic combustion and emission characteristics and providing an approach for attaining a stabilized gasoline/methanol blend with some solvent. Methanol is also known as methyl alcohol and is chemical formula is CH3OH commercially (3).

The octane number is the key parameter for gasoline fuel. For a conventional gasoline fuel, the octane number is a round (90-111). Fuels with high octane number result is smother engine operation and reduced emission of NO_x, particulate matter, hydrocarbons, and Co Methanol shows a prosperous market for its low price and easy obtainment(4).

Table (1) compares a parts of the fuel properties from which the advantages and disadvantages can be summarized as following.

In an attempt to have best investigation of operating process and how to choose different speed and compression ratio with time that affect the engines performance with the best efficiency DOE program was used.

1.1.DOE program

The technique for defining and investigating all possible conditions in an experiment involving multi factors is known as the Design of Experimental (DOE). DOE found to be a very necessary tool in; planning, conducting, analyzing and interpreting data investigated from the engineering experiment. The objective of a good designed experiment is to identify which set of factors in the process influences the process performance most, and then the best levels for these factors, in order to reach the desired quality level(5).

The parameters that would change in the experiment are named “factors” or “variables” as well. The different possibilities for a factor are called the levels which might be either qualitative or quantitative .The measured output from the experiment is named as response(6)..

Designed experiments are often happened in four phases: planning, screening (also called process characterization), optimization, and verification (7).

2. EXPERIMENTAL WORK

Design the experiments

The steps that should be followed to design a certain experiment are :-

1. Inputting factors that affect the Engine performance which are time, compression ratio and speed.
2. running the program sheet layout to design the operating process by variables (t, N and r) from minimum to maximum values as indicated in the table.(2).
3. Operate the engine with factors changing according to designed sheet.
4. Calculating the torque and other variables that assist the evaluation of the engine

EXPERIMENTAL SETUP

Experimental apparatus of industrial engine, water cooled, one cylinder, gasoline and diesel engine, with variable compression ratio. A water brake dynamometer was used to load the engine during the tests. A data acquisition system was coupled with the engine to measure the engine speeds, time temperature of water and torques. engine with variable two fuel tanks were used in the system, One for the gasoline fuel and the second gasoline and methanol with variable mixing ratio (90-10%) respectively, gasoline engine whose major specifications as shown in table (3).

In this study, the engine was worked in constant times and compression ratio and variable speed to obtain the different loads.

THEORETICAL CALCULATIONS

In designing experimental work by DOE – 9 program time, compression ratio and Speed (t, r, N) were the input factors .These factors were chosen depending on previous experimental works by literature. The calculated values of T is used to find break power, the break thermal efficiency, break specific fuel consumption, the break mean effective pressure, the volumetric and mechanical efficiency and the indicated power as shown in the following equations.

1-The fuel consumption rate:-

$m^{\cdot}f = \frac{20}{t} * \frac{1}{1000} * \rho$ ……………………………………………..…. (1)

2- the brake power for combustion engine work as shown in below:-

$BP = \frac{2\pi NT}{60}$…………………………………………………..……….(2)

3- The brake thermal efficiency:-

$$\eta_{th.b} = \frac{BP}{m^{\cdot}f * L.C.V.} = \frac{BP}{Q_c} \quad \text{……(3)}$$

4- The brake specific fuel consumption:-

$$b.s.f.c. = \frac{m^{\cdot}f}{BP} \quad \text{……(4)}$$

5- The brake mean effective pressure:-

$$b.m.e.p. = \frac{BP*60*2}{(\upsilon_s * n) * N} \quad \text{……(5)}$$

6- The swept volume:-

$$\upsilon_s = \frac{\pi}{4} * d^2 * L \quad \text{……(6)}$$

7- The air flow rate actually:-

$$m^{\cdot}a_{(act)} = \frac{2*\sqrt{h_o}}{3600} * \rho_{air} \quad \text{……(7)}$$

8- The fuel to air ratio:-

$$\frac{F}{A} = \frac{m^{\cdot}f}{m^{\cdot}a_{(act)}} \quad \text{……(8)}$$

9- The Air flow rate theoretically:-

$$m^{\cdot}a_{(theo)} = (\upsilon_s * n) * \frac{N}{2*60} * \rho_{air} \quad \text{……(9)}$$

10- The volumetric efficiency:-

$$\eta_v = \frac{m^{\cdot}a_{(act)}}{m^{\cdot}a_{(theo)}} \quad \text{……(10)}$$

11- The mechanical efficiency:-

$$\eta_m = \frac{BP}{IP} \quad \text{……(11)}$$

mechanical efficiency can be calculated if Bp is known which can be determined from figure (1) shown below . It should be noticed that brake power taken from the curve is absolute value neglecting the negative sign. Figure (2) show the brake power relation with average fuel consumption after 10% methanol addition.

