APPENDIX 1
ERROR ANALYSIS

GENERAL FORMS

The errors associated with various measurements and in calculations of performance parameters are computed in this section. The maximum possible errors in various measured parameters namely temperature, pressure, exhaust gas emissions time and speed estimated from the minimum values of output and accuracy of the instrument are calculated using the method proposed by Moffat (1985). This method is based on careful specification of the uncertainties in the various experimental measurements.

If an estimated quantity, $S$ depends on independent variables like $(x_1, x_2, x_3 \ldots x_n)$ then the error in the value of “$S” is given by

$$\frac{\delta S}{S} = \left\{ \left( \frac{\delta x_1}{x_1} \right)^2 + \left( \frac{\delta x_2}{x_2} \right)^2 + \ldots + \left( \frac{\delta x_n}{x_n} \right)^2 \right\}^{\frac{1}{2}}$$

where, $\left( \frac{\delta x_1}{x_1} \right)$, $\left( \frac{\delta x_2}{x_2} \right)$ etc are the errors in the independent variables.

ERRORS IN MEASURED QUANTITIES

A1.1 TEMPERATURE

A1.1.1 Reaction Temperature

Resistance Temperature Detector (RTD) is used to measure the reaction temperature. Digital temperature indicator displays the temperature measured by RTD. The maximum possible error in the case of temperature measurement is calculated from the minimum values of the temperature measured and accuracy of the instrument (RTD with temperature indicator). The errors in the temperature measurement are:
A1.1.2 Exhaust Gas Temperature

Al/Cr K-type thermocouple is used to measure the exhaust gas temperature. Digital temperature indicator displays the temperature measured by thermocouple. The maximum possible error in the case of temperature measurement is calculated from the minimum values of the temperature measured and accuracy of the instrument (Thermocouple with temperature indicator). The errors in the temperature measurement are:

\[
\frac{\partial T}{T}_{RT} = \left( \frac{\partial T_{\text{RTD}}}{T_{\text{RTD}}} \right)^2 + \left( \frac{\partial T_{\text{indi}}}{T_{\text{indi}}} \right)^2 \right)^{\frac{1}{2}}
\]

\[
\begin{align*}
\frac{\partial T}{T}_{RT} &= \left( \left( 0.1{^\circ}C \right)^2 + \left( 0.1{^\circ}C \right)^2 \right)^{\frac{1}{2}} = \left( \left( 0.00182 \right)^2 + \left( 0.00182 \right)^2 \right)^{\frac{1}{2}} \\
&= 0.002499 \text{ or } 0.249\%
\end{align*}
\]

A1.2 COMBUSTION CHAMBER PRESSURE MEASUREMENT

The combustion chamber pressure was measured by using pressure transducer and charge amplifier.

\[
\frac{\partial p}{p}_{Exp} = \left( \frac{\partial q_{\text{charge}}}{q_{\text{charge}}} \right)^2 + \left( \frac{\partial V_{\text{PP}}}{V_{\text{PP}}} \right)^2 \right)^{\frac{1}{2}}
\]
\[
\left( \frac{\partial p}{p} \right)_{Exp} = \left( \frac{0.16}{100} \right)^2 + \left( \frac{0.15}{100} \right)^2 = \left( (0.0016)^2 + (0.0015)^2 \right)^{\frac{1}{2}}
\]

\[
\left( \frac{\partial p}{p} \right)_{Exp} = 0.002193 = 0.22\%
\]

**A1.3 CRANK ANGLE**

The crank angle was measured by using Crank angle encoder.

\[
\left( \frac{\partial \text{CA}}{\text{CA}} \right)_{Exp} = \left( \frac{0.02}{1} \right) = 0.02 = 2\%
\]

**A1.4 BRAKE THERMAL EFFICIENCY (BTE)**

\[
\left( \frac{\partial \text{BTE}}{\text{BTE}} \right) = \left( \frac{\partial \text{Torque}}{\text{Torque}} \right)^2 + \left( \frac{\partial \text{rpm}}{\text{rpm}} \right)^2 + \left( \frac{\partial \text{time}}{\text{time}} \right)^2 \right)^{\frac{1}{2}}
\]

\[
\left( \frac{\partial \text{BTE}}{\text{BTE}} \right) = \left( \frac{0.021}{7.0} \right)^2 + \left( \frac{0.15}{1500} \right)^2 + \left( \frac{0.01163}{20.93} \right)^2 \right)^{\frac{1}{2}}
\]

\[
\left( \frac{\partial \text{BTE}}{\text{BTE}} \right) = \left( (0.003)^2 + (0.0001)^2 + (0.000555)^2 \right)^{\frac{1}{2}} = 0.00305 = 0.31\%
\]

**A1.5 EXHAUST GAS EMISSIONS**

The exhaust gas emissions are measured using exhaust gas analysers and smoke meter. The error is estimated for the minimum value of emissions measured and the accuracy of the instrument.

**A1.5.1 UBHC**

\[
\left( \frac{\partial \text{UBHC}}{\text{UBHC}} \right) = \left( \frac{0.15 \text{ ppm}}{3 \text{ ppm}} \right) = 0.05 \text{ or } 5\%
\]

**A1.5.2 CO**

\[
\left( \frac{\partial \text{CO}}{\text{CO}} \right) = \left( \frac{0.0025\%}{0.05\%} \right) = 0.05 \text{ or } 5\%
\]
A1.5.3 NOx

\[
\frac{\delta \text{NO}_x}{\text{NO}_x} = \left( \frac{7.75 \text{ ppm}}{155 \text{ ppm}} \right) = 0.05 \text{ or } 5\%
\]

A1.5.4 SMOKE INTENSITY

\[
\frac{\delta \text{smoke}}{\text{Smoke}} = \left( \frac{0.05}{1.0} \right) = 0.05 = 5\%
\]
LIST OF PUBLICATIONS

Papers published in International Journals:


6. **M.V.MALLIKAJUN**, VENKATA RAMESH MAMILLA, G.LAKSHMI NARARYANA RAO, “Performance, Combustion and Emission Analysis of

International conference

CURRICULUM VITAE

M.V. Mallikarjun obtained his Diploma in Mechanical Engineering from S.V. Govt. Polytechnic, Tirupati in 1987 and completed AMIE (I) from Institution of Engineers (I), Kolkata in 1990. Later worked in various industries for 10 years and in the year 2002 obtained Masters Degree in Thermal Power Engineering from Visveswaraiah Technological University, Belgaum with distinction. Later, worked as assistant professor in IACR Engineering College, Rayagada and in the year 2005 joined as an assistant professor in QIS College of Engineering and Technology, Ongole and currently working as professor with the same college. His research interest areas are Alternative fuels for I.C. Engines and Design of Heat transfer Equipments. He has more than 20 technical paper publications in international journals besides attending for two international conferences and a few national conferences.

Email: mvmsharma@yahoo.co.in; sharmamvm@gmail.com

Cell No. +919885029816,