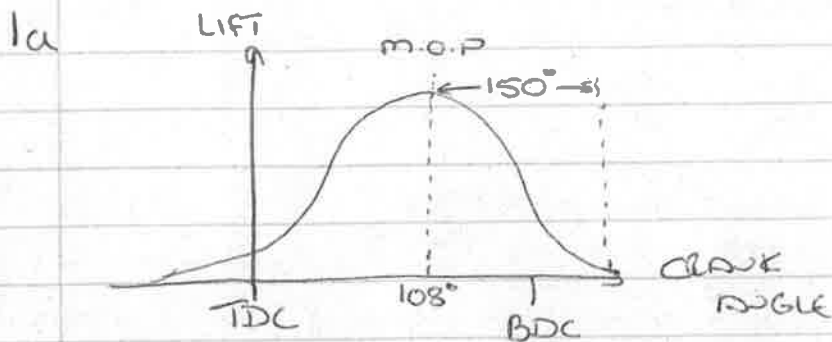


POWERTRAIN + CONTROL MAY 2016 PAPER



MAX SUCTION IS AT M.O.P

ANGLE FROM M.O.P TO BDC = 72°

.. .. CLOSING = 150°

.. .. MIDWAY BETWEEN BDC

$$\text{ADD CLOSING} = \frac{72 + 150}{2}$$

$$= 111^\circ$$

TIME FOR SUCTION PULSE TO TRAVEL FROM M.O.P
AND BACK TO VALVE =

$$\frac{n \times 2L}{\text{SPEED OF SOUND}} = \frac{111}{360} \times \frac{60}{\text{RPM}}$$

AT DESIGN TARGET OF 7200 RPM FOR MAX PULS,

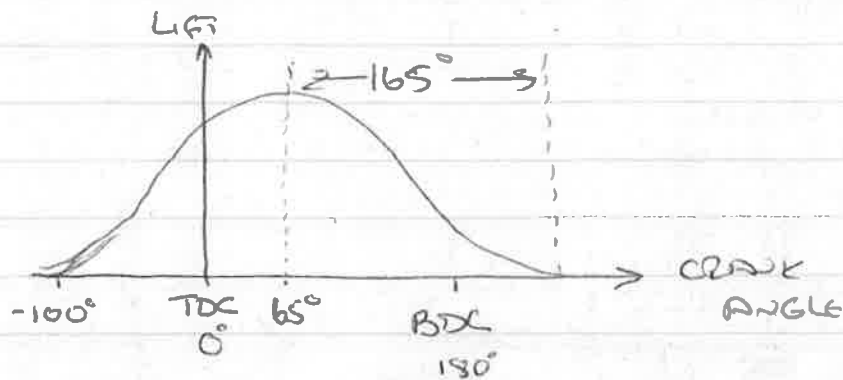
$$L = \frac{330}{2n} \times \frac{111}{360} \times \frac{60}{7200}$$

