SCHOOL OF ENGINEERING
TAYLOR'S UNIVERSITY

MEC60303

Theory of Machines & Mechanism

Title: Theory of Machines & Mechanism Assignment

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1.0 Assignment Task 1

1.1 Performance Ability

1.1.1 Climb-Ability

Gradeability defines as a maximum gradient a vehicle can climb while sustaining a specific speed set by the driver [1].

Traction force defines as the driving force as a result of friction between the tyre and road that moves the vehicle forward [2].

For the vehicle to climb up a slope, the traction force must be greater than the resistance forces. The table 1.0 below has listed all the gears which can overcome the total resistance based on the traction force accordingly. The table below also shows that Gear A uses more gears starting from 5% gradient compared to Gear B.

Table 1.0 Tabulated Data

| **Resistance, %** | **Traction Force A, N** | | | | | **Traction Force B, N** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Gear A** | | | | | **Gear B** | | | | |
| | **1** | **2** | **3** | **4** | **5** | **1** | **2** | **3** | **4** | **5** |
| 0 | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 3 | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 5 | √ | √ | √ | √ | √ | √ | √ | √ | √ | |
| 10 | √ | √ | √ | √ | | √ | √ | √ | | |
| 15 | √ | √ | √ | | | √ | √ | | | |
| 20 | √ | √ | | | | √ | | | | |
| 26 | √ | √ | | | | √ | | | | |
| 30 | √ | | | | | √ | | | | |
| 35 | √ | | | | | √ | | | | |

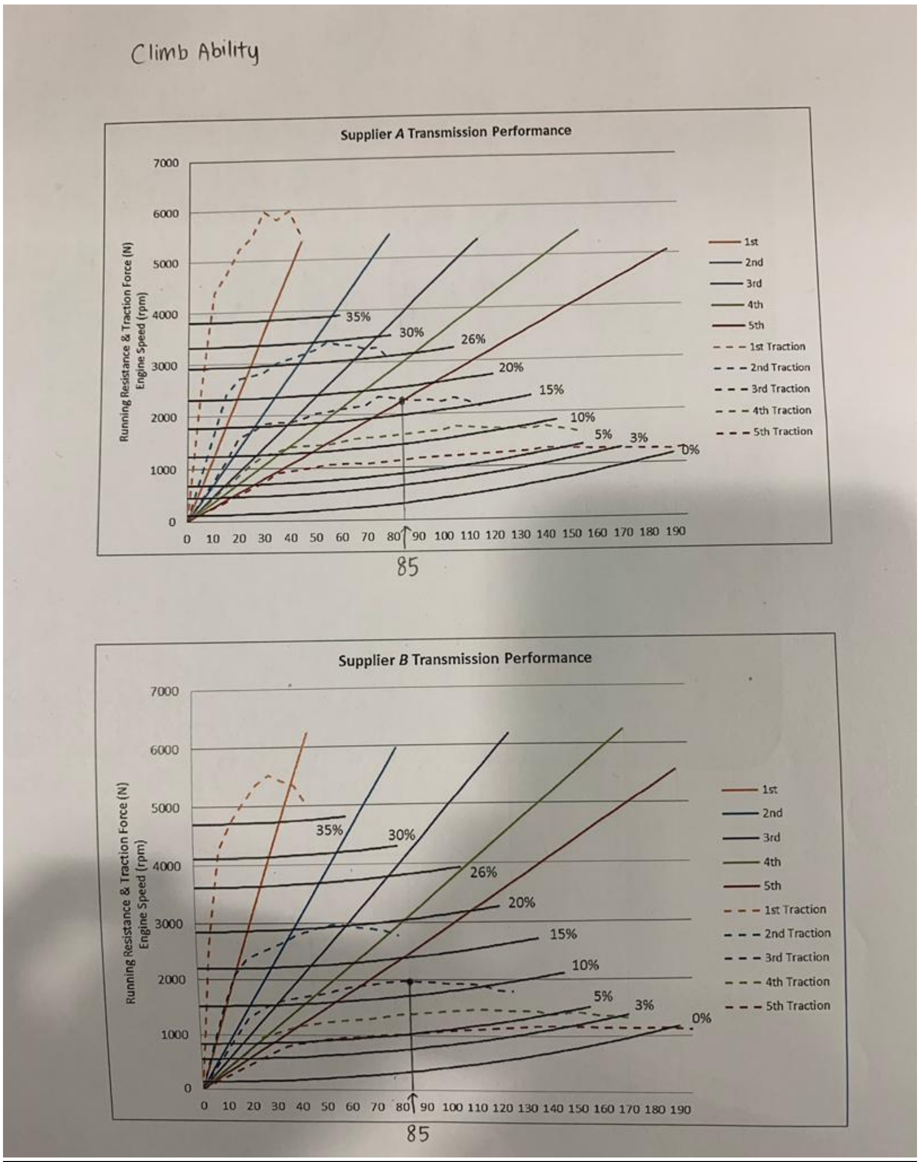



Figure 1.0 Traction Force at vehicle speed of 85 km/h

Taking a speed of 85 km/h, the transmission A can overcome a total resistance of 15% while the transmission B can only overcome a total resistance of 10% as shown in the figure above. Therefore, transmission B must lower down to gear 2 in order to overcome a total resistance of 15%. This also means that lower gear requires a greater torque as the gear size is bigger. This was proven in the torque formula:

$$\tau = F \times d$$

where d = length of arm

F= force acting on direction of rotation

Also, since the torque required by transmission B is higher, a greater power will be generated to climb the gradient. In this case, transmission A posses a better climb-ability compared to transmission B.

