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Effect of Temperature on the Performance Parameters of a Diesel Engine

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Abstract

The aim of this work is to study the effect of variation of air temperature on the performance parameters and on volumetric efficiency of diesel engine. The experimental measurement were carried out on this engine at different air temperature 25-85^{o}C and at different engine speed from 1000-2000rpm.

The results of experimental measurement show that a decrease (8-15%) in the volumetric efficiency when sucked air temperature change from 25-85^{o}C. It is also found that the engine output and torque decrease at increasing the sucked air temperature while specific fuel consumption, exhaust temperature and exhaust emission are increased.

The results of the experimental work were compared with result of a mathematical model and a good agreement was found.

الخلاصة

*يهدف البحث إلى دراسة تأثير تغير درجة حرارة الهواء الداخل إلى محرك ديزل على معالم أداء وعلى الكفاءة الحجمية. لقد أجريت التجارب المختبرية على محرك ديزل وبدرجة حرارة الهواء الداخل من **25-85^{o}C** وبسرع مختلفة للمحرك من **1000-2000rpm**.*

*وبينت نتائج التجارب بأن هناك تأثير كبير لتغير درجة حرارة الهواء الداخل إلى المحرك على معالم الأداء وعلى الاستهلاك النوعي للوقود وخاصة في درجات الحرارة العالية. وقد لوحظ إن الكفاءة الحجمية قلت بنسبة **(8-15%)** عندما تغيرت درجة حرارة الهواء الداخل من **25-85^{o}C**.*

لقد قورنت هذه النتائج العملية لهذا البحث مع الموديل الرياضي وظهر هناك توافق كبير بينهما.

1. Theoretical Analysis

1-1 Advanced, Main and Delayed Suction

Admission of charge to the engine considerably depends on value and duration of suction value opening. Mean area of suction hole is determined from the following formula as shown in **Fig.(1)** [1,2].

$$f_m = \pi h\left(d_h + \frac{h}{2}\sin 2\varphi\right)\mathrm{Cos}\,2\theta \quad \textbf{(1)}$$

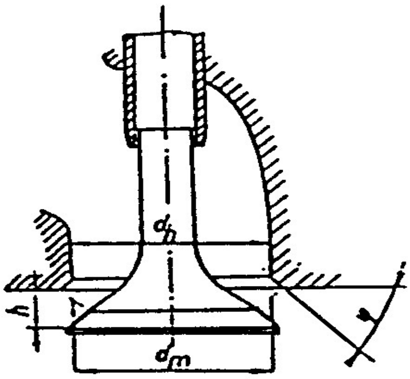

Figure (1) Scheme for Suction Hole and Valve

The duration of suction valve opening is a function of advance opening $\left[\alpha_a = 10 - 45^\circ\right]$ and delayed closing $\alpha_d = 100$. Generally the duration of suction valve opening is determined by the sum: $\alpha_a + 80^\circ + \alpha_d$.

Mass of fresh charge admitted to cylinder during advanced and main suction is denoted by m_m which represents the main mass of fresh charge which can enter the cylinder during the whole suction process. During the delayed suction these can be either the continuation of charging or the reverse blow out. This will be function of the number of revolutions. The mass of fresh charge admitted to the engine during this duration denoted by m_d.

The total mass of fresh charge admitted to cylinder per cycle can be express by the following equation:

$$m_c = m_m + m_s - m_b \quad \textbf{(2)}$$

If the mass admitted during delayed suction is $m_d = m_s - m_b$ then eq.(2) becomes $m_c = m_m + m_d$

Considering the coefficient of delayed suction v, it follows [3,4]:

$$v = \frac{m_c}{m_m} = \frac{m_m + m_d}{m_m} = 1 + \frac{m_d}{m_m} \quad \text{.. (3)}$$

1-2 Fresh Charge Admitted to Engine at Different Engine Speed

The mass of fresh charge, which is admitted to engine per cycle does not remain constant. At higher engine revolutions, the suction pressure will decease the admitted mass of fresh charge to engine per cycle. This mass can be expressed analytically [1,5,6].

$$m_c = v\frac{p_1 V_Z}{RT_1}\frac{e}{e-1} \quad \text{.. (4)}$$

The- suction pressure P_1, can be calculated from the following equation [1,5,6].

$$p_1 = p_a\left[1 - \frac{n_M^2}{520\times10^6}\left(\frac{V_z}{f_m}\right)^2\left(\frac{e}{e-1}\right)^2\left(\frac{1}{\zeta^2}\right)\right] \quad \text{.................................... (5)}$$

1-3 Volumetric Efficiency

Comparison of different engines according to the mass of fresh charge admitted to them is useless, because the engines with greater working volumes will always have also greater mass of fresh charge.