$$n_1 = 0.42 \text{ m}$$

$$n_2 = 0.21 \text{ m}$$

CHOOSE $n=1$ FOR STRONGEST TWINING, LENGTH JUST PRACTICAL

b



ANGLE FROM M.O.P TO BDL = 115°

CLOSING = 165°

MIDWAY BETWEEN BDL
AND CLOSING = $\frac{115 + 165}{2}$
 $= 140^\circ$

CALCULATE NEW LENGTHS -

$$L = \frac{330}{2\pi} \times \frac{140}{360} \times \frac{60}{7200}$$

$$n_1 = 0.53 \text{ m}$$

$$n_2 = 0.27 \text{ m}$$

THIS CAM TIMING WOULD REQUIRE LONGER INTER
LENGTHS FOR BEST TUNING

C CALCULATE HARMONICS FOR EACH CAM
ASSUMING A COMMON INLET LENGTH OF 0.42m

CAM FROM Q1a -

$$RPM = \frac{330}{2 \times n \times 0.42} \times \frac{111}{360} \times 60$$

$$n_1 = 7268 \text{ RPM}$$

$$n_2 = 3634 \text{ RPM}$$

$$n_3 = 2423 \text{ RPM}$$

$$n_4 = 1817 \text{ RPM}$$

CAM FROM Q1b -

$$RPM = \frac{330}{2 \times n \times 0.42} \times \frac{140}{360} \times 60$$

$$n_1 = 9167 \text{ RPM}$$

$$n_2 = 4583 \text{ RPM}$$

$$n_3 = 3056 \text{ RPM}$$

$$n_4 = 2292 \text{ RPM}$$

FOR HIGH SPEED TRACKS USE LONGER DURATION
CAM AND MATCH IT TO INLET LENGTH A
LITTLE BETTER FOR DESIRED DESIGN RPM (max
power).

FOR LOW SPEED TRACKS USE SHORTER DURATION
TO IMPROVE TORQUE AT LOWER RPM'S.

↓ TO INCREASE THE RPM WITH A FIXED LENGTH, YOU USED THE CRANK ANGLE FROM M.O.P TO MIDWAY BETWEEN TDC AND CLOSING TO INCREASE SO YOU NEED A HIGHER RPM FOR ITS TIME TO MATCH THE PULSE TIME IN THE PIST.

∴ INCREASE 108° IN PROPORTION TO $\frac{6100}{5600}$, THEREFORE NEEDING A LONGER DURATION.

$$Rpm = \frac{330}{2\pi(0.42)} \times \frac{x}{360} \times \frac{60}{1}$$

$$6100 \Rightarrow x = 93.1$$

0.545 how long for max torque at 8600

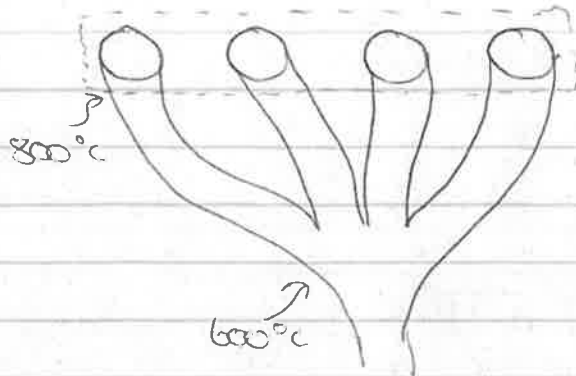
$$\frac{6100}{5600} = 1.089$$

$$111 \times 1.089 = \underline{120.9^\circ}$$

$$\frac{330 \times 120.9 \times 60}{2\pi(0.545) \times 360} = 6100 \checkmark$$

$$\Rightarrow 120.9 - 111 = 319.8 \text{ Duration}$$

2a

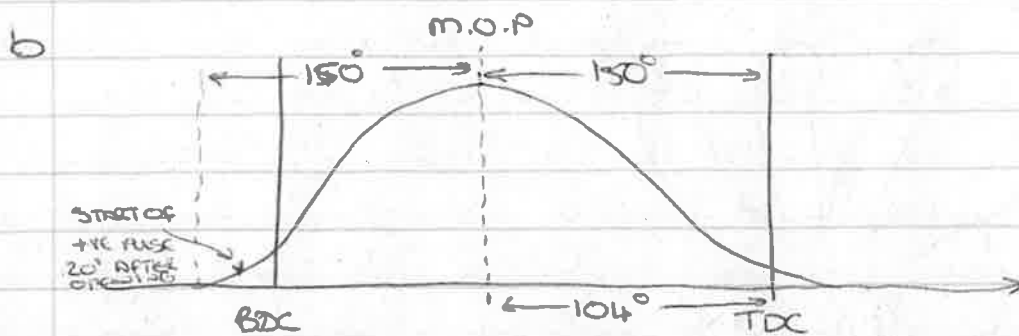


ASSUME ABOVE TEMPS : MEAN GAS TEMP
IN PRIMARY = $\frac{800 + 600}{2}$
 $= 700^{\circ}\text{C}$