1.1.2 Response (Low Vehicle Speed)

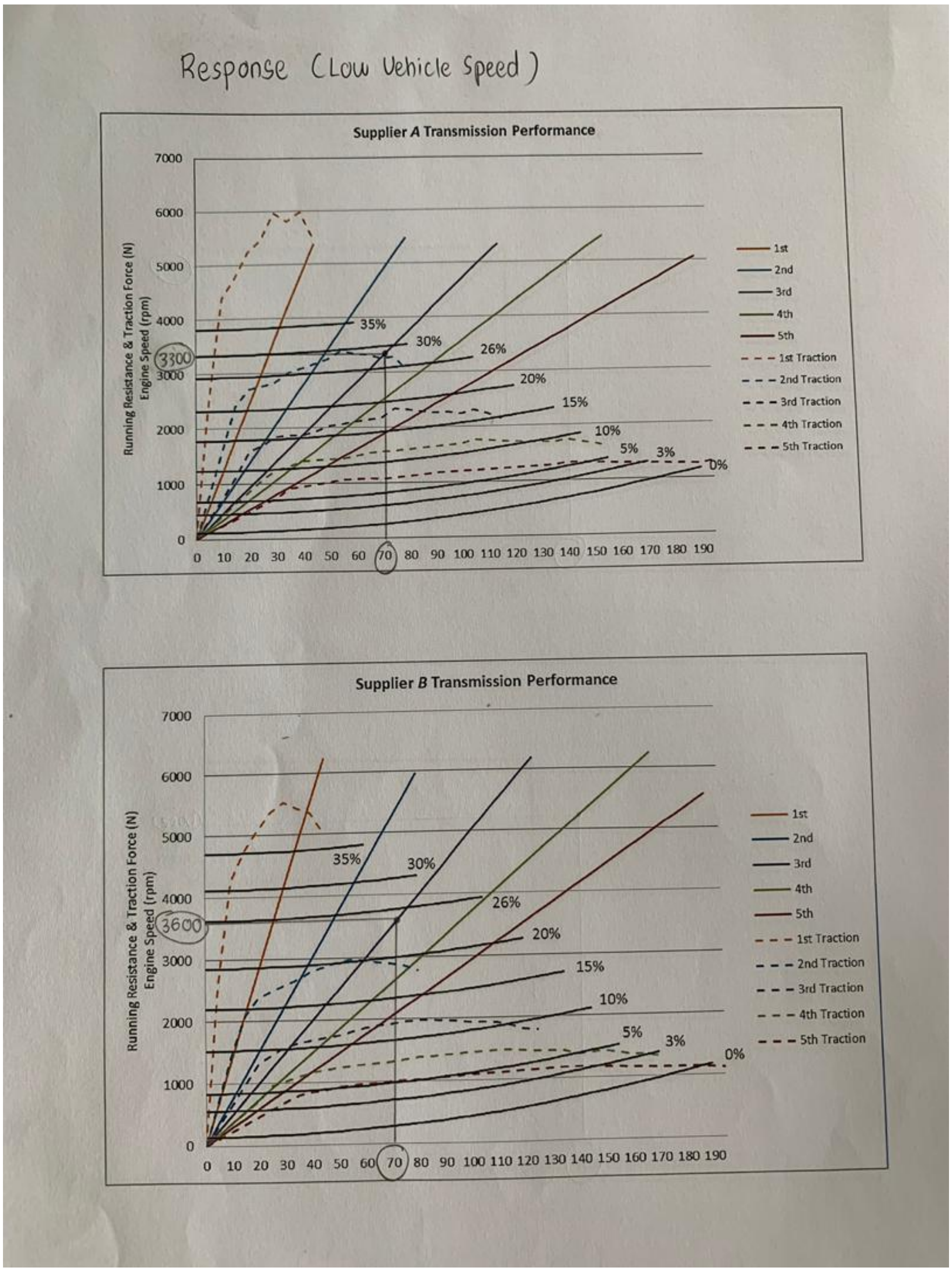



Figure 2.0 Engine Speed (rpm) at vehicle speed of 70 km/h on 3rd gear

Taking a speed of 70 km/h which lies on the 3rd gear as shown in figure 2.0 above, transmission A produces an engine speed of 3000 rpm while transmission B produces an engine speed of 3600 rpm. Therefore, transmission A has a better response at a low vehicle speed as it has a lower engine speed (rpm) comparing to B. Lower engine speed (rpm) also means better acceleration where the vehicle can reach a higher speed in a given specified time.

Besides, transmission B has a greater coloured solid line (engine speed) gradient compared to transmission A. Hence, this also proves that transmission A gives a better response at a low vehicle speed than B as the gradient A is lower which means the engine speed is lower.

