MAK 3031- Internal Combustion Engines

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Week-6/Exercises

Example: For complete combustion of $C_{10}H_{18}S$ Mair/Mfuel is given as 25, please calculate the excess air ratio, mass and mole number of combustion products, volume of the products at 40 ° C and 1 atm pressure.

Week-6/Exercises

$$\overline{C} = \frac{\overline{M_C}.10}{\overline{M_C}.10 + \overline{M_H}.18 + \overline{M_S}.1}$$

$$\frac{12.10}{12.10 + 1.18 + 32.1} = 0.705kg$$

$$\overline{H} = \frac{\overline{M_H}.18}{\overline{M_C}.10 + \overline{M_H}.18 + \overline{M_S}.1}$$

$$\frac{1.18}{12.10 + 1.18 + 32.1} = 0.105kg$$

$$\overline{S} = \frac{\overline{M_S}.1}{\overline{M_C}.10 + \overline{M_H}.18 + \overline{M_S}.1}$$

$$\frac{32.1}{12.10 + 1.18 + 32.1} = 0.1882kg$$

A

$$L_{\min} = \frac{O_{\min}}{0,232} \qquad \frac{kgair}{kgfuel}$$

$$O_{\min} = \left[\frac{\overline{C}}{12} + \frac{\overline{H}}{4} + \frac{\overline{S} - \overline{O_y}}{32}\right] \quad \frac{kmolO_2}{kgfuel}$$

$$O_{\min} = \left[\frac{0,705}{12} + \frac{0,105}{4} + \frac{0,1882 - 0}{32}\right].32 = 2.908 \qquad \frac{kgO_2}{kgfuel}$$

$$L_{real} = 25$$

$$L_{\min} = \frac{2,908}{0,232} = 12,53 \quad \frac{kgair}{kgfuel}$$

$$\lambda = \frac{L_{real}}{L_{\min}} = \frac{25}{12,53} = 1,9952$$

Week-6/Exercises

B

$$M_{CO_2} = \frac{11}{3}\overline{C} \qquad \frac{11}{3}0{,}705 = 2{,}585 \qquad \frac{kgCO_2}{kgfuel}$$

$$M_{H_2O} = 9.\overline{H} \qquad 9.0{,}105 = 0{,}945 \qquad \frac{kgH_2O}{kgfuel}$$

$$M_{SO_2} = 2\overline{S} \qquad 2.0{,}1882 = 0{,}3764 \qquad \frac{kgSO_2}{kgfuel}$$

$$M_{N_2} = 0{,}768.\lambda.L_{\min} \qquad 0{,}768.1{,}9952.12{,}53 = 19{,}199 \qquad \frac{kgN_2}{kgfuel}$$

$$M_{O_2} = (\lambda - 1).0{,}232.L_{\min} \qquad (1{,}9952 - 1).0{,}232.12{,}53 = 2{,}893 \qquad \frac{kgO_2}{kgfuel}$$

Week-6/Exercises

c

$$N_{CO_2} = \frac{1}{12}\overline{C} \qquad \frac{1}{12}0{,}705 = 0{,}058 \qquad \frac{kmolCO_2}{kgfuel}$$

$$N_{H_2O} = \frac{1}{2}\overline{H} \qquad \frac{1}{2}0{,}105 = 0{,}0525 \qquad \frac{kmolH_2O}{kgfuel}$$

$$N_{SO_2} = \frac{1}{32}\overline{S} \qquad \frac{1}{32}0{,}1882 = 0{,}0058 \qquad \frac{kmolSO_2}{kgfuel}$$

$$N_{N_2} = 0{,}79.\lambda.L_{\min}$$

$$N_{N_2} = 0{,}79.\lambda.\frac{O_{\min}}{0{,}21} \qquad 0{,}79.1{,}9952.\frac{0{,}0908}{0{,}21} = 0{,}6815 \qquad \frac{kmolN_2}{kgfuel}$$