Therefore, there is introduced a, dimensionless value which is called volumetric efficiency η_v. It is defined as the ratio of the actual mass of fresh charge m_{act} which is actually sucked to engine, to the theoretical mass of fresh charge m_{th} which would theoretically fill the working volume V_Z at atmospheric pressure and temperature.

$$\eta_v = \frac{m_{act}}{m_{th}} \quad \text{.. (6)}$$

For analytical determination of the coefficient η_v we may write $m_{act} = m_{th}$ and

$$m_{th} = \frac{p_a . V_Z}{R . T_a}$$, then:

$$\eta_v = \left[1 - \frac{n_M^2}{520\times10^6}\left(\frac{V_Z}{f_m}\right)^2\left(\frac{e}{e-1}\right)^2\frac{1}{\zeta^2}\right]^{k/\ k-1}\frac{e}{e-1}\frac{T_a V}{T_1} \quad \text{.................... (7)}$$

Equations 1-7 study the effect of variation of sucked air temperature on volumetric efficiency and then permit the study of this effect on the actual cycle of piston engine. The temperature T_1 at end of suction stroke can be calculated with an acceptable accuracy from equation:

$$T_1 = \frac{T_a + \Delta t + \gamma T_{th}}{1+\gamma} \quad \text{.......} \quad \mathbf{(8)}$$

where:

$T_a = 273 + t_s[K]$

$t_s -$ temperature of sucked air after heating $[^\circ C]$

It is possible to denote

$$K_1 = \frac{1}{520\times 10^6}\left(\frac{V_Z}{f_m}\right)^2\left(\frac{e}{e-1}\right)\frac{1}{\zeta^2}$$

$$K_2 = \left(\frac{e}{e-1}\right) vT_a$$

The equation (7) can be expressed as:

$$\eta_v = \left[1 - K_1 n_M^2\right]^{k/\ k-1} \frac{K_2}{T_1} \quad \text{.......} \quad \mathbf{(9)}$$

where: K_1, and K_2 with an acceptable accuracy will be constant for given engine.

According to eq.(8) for different chosen value of the temperature t_s, we obtain from eq. (9) different graphs for the coefficient of volumetric efficiency η_v as a function of engine speed.

Figure (2) shows the results of applying eqs. (8) and (9) to a diesel engine type 2001.

2. Experimental Measurement

Experiments were done on the diesel engine type 2001. The temperature of sucked air was regulated by system type vertex. **Figure (3)** shows the layout for testing stand. The measurement was carried at for different temperature t_s at full load and 70% load.

Figure (4) shows the result of these tests. The experimental measurement are also carried out to find the effect of variation of sucked air temperature on the engine effective power P_e, engine torque M_t, specific fuel consumption m_{pe} exhaust temperature t_v, mass fuel flow rate m_{pH}, and exhaust emission E at different engine speed.