$\therefore$ MEAN SPEED OF SOUND IN PRIMARY

$$= 330 \times \sqrt{\frac{973}{293}}$$

$$= 601 \text{ m/sec}$$



ASSUME START OF PULSE IS 20° AFTER OPENING
AND YOU WANT -VE PULSE BACK MIDWAY BETWEEN
TDC + CLOSING TO MINIMISE FLOW REVERSAL.

$$\text{START OF PULSE TO M.O.P} = 150 - 20 = 130^\circ$$

$$\text{M.O.P TO MIDWAY BETWEEN TDC + CLOSING} \\ = \frac{104 + 150}{2}$$

$$= 127^\circ$$

$$\therefore \text{START OF PULSE TO MIDWAY BETWEEN TDC} \\ \text{+ CLOSING} = 130 + 127 \\ = 257^\circ$$

$\therefore$ Time for crank to turn 257° :

$$\frac{257}{360} \times \frac{60}{\text{RPM}} \text{ seconds.}$$

FOR BEST TUNING THIS TIME MUST EQUAL =

$$\frac{n \times 2L}{601} \text{ seconds} \quad \text{WHERE } L = \text{MANIFOLD LENGTH} \\ n = \text{HARMONIC}$$

$$\therefore n \times \frac{2L}{601} = \frac{257}{360} \times \frac{60}{7200}$$

$$\therefore L = \frac{601}{2n} \times \frac{257}{360} \times \frac{60}{7200}$$

$$\therefore n_1 \text{ LENGTH} = 1.78 \text{ m}$$

$$n_2 \text{ LENGTH} = 0.89 \text{ m}$$

n_1 WOULD HAVE STRONGEST EFFECT.

$$C \text{ CYLINDER DISPLACEMENT} = 500 \text{ cc}$$

$$\text{DENSITY RATIO EXHAUST/INLET} = \frac{1}{\left(\frac{293}{973}\right)}$$
$$= \cancel{3.3}$$

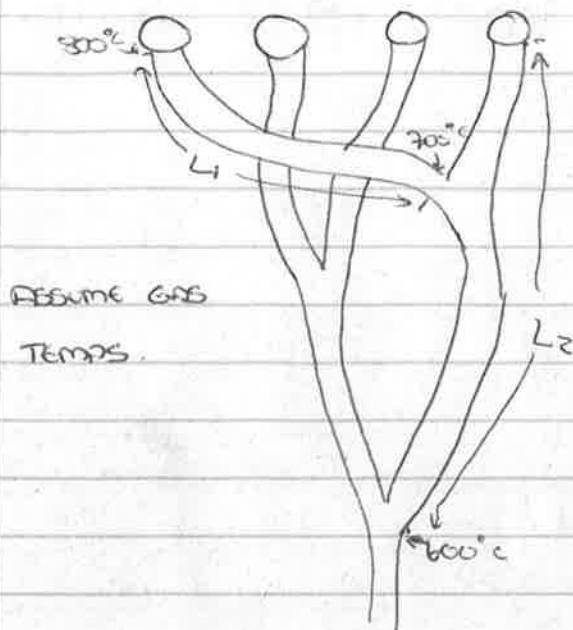
$$\therefore \frac{\pi D^2}{4} \times L = \cancel{500} \times 3.3$$

$$\therefore L = \frac{500 \times 3.3}{\frac{\pi D^2}{4}} \quad \text{BUT } L = 1.78 \text{ m}$$
$$= 178 \text{ cm}$$

$$\therefore D = \sqrt{\frac{4 \times 500 \times 3.3}{\pi \times 178}}$$

$$= 3.435 \text{ cm}$$

d



ASSUME GAS
TEMPS.

L2 IS SAME LENGTH
AS 4 INTO 1 MANIFOLD
= 1.78m

CALCULATE RPM FOR
HARMONICS USING L2
THEN PLOT.