12- The indicated power:-

Calculating the IP after obtaining the friction power from the curve and calculating the brake power .

$$IP = BP + FP \quad \text{……(12)}$$

3. RESULTS

Performing Data Analysis of DOE program was done by testing the ANOVA Table. First of all, the P-value should be checked. P-value is a measure of how likely the sample results are, assuming the null hypothesis is true. P-values range from “0 “to” 1”. A small ($\alpha <$ 0.05, commonly used level of significance) p-value indicates that the Power Level has statistically significant effect on the desired response(8). ANOVA of affecting factors in table. (4) showed that the experiment design is valid .

After testing the validity of the designed model the interaction of the primary factors affecting the engine performance and predicting advance variables are done by perturbation curves. perturbation plots in response surface and factorial designs help to compare the effects of all the components in the design space.

The factors tool is used to set the reference blend through which the trace tare plotted. The aim is to determine how sensitive the response is to deviation from the formulation near the reference state. Trace is used to predict the behavior of all responses as a result of changing the factors(9).

Considering Torque as response, the predicted results from DOE program shown in figure. (3).it is clear that Torque decrease as number of revolution and compression ratio increase. But increase with the decrease of time .

Figure(4) depicted that Bp increase as number of revolution increase and decrease when time of operating and compression ratio decrease.

Figure (5) showed that b.s.f.c. increase as r , t and N decrease and increase with the increment in Torque.

Figure (6) show that b.m.e.p. increase as r, t and N decrease and increase with the increment in Torque.

Figure (7) show that ηth. increase as r , t and T decrease and increase with the increment in N.

These results agree well with the experimental results for composition engine working with gasoline listed in table.(5).The minimum and maximum values of time of operating, compression ratio and number of revolution per minute are as in table.(2). After mixing the operating fuel with 10% ethanol ,all the engine factors increase significantly .this can be attributed to the effect of ethanol in reducing the impurities and enhancing the b.s.f.c. and b.m.e.p. Table.(6) show Engine experimental performance . 7

4- CONCLUSIONS

Studying the experimental results several observations can be made engine performance for the same fuel flow and temperature variation which are:-

1- Torque values after mixing the fuel with methanol are better than that of pure gasoline.
2- Break power variations of mixed fuel are larger than pure fuel.
3- b.m.e.p values values after mixing the fuel with methanol are better than that of pure gasoline.
4- Volumetric efficiency of mixed fuel is better than of pure gasoline.

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbol	*Description*
$T = Torque\ in\ N.m$	$N.m$
$N = Revolution\ per\ minte$	$Revolution\ per\ minte$ (r.p.m.)
$m^{\cdot}f$	$Fuel\ consumption\ rate\ (\frac{kg}{sec})$
ρ	$Fuel\ density\ (\frac{kg}{m^3})$
L	$Stroke\ length\ (m)$
t	$time\ (sec)$
v_s	$Swept\ volume\ (m^3)$
d	$Cylinder\ diameter\ (m)$
BP	$Brake\ Power\ (kwatt)$
$b.m.e.p.$	$Brake\ mean\ effective\ pressure\ (\frac{kN}{m^2})$
$b.s.f.c.$	Brake $specific\ fuel\ consumption\ (\frac{kg}{kw.hr})$
$L.C.V.$	$Lower\ calorfic\ Value\ of\ fuel\ (\frac{kJ}{kg})$
$\eta_{th.b}$	$Brake\ Thermal\ Efficiency$ (%)
$m^{\cdot}a_{(act)}$	$Air\ flow\ rate\ actually\ (\frac{kg}{sec})$
h_o	$Manometer\ reading\ (m)$
ρ_{air}	$Air\ density\ (\frac{kg}{m^3})$
$m^{\cdot}a_{(theo)}$	$Air\ flow\ rate\ theoretically\ (\frac{kg}{sec})$
η_m	$Mechanical\ efficiency$ (%)
IP	$Indicated\ power\ (kwatt)$
FP	$Friction\ power\ (kwatt)$
DOE	Design of Experimental Work
ANOVA	Analysis of Variances