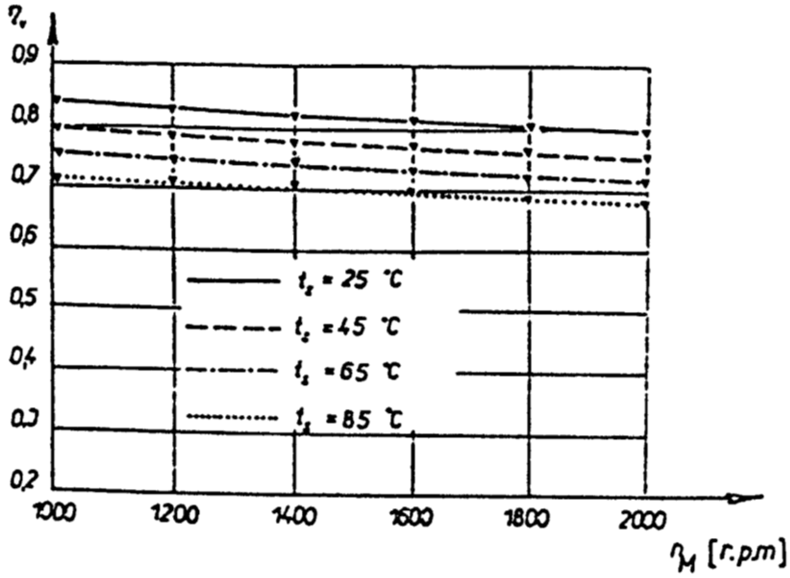

Figure (2) Effect of Sucked Air Temperature t, on the Volumetric Efficiency Y7, (Calculated)

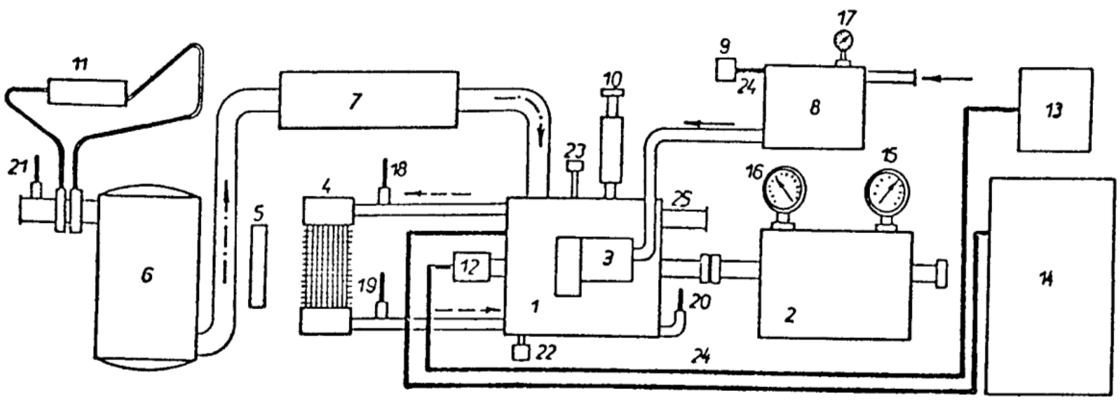

Figure (3) Layout for Testing Stand

1. *Tested Engine Zetor 2001.* ***2.*** *Heenan dynamometer.* ***3.*** *Injection pump.* ***4.*** *Radiator.* ***5.*** *Fan.* ***6.*** *Air tank.* ***7.*** *Heating system.* ***8.*** *Glass vessel of fuel.* ***9.*** *Switch.* ***10.*** *Bosch smokemeter.* ***11.*** *Micromanometer.* ***12.*** *Photocell.* ***13.*** *Counter.* ***14.*** *Oscilloscope.* ***15,16.*** *Gauges.* ***17.*** *Stop watch.* ***18.*** *Outlet water mercury thermometer.* ***19.*** *Inlet water mercury thermometer.* ***20.*** *Oil mercury thermometer.* ***21.*** *Atmospheric mercury thermometer.* ***22.*** *Oil pressure sending unit.* ***23.*** *Exhaust temperature sending unit.* ***24.*** *Electric cables.* ***25.*** *Exhaust manifold.*