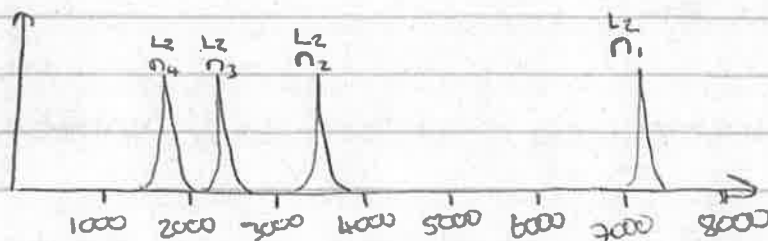
$$\text{RPM} = \frac{601}{2 \times n \times 1.78} \times \frac{257}{360} \times 60$$

$$n_1 = 7231 \text{ RPM}$$

$$n_2 = 3616 \text{ RPM}$$

$$n_3 = 2410 \text{ RPM}$$

$$n_4 = 1808 \text{ RPM}$$



NOW NEED TO FILL IN THE GAPS. CALCULATE
NEW GAS SPEED FOR L1.

$$= \frac{800 + 700}{2} = 750^\circ\text{C}$$

$$1. \text{ NEW MEAN SPEED IN } L1 = 330 \times \sqrt{\frac{1023}{293}} = 617 \text{ m/s}$$

CHOOSE ANOTHER ~~APPROX~~ LENGTH FOR L_1 , WITH NEW RPM EG. 6500

$$L_1 = \frac{617}{2n} \times \frac{257}{360} \times \frac{60}{6500}$$

$$n_1 = 2.038 \text{ m} \quad \text{TOO LOW}$$

$$n_2 = 0.018 \text{ m} \quad \text{" "}$$

$$n_3 = 0.678 \text{ m}$$

USE NEW LENGTH, CALCULATE NEW RPM'S

$$\text{RPM} = \frac{617}{2n \times 0.678} \times \frac{257}{360} \times 60$$

$$n_1 = 19490 \text{ RPM} \quad - \text{TOO HIGH}$$

$$n_2 = 9745 \text{ RPM} \quad - \text{" "}$$

$$n_3 = 6497 \text{ RPM}$$

$$n_4 = 4872 \text{ RPM}$$

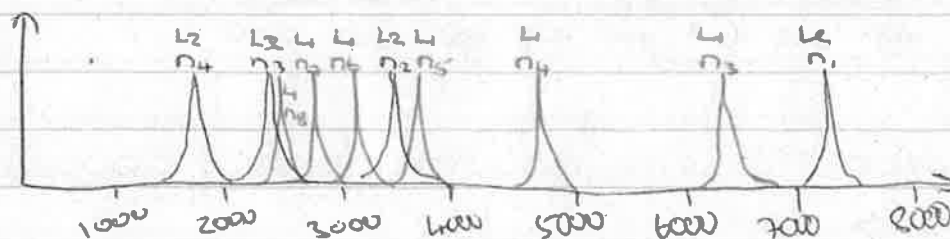
$$n_5 = 3898 \text{ RPM}$$

$$n_6 = 3248 \text{ RPM}$$

$$n_7 = 2764 \text{ RPM}$$

$$n_8 = 2436 \text{ RPM}$$

PLOT L_1 HARMONICS WITH L_2 HARMONICS



USE LATER HARMONICS OF L_1 TO IMPROVE MIDLANGE

5

Answer

A Count Average	B LFT mm	C V _{act} mm/ (L ₂ -L ₁)	D Acc mm/ (V ₂ -V ₁)	E Acc mm/s/s ₂ $= \frac{D \times (6 \text{ RPM})^2}{1000}$
106	7,988	~~0,006~~		
107	7,994	0,006		
108	7,998	0,004	-0,002	-4608
109	8,000	0,002	-0,002	-4608
110	8,000	0,000	-0,002	-4608
111	7,998	-0,002	-0,002	-4608
112	7,994	-0,004	-0,002	-4608
113	7,988	-0,006	-0,002	-4608
114				

Assume Float speed = 8000 RPM

In above calculation

6

THUS F_{int} , IN x TA F_{int} AT
8000 RM FULL LIFT.