1.1.3 Response (High Vehicle Speed)

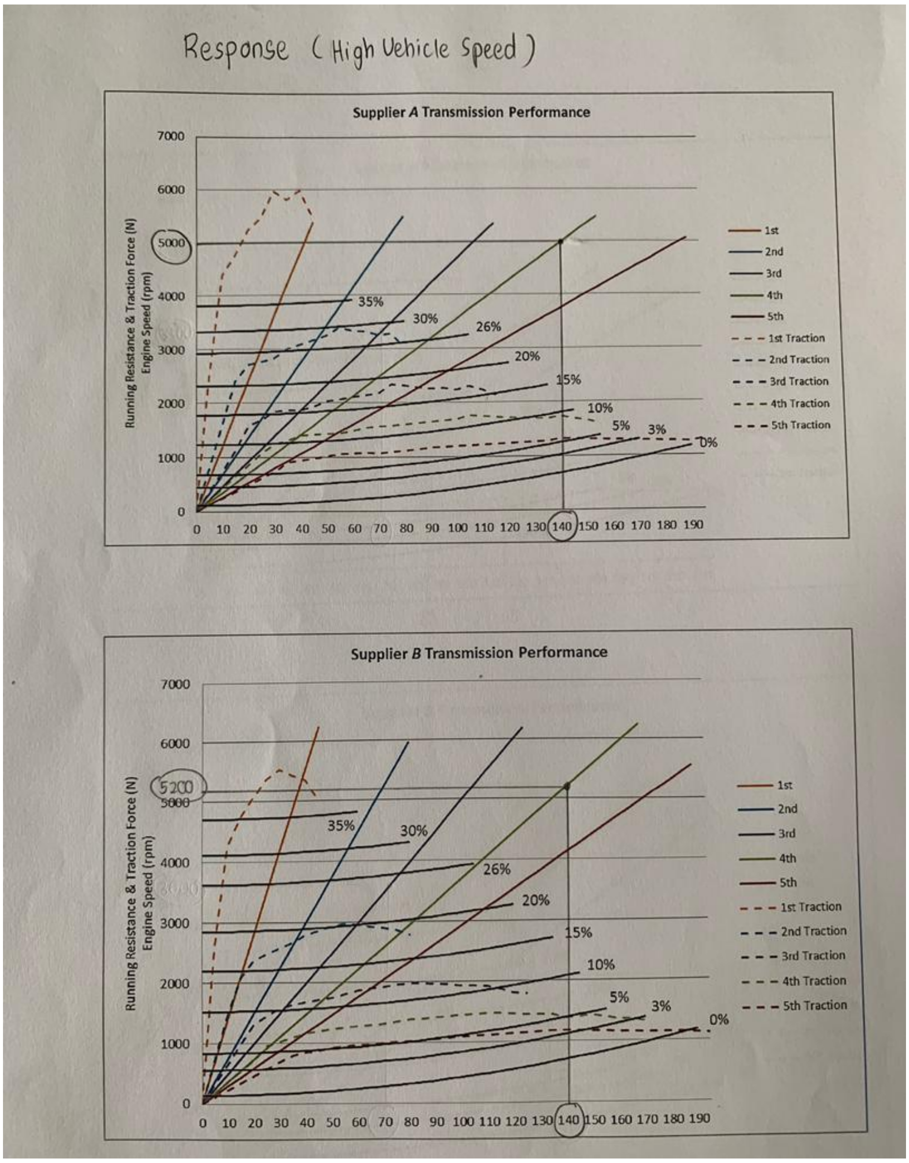



Figure 3.0 Engine Speed (rpm) at vehicle speed of 140 km/h on 4$^{th}$ gear

Taking a speed of 140 km/h which lies on the 4th gear as shown in figure 3.0 above, transmission A produces an engine speed of 5000 rpm while transmission B produces an engine speed of 5200 rpm. Therefore, transmission A has a better response at a high vehicle speed as it has a lower engine speed (rpm) comparing to B.

1.1.4 Fuel Consumption

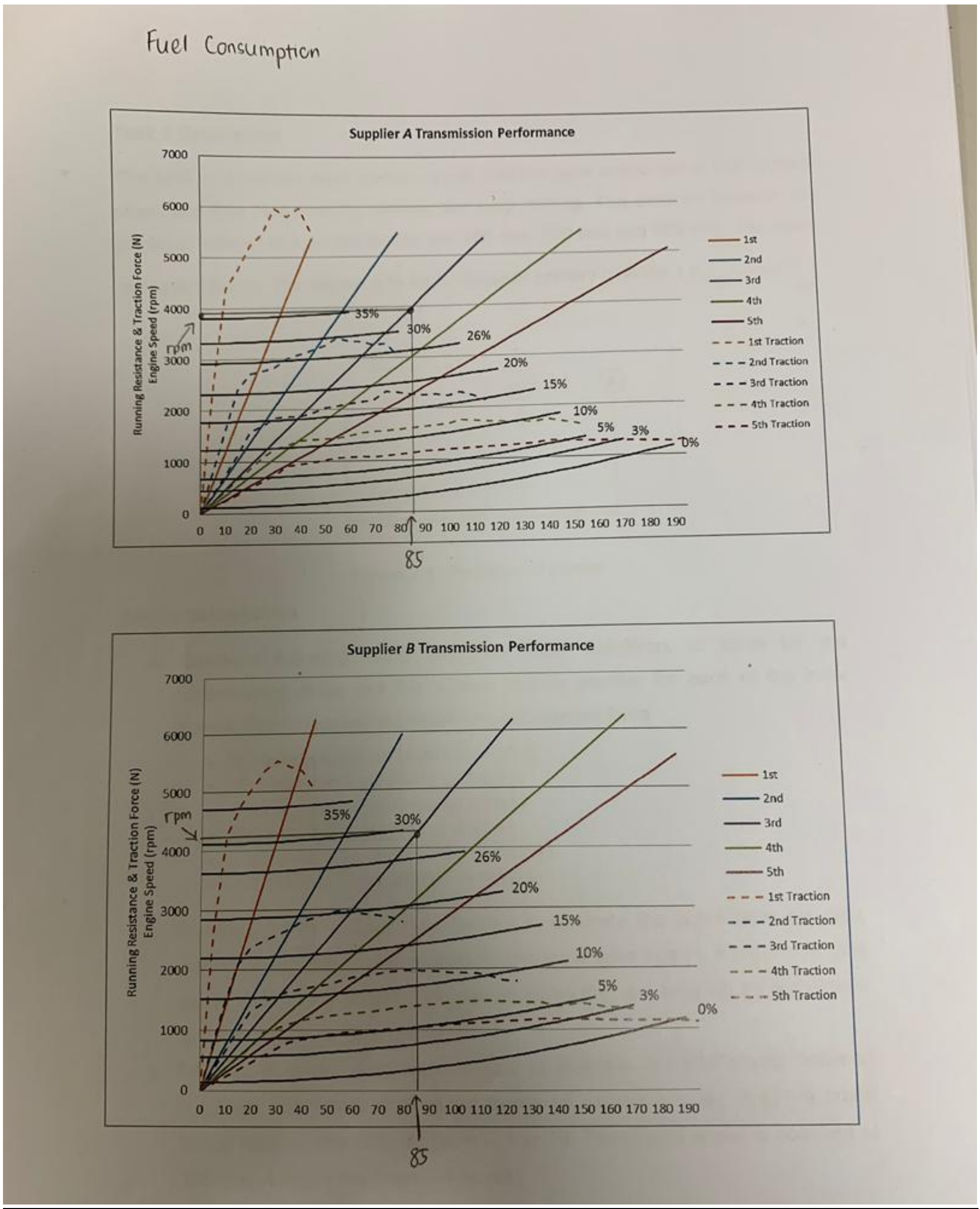



Figure 4.0 Engine Speed (rpm) at vehicle speed of 85 km/h on 3rd gear

Taking the speed of 85 km/h with a 3rd gear ratio as shown in figure 4.0 above, the transmission A indicates an estimated of 3900 rpm while the transmission B shows an estimated rpm of 4200 as shown in the figure above. A greater engine speed (rpm) requires more fuel to perform. Therefore, the fuel consumption for transmission B is greater compared to A due to its higher engine speed (rpm). In this case, transmission A gives out a better fuel consumption compared to B.