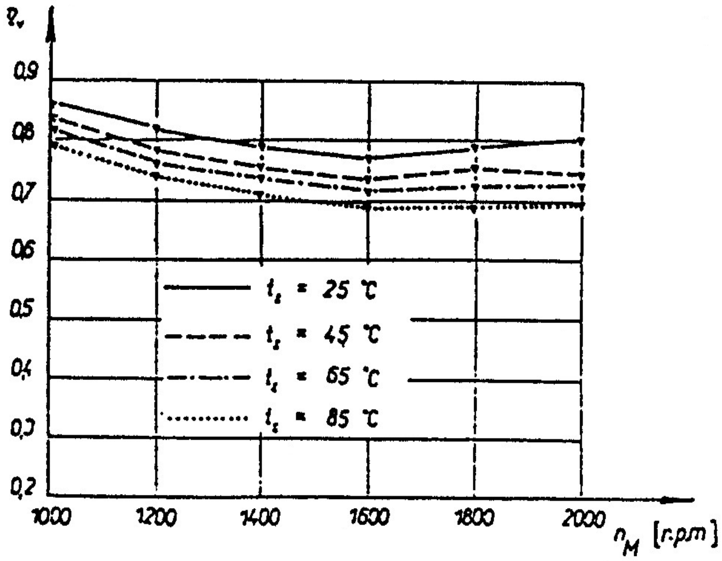

Figure (4) Effect of Sucked Air Temperature t_s on the Volumetric Efficiency η_v (Measured)

3. Result and Conclusion

The result of theoretical and experimental work for 70% and full load of the tested engine at the range of revolutions from 1000 to 2000 rpm are:

1. **Figure (2)** shows the volumetric efficiency as a function of engine speed. It is clear from theoretical model that the coefficient of volumetric efficiency decreases with increasing the temperature of sucked air t_s and engine speed (rpm).
2. The result of experimental measurement of η_v, as a function of t_s are shown in **Fig.(4)** with increasing sucked air temperature t_s volumetric efficiency will decrease.
3. **Figures (5,6)** show the speed characteristic at 70% and full load for different engine speeds. The drop in the volumetric efficiency reflects it self on effective engine parameters.

It is clear that with increasing of t_s the effective fuel consumption m_{pe} is increases especially at high t_s, also the effective power P_e, and engine torque M_t are decreased.

The results of experiments show that as t_s increases the percentage of the exhaust emission E increases (15-25 %) and the exhaust temperature t_v increases (8-12 %) as shown in **Figs.(5,6)**.

4. The result of the effect of increasing of sucked air temperature t_s from 25 to 85^{o}C causes a decrease (8-15 %) in the volumetric efficiency as shown in **Figs.(7,8,9 and 10)**.

It can be said that the divergence of a very small number of points between theoretical model and experimental measurements does not exceed 5% and this is due to the following factors:

- Range of chosen parameters.
- Accuracy of measurement.
- Accuracy of measuring instruments.
- Random errors.

Finally, It can be concluded that this work present good agreement between theoretical model and experimental measurements. This work may be used as a good basis for future investigations to study the ignition delay period in a diesel engine and its relation with sucked air temperature, cetane number (fuel types), engine speed and engine roughness.