Table (1) comparison of fuel properties

Mode	Methanol	Ethanol	Gasoline
Molecular formula	CH_3OH	C_2H_5OH	C_8H_{15}
Molecular weight	32	46	95-120
Oxygen content, %	50 %	34.8 %	0
Density, kg/m^3	792	785	740
Octane number	111	108	90 %
Auto temperature °C	465	425	228~470
Stichometric A/F ratio	6.47	9.00	14.8

Table.(2) factors of DOE program

Factor	Name	Level	Low Level	High Level	Std. Dev.	Coding
A	N	2000.00	1500.00	2500.00	0.000	Actual
B	t	100	200	180	0.000	Actual
C	r	10.00	8.00	12.00	0.000	Actual

Table (3) specification of the engine used for the test.

Name of the engine	Specification of engine
General details	One cylinder, two stroke, water cool, variable compression ratio
Bore	82 mm
Stroke	76 mm
Maximum pressure on the cylinder	200 kN/m^2

Table.(4). ANOVA of affecting factors

ANOVA for Response Surface Cubic model for response (TORQUE).						
	Sum of		**Mean**	**F**	**p-value**	
Source	**Squares**	**df**	**Square**	**Value**	**Prob > F**	
Model	0.25	13	0.019	83.37	< 0.0001	significant
A-N	*0.012*	*1*	*0.012*	*54.35*	*0.0003*	
B-t	*2.511E-004*	*1*	*2.511E-004*	*1.10*	*0.3341*	
C-r	*3.825E-004*	*1*	*3.825E-004*	*1.68*	*0.2426*	
AB	*1.966E-003*	*1*	*1.966E-003*	*8.63*	*0.0260*	
AC	*2.013E-004*	*1*	*2.013E-004*	*0.88*	*0.3834*	
BC	*9.445E-003*	*1*	*9.445E-003*	*41.49*	*0.0007*	

Table.(5)Engine experimental performance

t =185sec., r=8, N=1000-2500 r.p.m., m_f = 8x10^{-5}, m_a =2.34x10^{-4}						
T N.m	Bp kw	$Eff_{b.th}$ %	b.s.f.c. kg/kw.hr	b.m.e.p. KN/m^2	Eff_v %	Eff_m %
12	1.884	53.5	0.1528	375.715	3.98	83.2
10.5	2.19	62.4	0.131	328.752	2.99	83.2
10	2.617	74.3	0.11	313.096	2.39	83.2
t =150sec. r=10 N= 1000-25000 r.p.m. m_f = 8x10^{-5}, m_a =2.34x10^{-4}						
10	1.57	36.1	0.22	313.096	3.98	83.2
9.5	1.98	45.8	0.178	297.441	2.99	83.2
9	2.35	54.2	0.15	281.78	2.3	83.2
t =120sec. r=12 N= 1000-25000 r.p.m. m_f = 8x10^{-5}, m_a =2.34x10^{-4}						
9.5	1.49	27.5	0.297	297.441	3.98	83.2
9.4	1.968	36.2	0.225	294.311	2.99	83.2
9.2	2.4	44.3	0.184	288	2.39	83.2

Table.(6)Engine experimental performance

t =185sec., r=8, N=1000-2500 r.p.m., m_f = 8x10^{-5}, m_a =2.34x10^{-4}						
T N.m	Bp kw	$\eta_{th.b.}$ %	b.s.f.c. Kg/Kw.hr	b.m.e.p. KN/ m^2	Eff_v %	Eff_m %
14	2.199115	62.47	0.13	438.336	3.98	95.66
12	2.513274	71.39	0.114	375.716	2.99	95.66
11.5	3.010692	85.53	0.095	360.061	2.39	95.66
t =150sec. r=10 N= 1000-25000 r.p.m. m_f = 8x10^{-5}, m_a =2.34x10^{-4}						
12	2.303835	53	0.1884	375.716	3.98	95.66
11	2.748894	63.3	0.1785	344.406	2.99	95.66
10.5	2.042035	37.6	0.1292	328.752	2.39	95.66
t =120sec. r=12 N= 1000-25000 r.p.m. m_f = 8x10^{-5}, m_a =2.34x10^{-4}						
13	2.042035	37.6	0.2174	407.026	3.98	95.66
12.6	2.638938	48.6	0.1682	394.502	2.99	95.66
12.4	3.246312	59.8	0.1367	388.24	2.39	95.66