Furthermore, this can also relate to climb ability where transmission B must lower down to gear 2 in order to overcome a total resistance of 15% whereas transmission A can maintain at gear 3. This means that the consumption of fuel for transmission B is required as lower gear gives out a higher rpm. This also proves that transmission A has a better fuel consumption.

Besides that, relating to the response, transmission A has a better response at low and high vehicle speed compared to B. This shows that lesser fuel will be consumed by transmission A since it doesn't require a higher rpm to accelerate the car to a specified speed in a given time.

1.2 Regulation (emission requirement)

Based of the research, the pollutants emitted from the emission were nitrogen oxide, carbon monoxide, hydrocarbon, etc. Based on the data taken from the real driving emission (RDE), Euro 5 has the best RDE as it released the least pollutants compared to Euro 3 [3].

According to the emission standards which were published by the European commission, Euro 5 has a lower emission limit compared to Euro 3 [4]. This means that lesser pollutants will be released to the atmosphere by Euro 5 fuel.

In this case, transmission B is better in terms of emission compared to transmission A if environment factor is taken into consideration.

1.3 After Market Value

Table 2.0 Data's from both suppliers

| | Supplier A Transmission | Supplier B Transmission |
|---|---|---|
| Warranty | 60000km or 5 years | 30000km or 3 years |
| Transmission oil service | 60000km or 120000km | |
| Transmission oil price | RM48 per litre | RM30 per litre |

According to table 2.0 above, the warranty period based on the distance for supplier A transmission doubles by half and has 2 extra years of warranty compared to supplier B transmission. This means that supplier A transmission is dominating in this factor and it will be risky for supplier B transmission as the part price will doubles after the warranty period has ended.

As for the serviceability, the transmission oil price for transmission B is cheaper by 60% comparing to A.

In this case, the period of warranty plays a bigger role it will cause a bigger cost damage compared to the serviceability factor. This is measured based on the riskiness level where a vehicle parts can become faulty at any period while the servicing of car is only required at either 60000km or 120000km. Therefore, supplier A's transmission has a better after market value compared to supplier B's transmission.

1.4 Recommendations

All in all, I would suggest supplier A transmission due to its good climb-ability, better response, a good after market value and also better fuel consumption. Since the target markets are fresh graduates and young executives, cost would be a priority in this case, and it is better for them to choose a vehicle with longer warranty period. This is because the part price will double up when the warranty is over.

Also, they are more of an active user where the vehicle will be used more frequently. In this case, better fuel consumption will be an important factor for them to choose A.

## 2.0 Assignment Task 2

a)

### 2.1 Data Tabulation

Table 3.0 Tabulation of Data

| **Plane** | **Mass (m), kg** | **Radius (r), m** | **$F_c$ / $w^2$ (m*r), kg.m** | **Distance from plane 2 (l), m** | **Couple / $w^2$ (m.r.l), $kg.m^2$** |
|---|---|---|---|---|---|
| 1 | 400 | 0.3 | 120 | -0.45 | -54 |
| 2 | $m_2$ | 0.3 | 0.3 $m_2$ | 0 | 0 |
| 3 | $m_3$ | 0.3 | 0.3 $m_3$ | 0.75 | 0.225 $m_3$ |
| 4 | 400 | 0.3 | 120 | 1.35 | 162 |