Week-6/Exercises

D

$$N_{total} = 0,058 + 0,0525 + 0,0058 + 0,6815 + 0,0903$$

$$N_{total} = 0,8881$$

$$PV = n\bar{R}T$$

$$1,013.10^{2}\, xV = 0,8881x8,314x313 = 22,814$$

$$\frac{m^3 exhaust}{kgfuel}$$

Example

Example:

Fuel chemical formuale C_2H_6,

Excess air ratio $\lambda = 0{,}8$

Fuel quantity 1 kg

Calculate the combustion products as kg, kmol, Nm^3

(Ambient pressure and temperature are 1 atm ve 15°C)

Week-6/Exercises

$$\overline{C} = \frac{\overline{M_C}.2}{\overline{M_C}.2 + \overline{M_H}.6} = \frac{12.2}{12.2 + 1.6} = 0{,}8 \text{ kg}$$

$$\overline{H} = \frac{\overline{M_H}.6}{\overline{M_C}.2 + \overline{M_H}.6} = \frac{1.6}{12.2 + 1.6} = 0{,}2 \text{kg}$$

$$L_{\min} = \frac{O_{\min}}{0{,}232} \quad \frac{kgair}{kgfuel}$$

$$O_{\min} = \left[\frac{\overline{C}}{12} + \frac{\overline{H}}{4} + \frac{\overline{S} - \overline{O_y}}{32} \right] \quad \frac{kmolO_2}{kgfuel}$$

$$O_{\min} = \left[\frac{0{,}8}{12} + \frac{0{,}2}{4} \right]. = 0{,}1166 \quad \frac{kmolO_2}{kgfuel}$$

$$O_{\min} = \left[\frac{0{,}8}{12} + \frac{0{,}2}{4} \right].32 = 3{,}733 \quad \frac{kgO_2}{kgfuel}$$

$$L_{\min} = \frac{3{,}733}{0{,}232} = 16{,}091 \quad \frac{kgair}{kgfuel}$$

$$x = \frac{3}{4}(1 - \lambda)\frac{O_{\min}}{C}$$

$$x = \frac{3}{4}(1 - 0{,}8)\frac{3{,}733}{0{,}8} = 0{,}699$$

Week-6/Exercises

$$M_{CO_2} = \frac{11}{3}\overline{C}(1-x) \ , \ \frac{11}{3}0{,}8(1-0{,}699) = 0{,}8829 \ \frac{kgCO_2}{kgfuel}$$

$$M_{H_2O} = 9.\overline{H} \ , \ 9.0{,}2 = 1{,}8 \ \frac{kgH_2O}{kgfuel}$$

$$M_{CO} = \frac{7}{3}\overline{C}(x) \ , \ \frac{7}{3}0{,}8(0{,}699) = 1{,}3048 \ \frac{kgCO}{kgfuel}$$

$$M_{N_2} = 0{,}768.\lambda.L_{\min} \ , \ 0{,}768.0{,}8.16{,}09 = 9{,}88 \ \frac{kgN_2}{kgfuel}$$

Week-6/Exercises

$$N_{CO_2} = \frac{1}{12}\overline{C}(1-x)\ ,\ \ \frac{1}{12}0{,}8(1-0{,}699) = 0{,}02\ \frac{kmolCO_2}{kgfuel}$$

$$N_{CO} = \frac{1}{12}\overline{C}(x)\ ,\ \ \frac{1}{12}0{,}8(0{,}699) = 0{,}0466\ \frac{kmolCO}{kgfuel}$$

$$N_{H_2O} = \frac{1}{2}\overline{H}\ ,\ \ \frac{1}{2}0{,}2 = 0{,}1\ \frac{kmolH_2O}{kgfuel}$$

$$N_{N_2} = 0{,}79.\lambda.L_{\min}\ ,\ N_{N_2} = 0{,}79.\lambda.\frac{O_{\min}}{0{,}21}\quad 0{,}79.0{,}8.\frac{0{,}1166}{0{,}21} = 0{,}3509\ \frac{kmolN_2}{kgfuel}$$