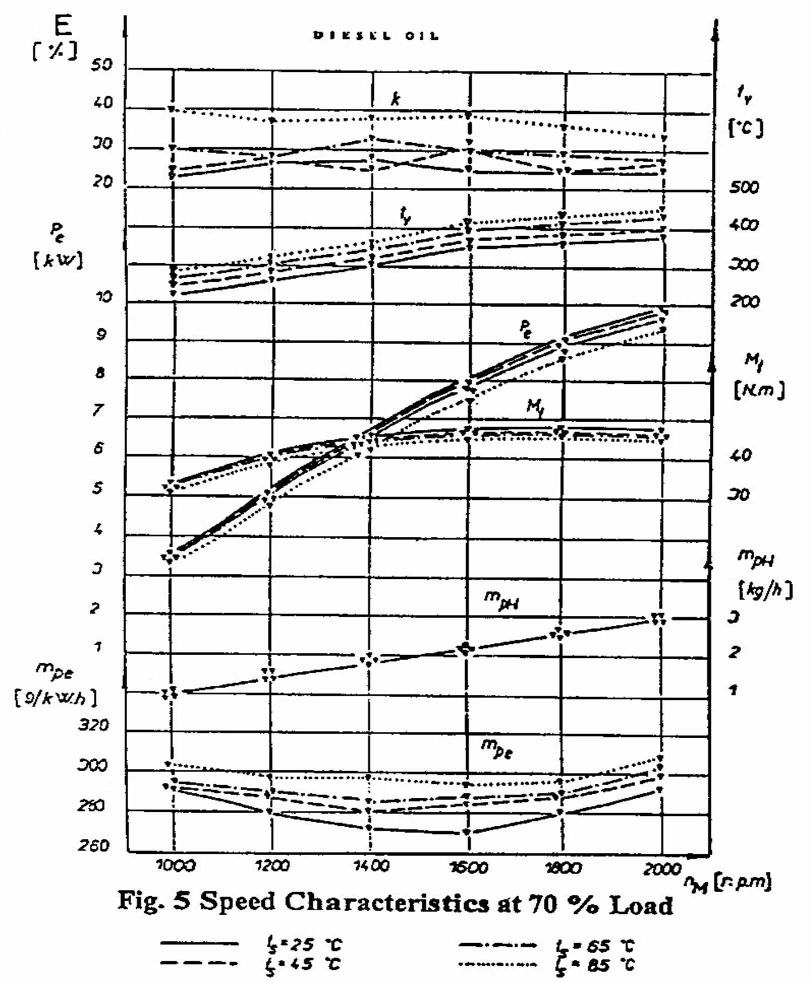

Figure (5) Speed Characteristics at 70% Load

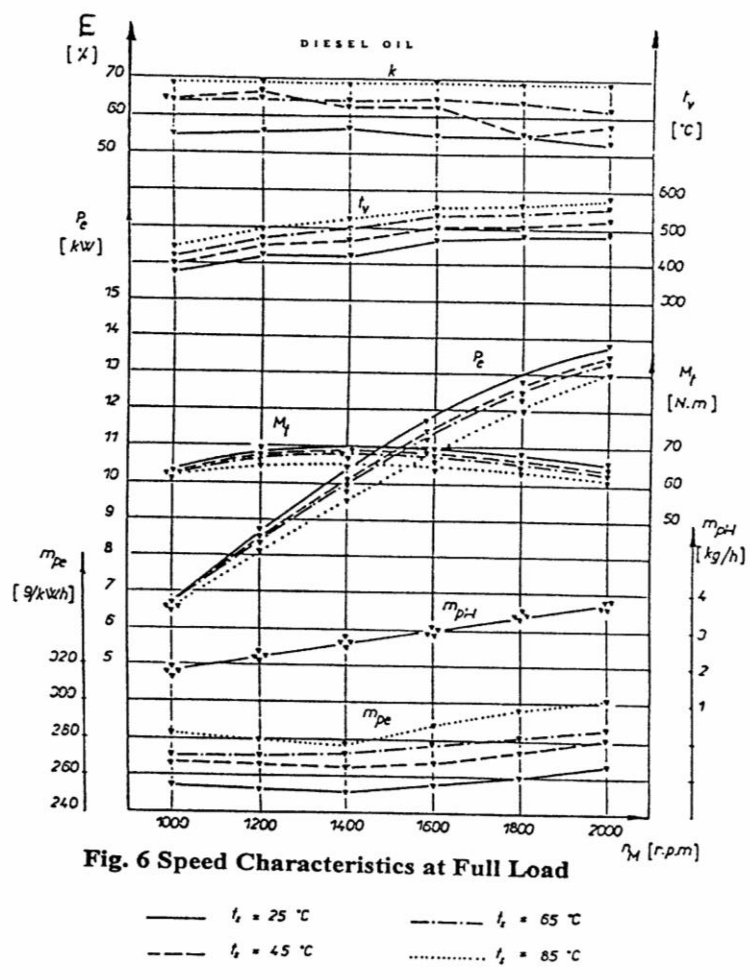

Figure (6) Speed Characteristics at Full Load

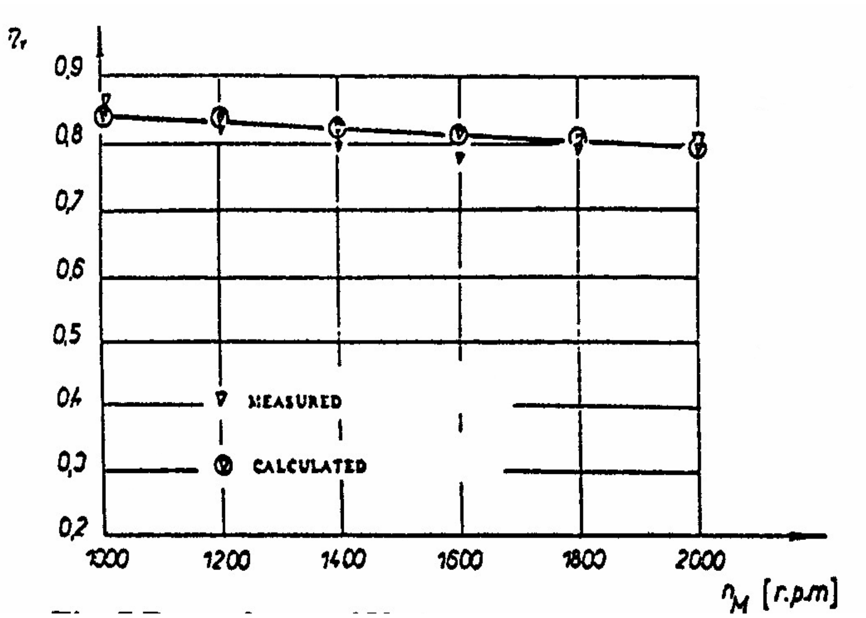