Examples of calculations

$F_c$

$F_c = m \times r$

$= 400kg \times 0.3m$

$= 130$ kg.m

Couple

Couple = m × r × l

$= 400kg \times 0.3m \times -0.45m$

$= -54\ kg.m^2$

## 2.2 Solid Works Drawings

### 2.2.1 Primary Crank Positions

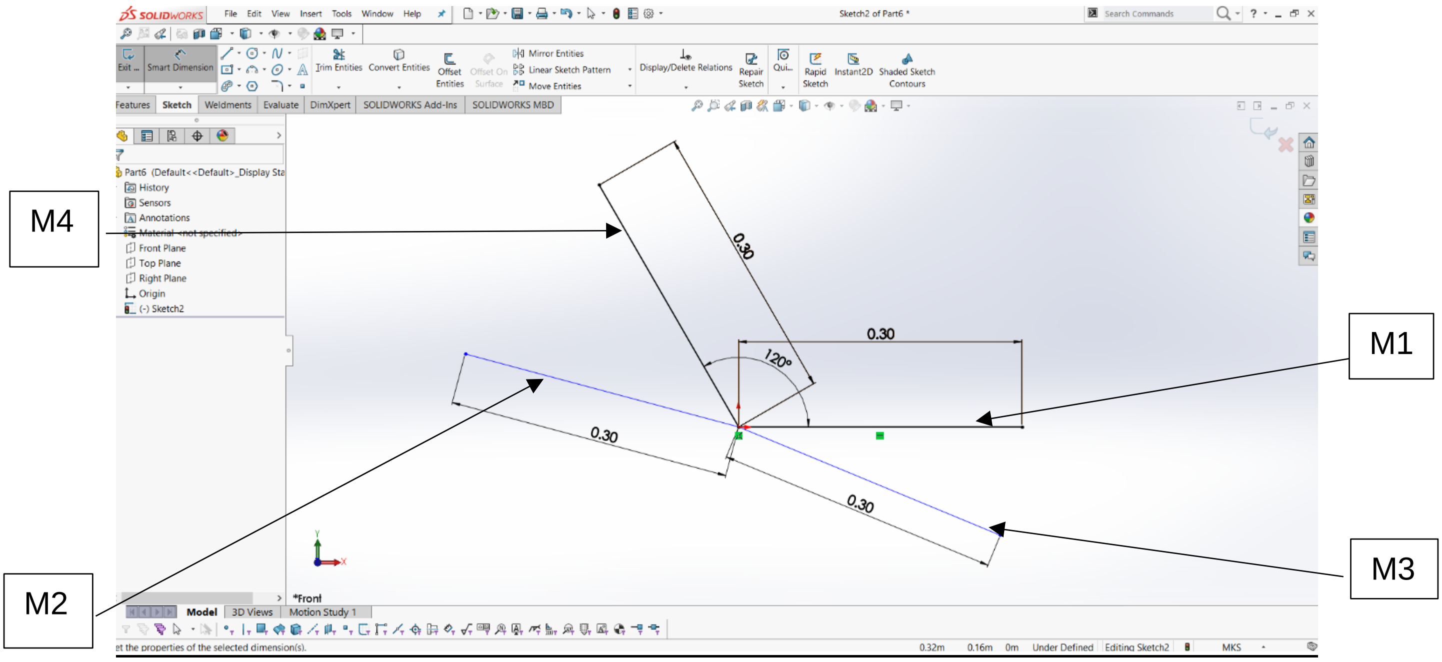



Figure 5.0 SolidWorks sketch of primary crank positions

### 2.2.2 Primary Couple Polygon

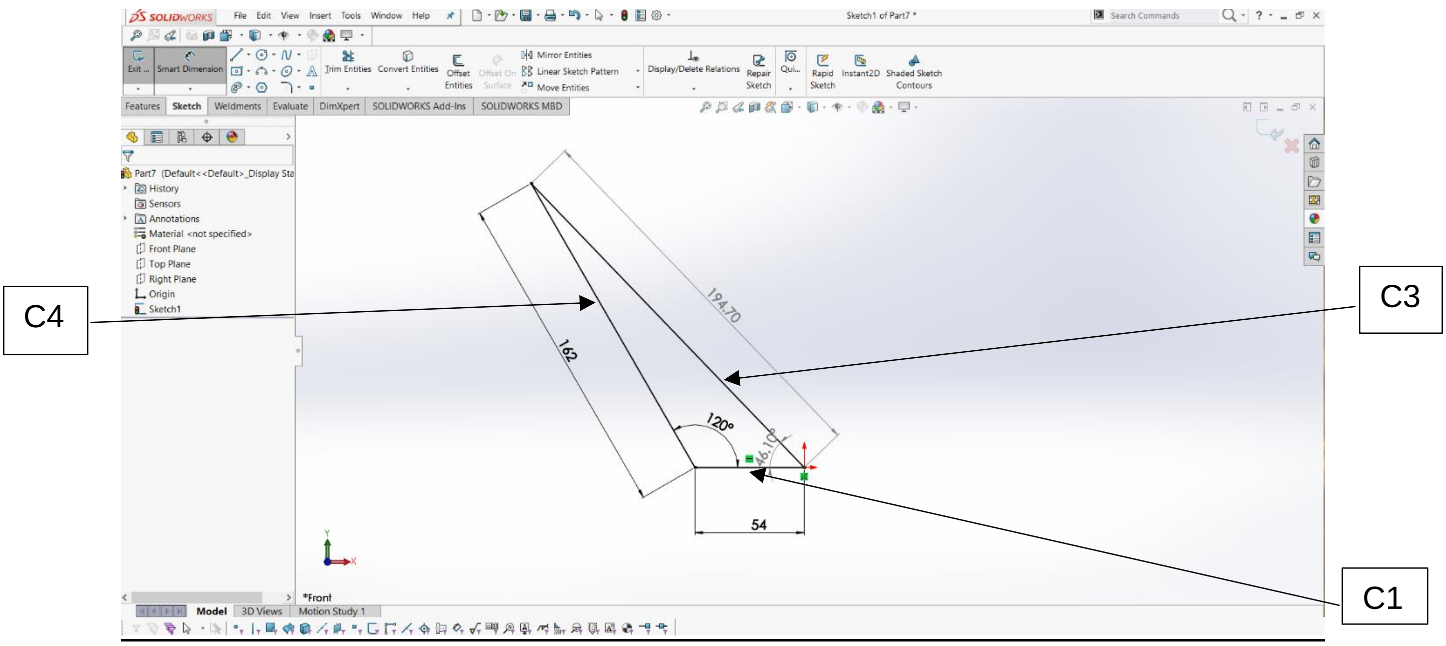



Figure 6.0 SolidWorks sketch of primary couple polygons

### 2.2.3 Primary Force Polygon

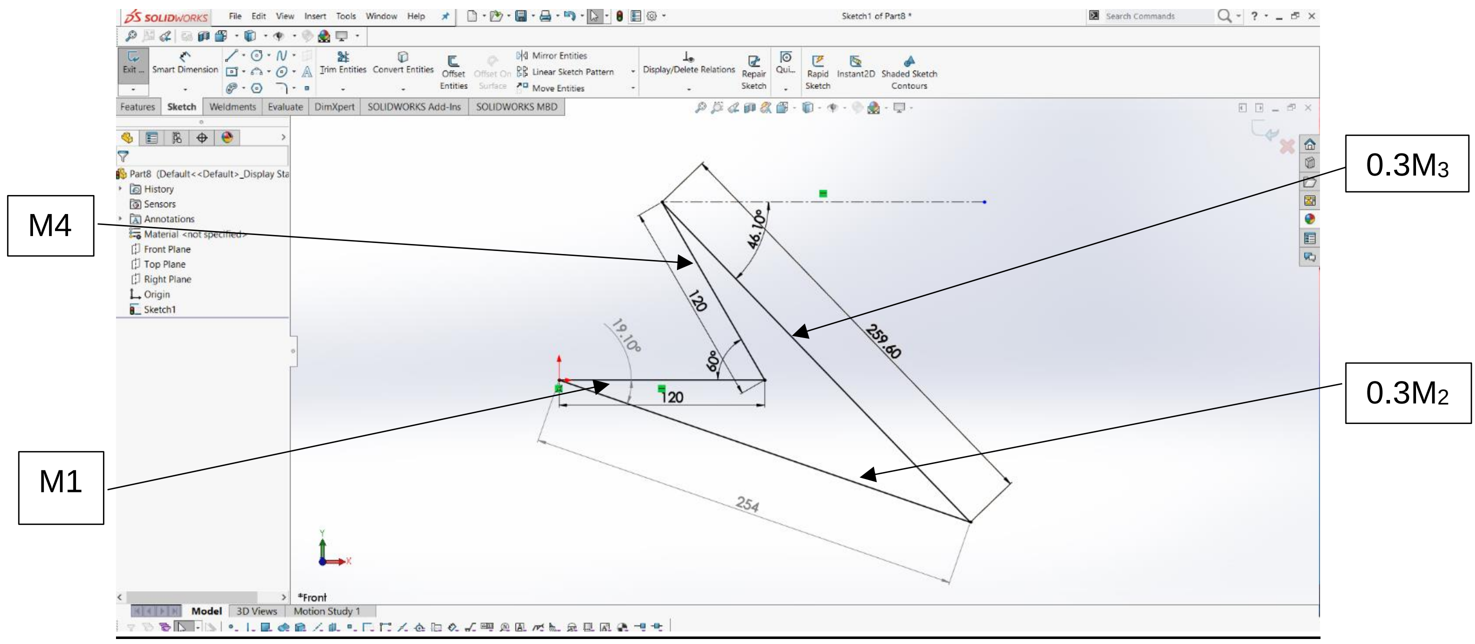



Figure 7.0 SolidWorks sketch of primary force polygon

### 2.2.4 Secondary Crank Positions

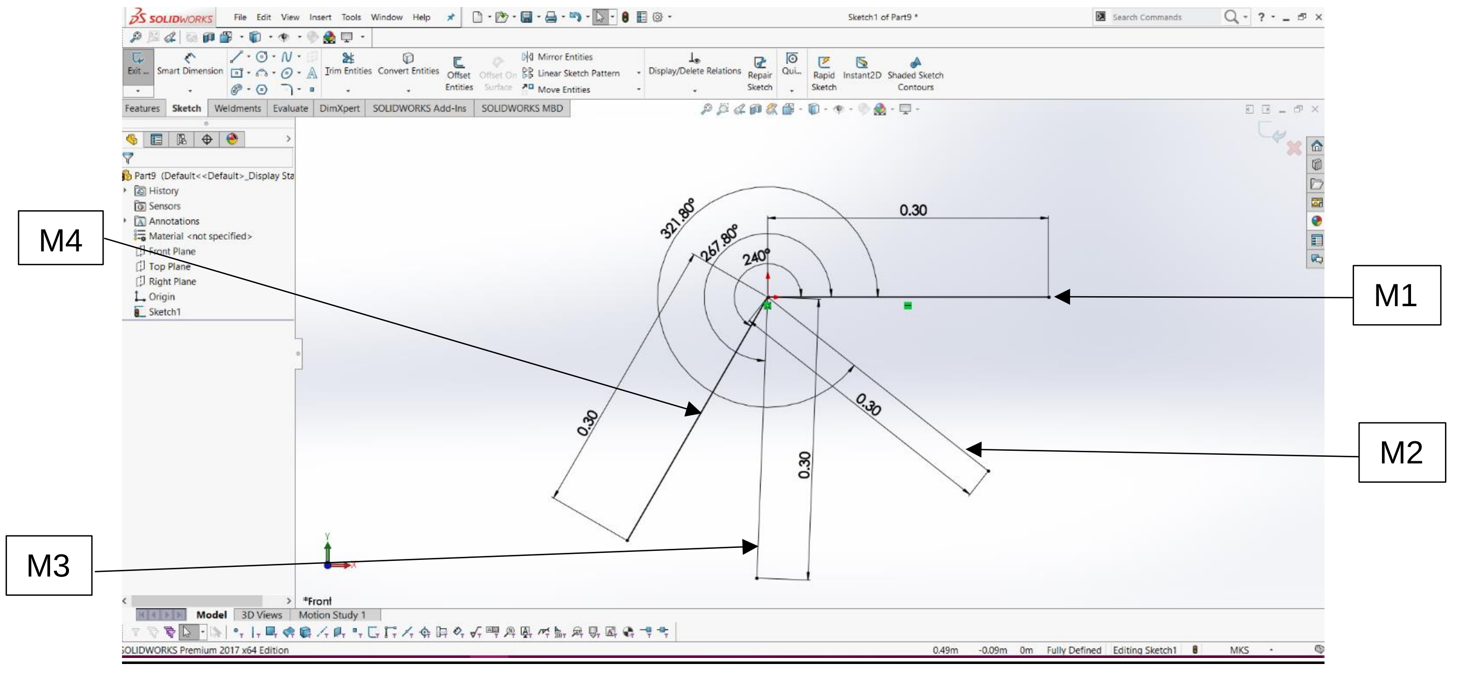