Week-6/Exercises

$$V_{CO_2} = 0,02.24 = 0,48 \ \mathrm{Nm}^3$$

$$V_{CO} = 0,0466.24 = 1,1184 \ \mathrm{Nm}^3$$

$$V_{N_2} = 0,3509.24 = 8,4216 \ \mathrm{Nm}^3$$

Week-6/Exercises

Fuel chemical formulae C_2H_3OHS

$\lambda = 0{,}8$

Calculate the mass of combustion products

A

$$\overline{C} = \frac{\overline{M_C}.2}{\overline{M_C}.2 + \overline{M_H}.4 + \overline{M_S}.1 + \overline{M_O}.1} = \frac{12.2}{12.2 + 1.4 + 32.1 + 16.1} = \frac{24}{76} = 0{,}315 \text{ kg}$$

$$\overline{H} = \frac{\overline{M_H}.4}{\overline{M_C}.2 + \overline{M_H}.4 + \overline{M_S}.1 + \overline{M_O}.1} = \frac{1.4}{12.2 + 1.4 + 32.1 + 16.1} = \frac{4}{76} = 0{,}0526 \text{ kg}$$

$$\overline{O} = \frac{\overline{M_O}.1}{\overline{M_C}.2 + \overline{M_H}.4 + \overline{M_S}.1 + \overline{M_O}.1} = \frac{16.1}{12.2 + 1.4 + 32.1 + 16.1} = \frac{16}{76} = 0{,}21 \text{ kg}$$

$$\overline{S} = \frac{\overline{M_S}.1}{\overline{M_C}.2 + \overline{M_H}.4 + \overline{M_S}.1 + \overline{M_O}.1} = \frac{32.1}{12.2 + 1.4 + 32.1 + 16.1} = \frac{32}{76} = 0{,}421 \text{ kg}$$

Week-6/Exercises

$$O_{\min} = \left[\frac{\overline{C}}{12} + \frac{\overline{H}}{4} + \frac{\overline{S} - \overline{O_y}}{32} \right] \frac{kmolO_2}{kgfuel}$$

$$O_{\min} = \left[\frac{\overline{0,315}}{12} + \frac{\overline{0,0526}}{4} + \frac{\overline{0,421} - \overline{0,21}}{32} \right] = 0,0459 \frac{kmolO_2}{kgfuel}$$

$$O_{\min} = 0,0459.32 = 1,4718 \frac{kgO_2}{kgfuel}$$

$$L_{\min} = \frac{O_{\min}}{0,232} \frac{kgair}{kgfuel}$$

$$L_{\min} = \frac{1,4718}{0,232} = 6,3439 \frac{kgair}{kgfuel}$$

$$x = \frac{3}{4}(1 - \lambda)\frac{O_{\min}}{C}$$

$$x = \frac{3}{4}(1 - 0,8)\frac{1,4718}{0,315} = 0,700$$

Week-6/Exercises

$$M_{CO_2} = \frac{11}{3}\overline{C}(1-x) \ , \ \frac{11}{3}0{,}315(1-0{,}7) = 0{,}3465 \ \frac{kgCO_2}{kgfuel}$$

$$M_{H_2O} = 9.\overline{H} \ , \ 9.0{,}0526 = 0{,}4736 \ \frac{kgH_2O}{kgfuel}$$

$$M_{CO} = \frac{7}{3}\overline{C}(x) \ , \ \frac{7}{3}0{,}315(0{,}700) = 0{,}5145 \ \frac{kgCO}{kgfuel}$$

$$M_{N_2} = 0{,}768.\lambda.L_{\min} \ , \ \ 0{,}768.0{,}8.6{,}343 = 3{,}897 \ \frac{kgN_2}{kgfuel}$$

$$M_{SO_2} = 2\overline{S} \ \ , \ 2.0{,}421 = 0{,}842 \ \frac{kgSO_2}{kgfuel}$$