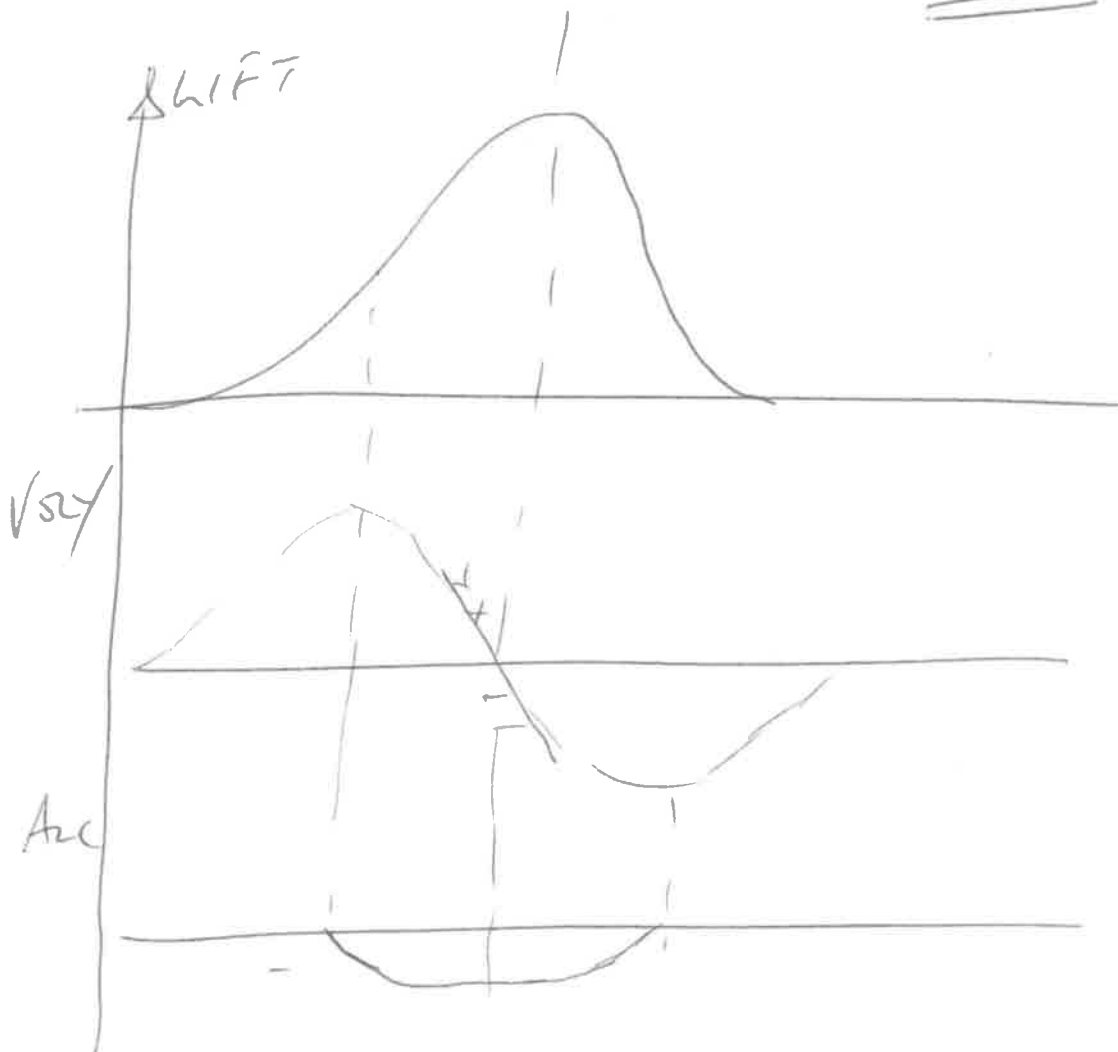
$$= M \times acc$$

$$ASSUME \quad M = 0,1 kg$$

$\therefore$ IN x TA F_{int} AT

$$FULL LIFT A 8000 RM = -0,1 \times 4608$$

$$= \underline{\underline{-460,8 N}}$$



7



Let $x_0 =$

Initial compression
in mm (5mm)