Figure 8.0 SolidWorks sketch of secondary crank positions

## 2.2.5 Secondary Force Polygon

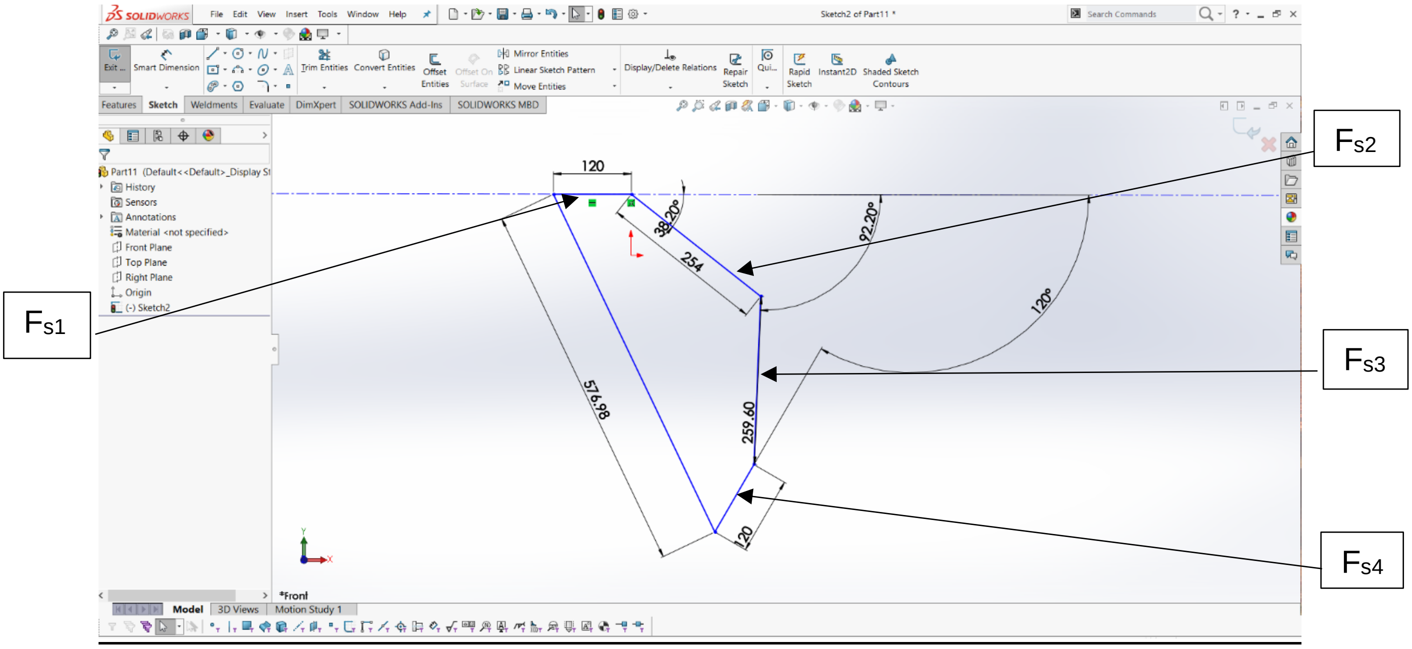



Figure 9.0 SolidWorks sketch of secondary force polygon

<u>Measurement of Secondary Unbalanced Force</u>

$F_{s(max)}$ = 576.98 m

b)

The mass of $m_2 = \frac{254}{0.3}$

$= 846.67$ kg

The mass of $m_3 = \frac{194.7}{0.225}$

$= 865.33$ kg

Table 4.0 Tabulation of Datas

| Range of Engine Speed, (rpm) | ω, rad/s | Maximum Secondary Unbalanced Forces | | | |
|---|---|---|---|---|---|
| | | Mass of cranks, kg | | | |
| | | M1= 400 | M2 = 846.67 | M3=865.33 | M3=400 |
| 0 | 0 | 0 | 0 | 0 | 0 |
| 100 | 10.472 | 3289.868 | 6963.582 | 7117.054 | 3289.868 |
| 200 | 20.944 | 13159.473 | 27854.327 | 28468.216 | 13159.473 |
| 300 | 31.416 | 29608.813 | 62672.235 | 64053.486 | 29608.813 |
| 400 | 41.888 | 52637.890 | 111417.306 | 113872.864 | 52637.890 |
| 500 | 52.360 | 82246.703 | 174089.541 | 177926.350 | 82246.703 |
| 600 | 62.832 | 118435.253 | 250688.939 | 256213.943 | 118435.253 |
| 700 | 73.304 | 161203.539 | 341215.500 | 348735.645 | 161203.539 |
| 800 | 83.776 | 210551.561 | 445669.224 | 455491.455 | 210551.561 |
| 900 | 94.278 | 266479.319 | 564050.112 | 576481.372 | 266479.319 |
| 1000 | 104.720 | 328986.813 | 696358.163 | 711705.398 | 328986.813 |

Examples of calculations

Rpm = ω

$$\omega = \frac{100rpm}{1sec} \times \frac{1min}{60sec} \times \frac{2\times\pi}{1}$$