Figure (7) Dependence of Volumetric Efficiency η_v on Engine Revolution n_M at Sucked Air Temperature t_s=25°C

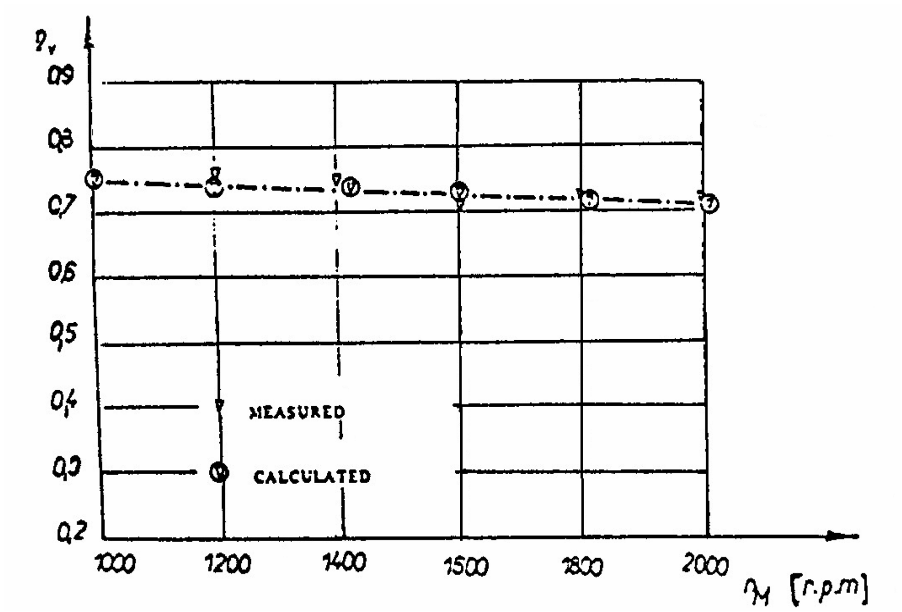

Figure (8) Dependence of Volumetric Efficiency η_v on Engine Revolution n_M at Sucked Air Temperature t_s=45°C