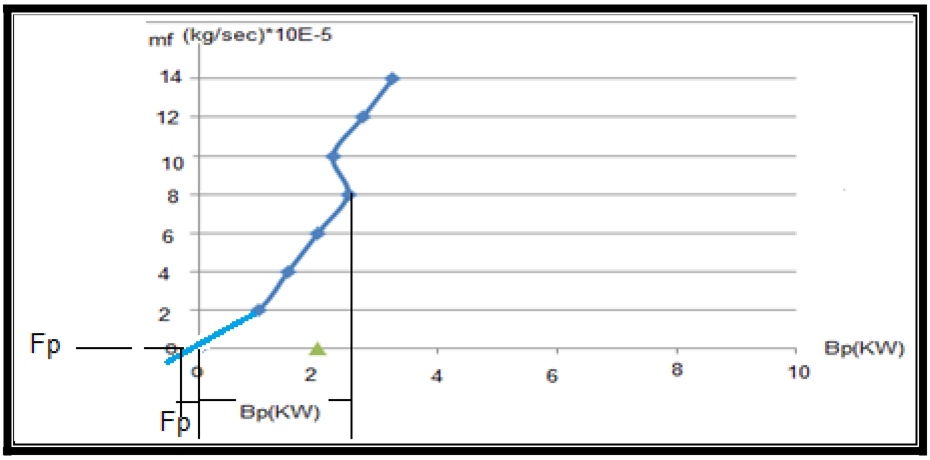

Fig.(1) brake power with average fuel consumption for engine working

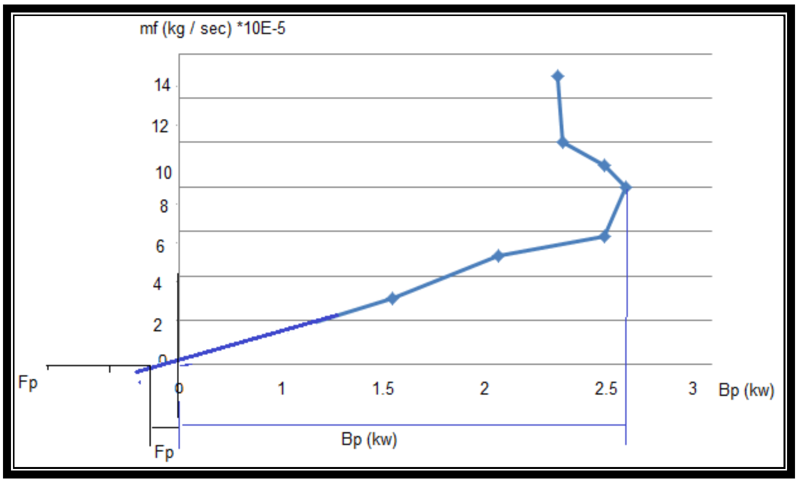

Fig.(2) brake power with average fuel consumption for composition engine working with 10% methanol + 90% gasoline.

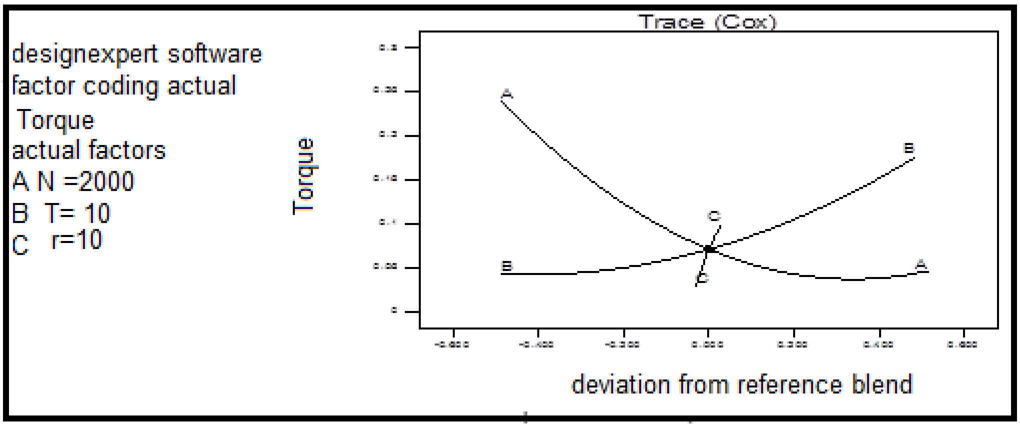

Fig.(3) Predicted behavior of Torque as a response to N,r,t change.