$= 10.472$ rad/s

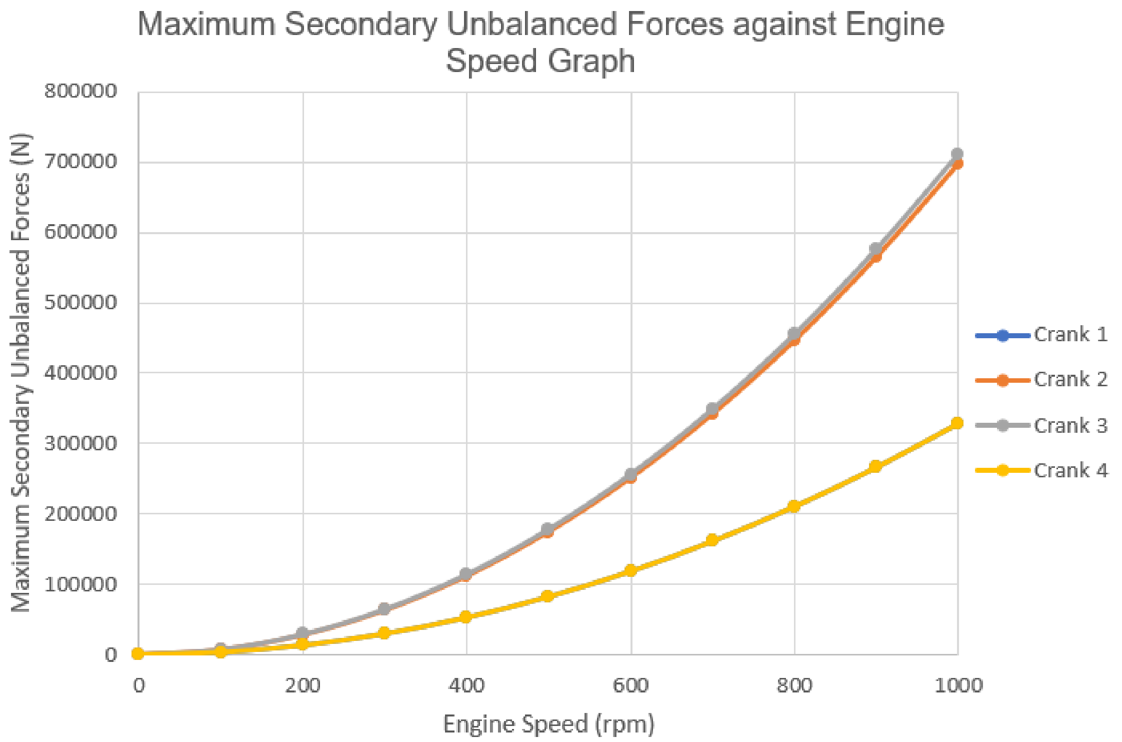
$F_{s(max)}$

Given crank radius, n=4 , mass=400kg, ω=10.472rad/s, r=0.3m

$F_{s(max)}$ = (400kg)×(10.472rad/s)$^2$× $\frac{0.3m}{4}$

= 3289.868 N

2.3 Graph of Maximum secondary unbalanced force against engine speed




Analysing

The graph shows that the maximum secondary unbalanced force is increasing proportionally with the engine speed. Crank 1 and crank 4 has the lowest maximum secondary unbalanced force but both have the same values since both of their masses are the same (400kg). Hence, the graph lines for both crank 1 and 4 overlap one another. Crank 3 has the highest maximum secondary unbalanced forces followed by crank 2, crank 1 and crank 4.

c)

Table 5.0 Tabulation of Data

| Range of Engine Speed, (rpm) | ω, rad/s | Maximum Secondary Unbalanced Forces | | | |
|---|---|---|---|---|---|
| | | Mass of cranks, kg | | | |
| | | M1= 400 | M2 = 846.67 | M3=865.33 | M3=400 |
| 1 | 31.416 | 118435.253 | 250688.939 | 256213.943 | 118435.253 |
| 2 | 31.416 | 59217.626 | 125344.470 | 128106.972 | 59217.626 |
| 3 | 31.416 | 39478.418 | 83562.980 | 85404.648 | 39478.418 |
| 4 | 31.416 | 29608.813 | 62672.235 | 64053.486 | 29608.813 |
| 5 | 31.416 | 23687.051 | 50137.788 | 51242.789 | 23687.051 |
| 6 | 31.416 | 19739.209 | 41781.490 | 42702.324 | 19739.209 |
| 7 | 31.416 | 16919.322 | 35812.706 | 36601.992 | 16919.322 |
| 8 | 31.416 | 14804.407 | 31336.117 | 32026.743 | 14804.407 |
| 9 | 31.416 | 13159.473 | 27854.327 | 28468.216 | 13159.473 |
| 10 | 31.416 | 11843.525 | 25068.894 | 25621.394 | 11843.525 |

Examples of calculations

Rpm = ω

$$\omega = \frac{300rpm}{1sec} \times \frac{1min}{60sec} \times \frac{2\times\pi}{1}$$

= 31.416 rad/s

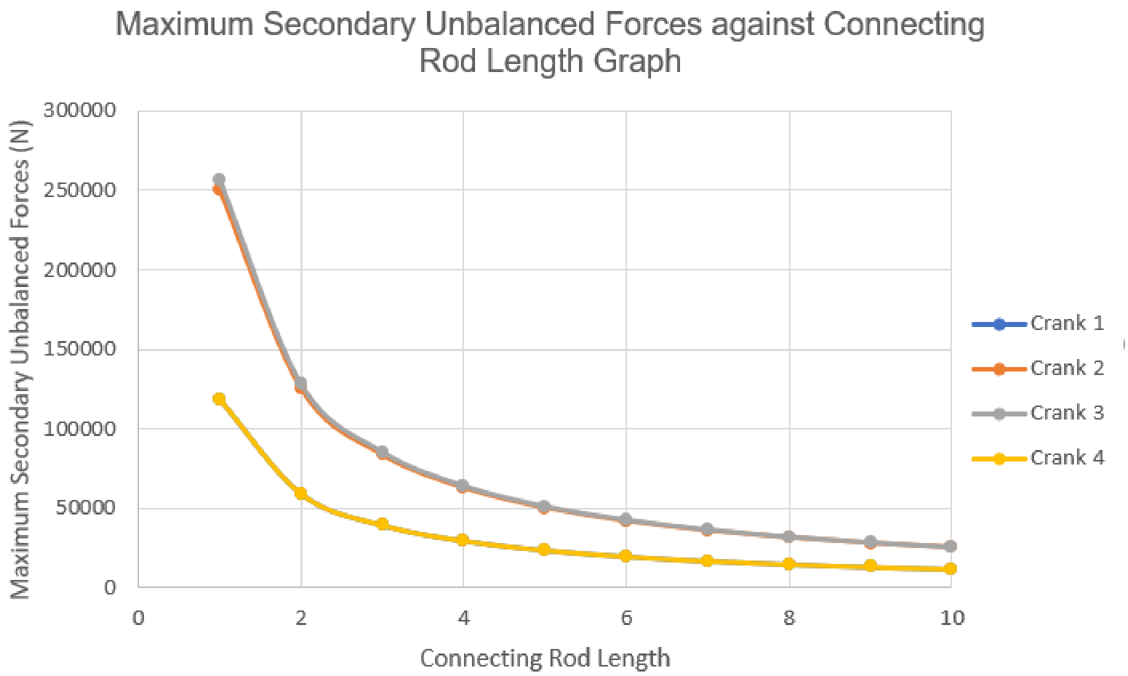
$\underline{F_{s(max)}}$

Given crank radius, n=1, mass=400kg, ω=31.416rad/s, r=0.3m

$F_{s(max)} = (400kg)\times(31.416rad/s)^2 \times \frac{0.3m}{1}$

$= 118435.807$ N

2.4 Graph of Maximum secondary unbalanced force against connecting rod length




Analysing

The graph shows that the maximum secondary unbalanced force is decreasing proportionally with the length of connecting rod. Crank 1 and crank 4 graph lines overlap one another again due to the same mass of 400 kg. Both have a smaller gradient comparing to crank 2 and crank 3. Crank 3 has a higher gradient comparing to crank 2 due to its highest mass but both have the same decreasing trend.

d)

## 2.5 Conclusion

As a conclusion, the maximum secondary unbalanced force (N) will increase proportionally with the speed of the engine (rpm). On the other hand, the maximum secondary unbalanced force will decrease proportionally with the length of connecting rod.

## 3.0 References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