$$F_c - k(x_c + x_0) = M \times a_{cc}$$

$$F_c = k(x_c + x_0) + M \times a_{cc}$$

At full WFT, 8000 RPM, $F_c = 0$

$$0 = k(8 + 5) - 460,8$$

$$k = \frac{460,8}{13} = \underline{\underline{35,4 \text{ N/mm}}}$$

$$= \underline{\underline{35446 \text{ N/m}}}$$

4a TO CALCULATE POWER -

$$\text{Power} = 2\pi \times \text{TORQUE} \times \frac{\text{RPM}}{60} \quad \text{WATTS FOR EACH RPM.}$$

EG. 1001 RPM

$$\begin{aligned} \text{Power} &= 2 \times \pi \times 129.9 \times \frac{1001}{60} \\ &= 13618 \text{ WATTS} \\ &= 13.6 \text{ kW} \end{aligned}$$

DO FOR EACH RPM

4b FUEL EQUIVALENCE RATIO = $\frac{\text{STOICHIOMETRIC AFR}}{\text{ACTUAL AFR}}$

EG. 1001 RPM

$$\text{FUEL EQUIVALENCE RATIO} = \frac{14.5}{15.2} = 0.93$$

COMPLETE FOR ALL RPM.

4c $\text{LAMBDA} = \frac{1}{\text{FUEL EQUIVALENCE RATIO}}$

EG. 1001 RPM

$$\text{LAMBDA} = \frac{1}{0.93} = 1.08$$

COMPLETE FOR ALL RPM

4d AT 1001 RPM, PRODUCING 13.6 KW FOR 1 HOUR
USES 3.51 kg FUEL

PRODUCING 1KW FOR 1 HOUR USES $\frac{3.51}{13.6}$ kg FUEL

= 0.258 kg FUEL

$\therefore$ BSFC = 0.258 kg/kw.hr
= 258 ggs/kw.hr

COMPLETE FOR ALL RPM

4e ENERGY PER HOUR OUT = FUEL MASS $\times$ CALORIFIC VALUE

MECHANICAL ENERGY PER HOUR = POWER (WATTS) $\times$ 3600

OVERALL ENGINE EFFICIENCY = $\frac{\text{MECHANICAL ENERGY}}{\text{ENERGY PER HOUR OUT}}$

EG 1001 RPM

ENERGY OUT/HOUR = $3.51 \times 43.391 \times 10^6$
= 152.3 MJ

MECHANICAL ENERGY/HOUR = 13618×3600
= 49.02 MJ

OVERALL ENGINE EFFICIENCY = $\frac{49.02}{152.3}$

= 0.322

= 32.2%

COMPLETE FOR ALL RPM

44 TO ACHIEVE BETTER EFFICIENCY AT HIGH RPM YOU NEED TO LOWER THE FRICTION WITHIN THE ENGINE.

$$45 \text{ BMEP} = \frac{\text{TORQUE} \times 4\pi}{\text{ENG. DISP}} \quad (\text{N/m}^2)$$

$$1 \text{ BAR} = 10^5 \text{ N/m}^2$$

E.G. 1000 RPM

$$\text{BMEP} = \frac{129.9 \times 4\pi}{1.6 \times 10^{-3}}$$

$$= 1020,364.5 \text{ N/m}^2$$

$$= 10.2 \text{ BAR}$$

COMPLETE FOR ALL RPM