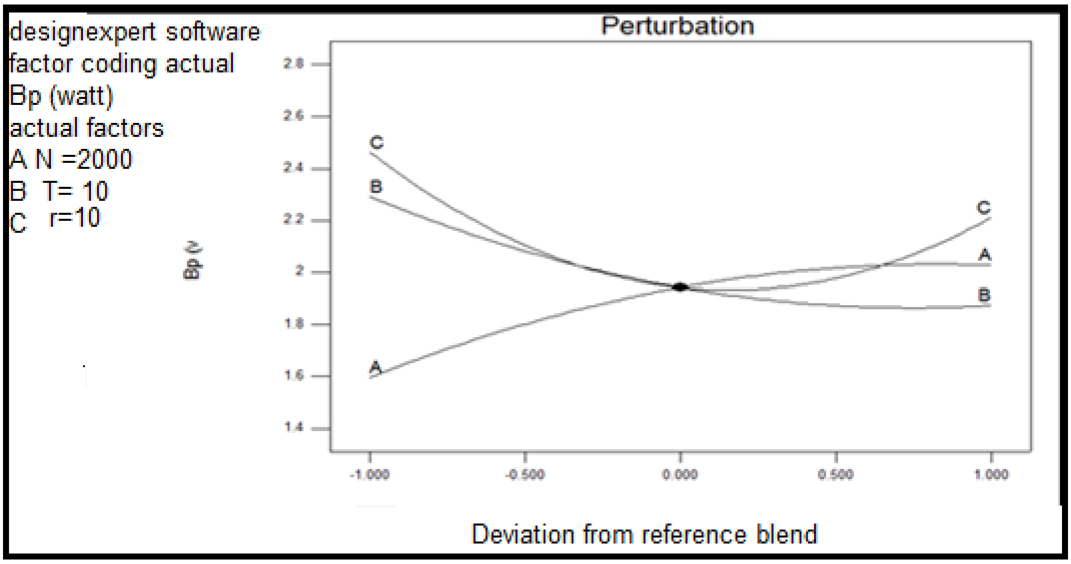

Fig.(4) Predicted behavior of Bp as a response to N,r,t change.

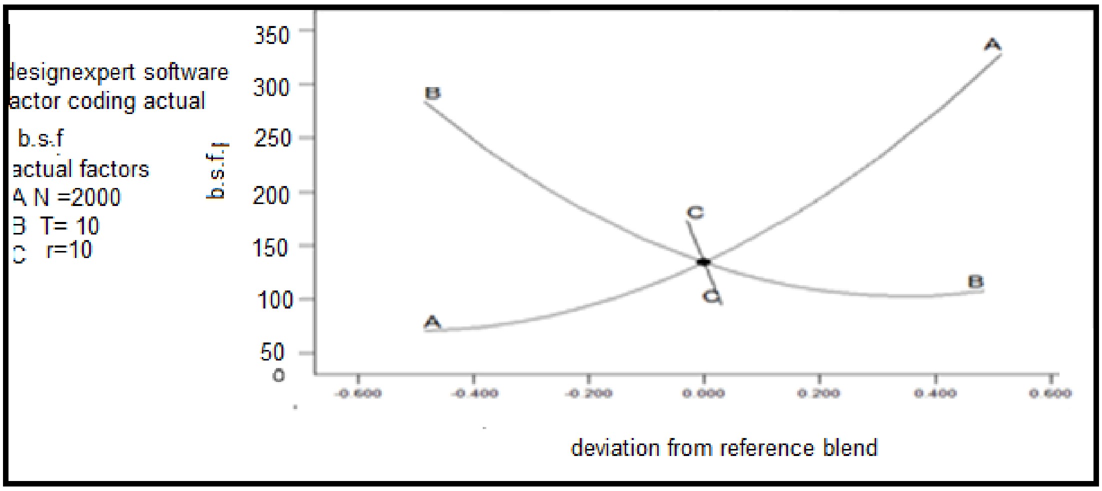

Fig.(5) Predicted behavior of b.s.f.c. as a response to N,r,t change.