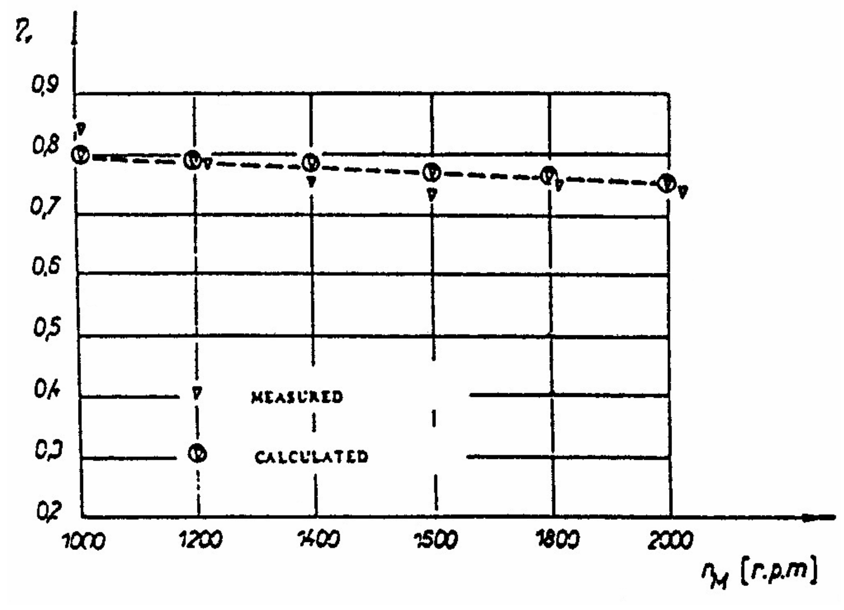

Figure (9) Dependence of Volumetric Efficiency η_v on Engine Revolution n_M at Sucked Air Temperature t_s=65°C

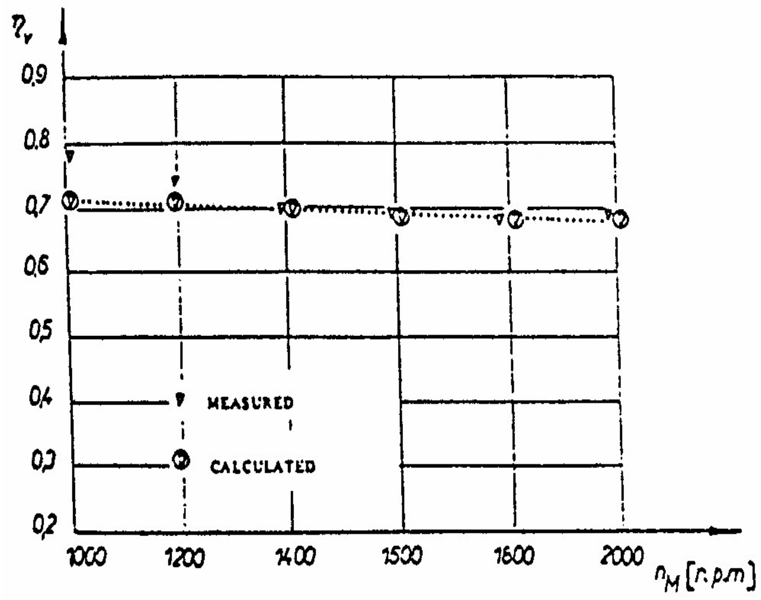

Figure (10) Dependence of Volumetric Efficiency η_v on Engine Revolution n_M at Sucked Air Temperature t_s=85°C

4. References

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Notations and Units

d_h	m	Suction hole diameter
d_m	m	Mean diameter of valve contact surface
E	---	Exhaust emission %.
f_m	m^2	Mean area of suction hole
h	m	Mean height of valve lift
K_1, K_2	---	Constants
k	---	Adiabatic exponent (k=1.4)
M_t	N.m	Engine torque
m_{act}	kg	Actual mass of fresh charge
m_b	kg	Mass of fresh charge which is blown out
m_c	kg	Total mass of fresh charge per cycle
m_d	kg	Mass admitted during delayed suction
m_m	kg	Mass admitted during advanced and main suction
m_{pe}	$g.kW^{-1}.h^{-1}$	Specific fuel consumption
m_{pH}	$kg.h^{-1}$	Fuel consumption (mass fuel flow rate)
m_s	kg	Mass admitted during continuation of charging
m_{th}	kg	Theoretical mass
n_M	min^{-1}	Engine revolution
P_e	kW	Engine power output (effective)
P, P_A	$N.m^{-2}$	Pressure
R	$J.kg^{-1}.K^{-1}$	Gas constant
T_1	K	Suction temperature
T_a	K	Temperature
T_{zb}	K	Residual gas temperature
t_s	$^{\circ}C$	Air temperature after heating
t_v	$^{\circ}C$	Exhaust gases temperature
V_z	m^3	Stroke volume
α	$^{\circ}CA$	Crankshaft angle
α_a	$^{\circ}CA$	Advanced suction angle
α_d	$^{\circ}CA$	Delayed suction angle
e	---	Compression ratio (geometrical)

η_v	---	Volumetric efficiency
V	---	Delayed suction coefficient
ζ	---	Manifold resistance coefficient
γ	---	Residual gas coefficient
φ	**deg**	Valve seat inclination angle.