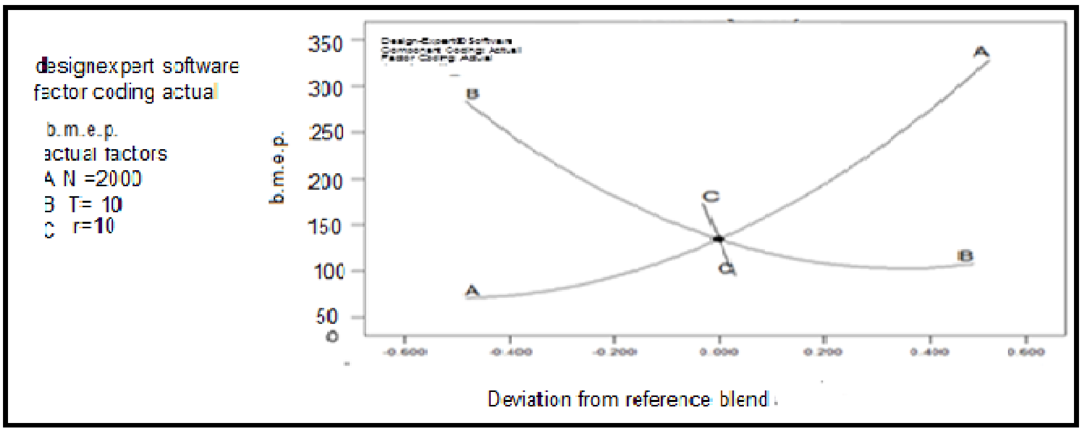

Fig.(6) Predicted behavior of b.s.f.c. as a response to N,r,t change.

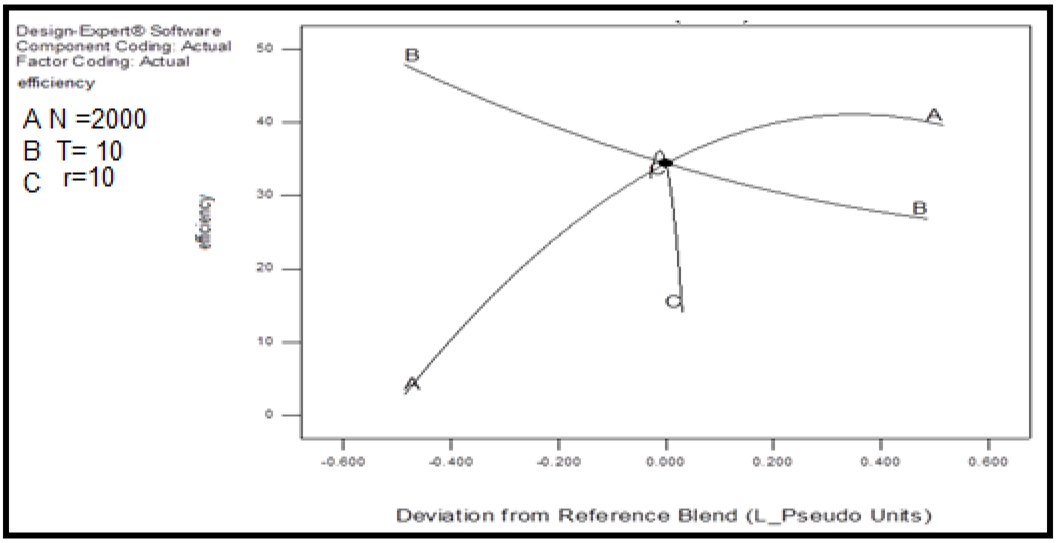

Fig.(7) Predicted behavior of η_{th} as a response to N,r,t change.

تصميم وتقويم معاملات الاداء لمحرك الاحتراق الداخلي

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الخلاصة:

تشغيل محركات الاحتراق الداخلى ذات القيم المتغيرة من الزمن والسرعة ونسبة الانضغاط يحتاج الى المزيد من العمل والجهد.ولاجل الحصول على افضل تقييم لعملية تشغيل واداء المحرك تم استخدام تقنية Design of experimental.فى عملية التصميم ادخل الزمن – السرعة ونسبة الانضغاط كعوامل متغيرة تؤثر على انتائج العزم والتى يمكن بواسطتها حساب (الكفاءة ,قدرة المحرك والكفاءة الميكانيكية والحجمية). صمم الجزء العملى اولا باستخدام الكازولين فقط ومن ثم تم اضافة نسب خلط مختلفة للكازولين مع الميثانول. اظهرت النتائج المصممة ل – DOE 9والنتائج التى تم الحصول عليها عمليا درجة جيدة من التوافق مع بعضهما. اظهر مخطط اضطراب ل 9 – DOE حصول زيادة في الكفاءة الميكانيكية والسرعة والقدرة الفرملية بنسبة (% 10).

الكلمات المفتاحية: الشغل , العزم , السرعة , نسبة الانضغاط , الكازولين , الميثانول , برنامج تصميم التجارب النسخة التاسعة.