

# Engine Design

## ASSIGNMENT 3\_SAMPLE ANSWER

by

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# ENGINE SPECIFICATIONS

## 1.1 Engine Specifications

**Table 1:** KTM Duke 200 Specifications

Bore, B	72mm
Stroke, S	49mm
Connecting Rod, l	98mm
Crank Radius, r	24.5mm
Idle Speed	3000rpm
Power Max	18.6425 kW @10000rpm
Torque Max	19.2 Nm @ 8000rpm
Compression Ratio	8.6:1



## Plot of Gas Pressure vs. Crank Angle

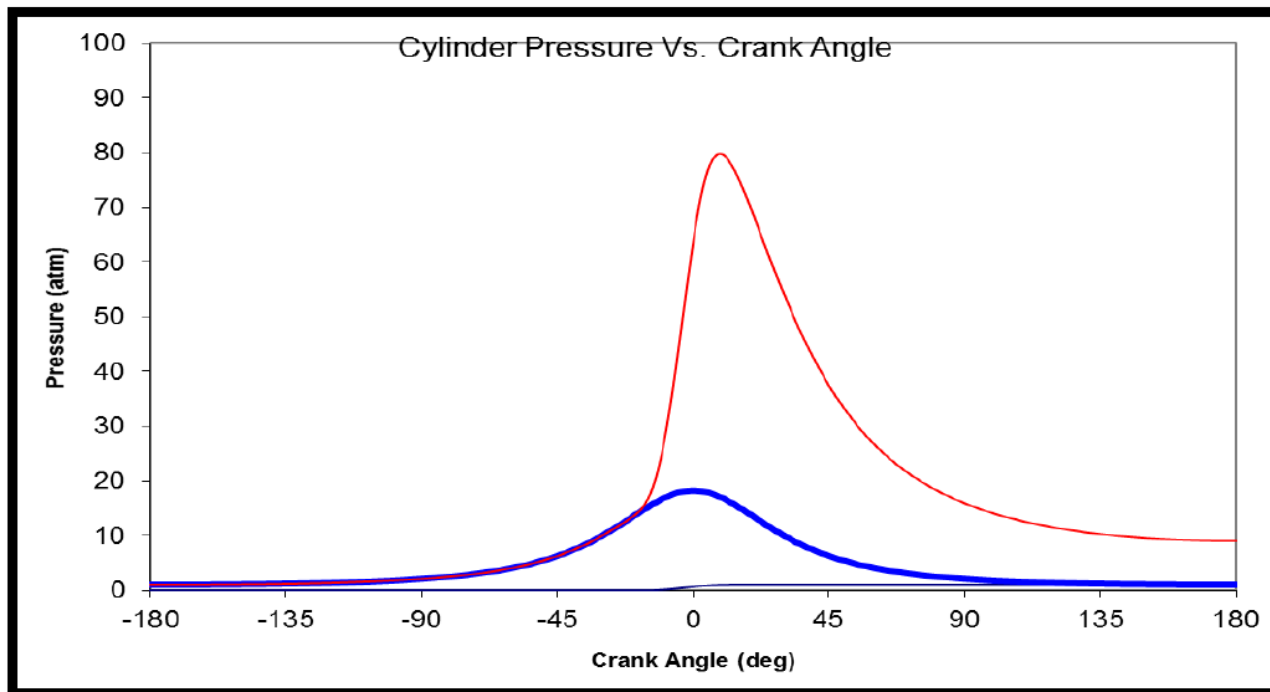


Figure 1: Cylinder Pressure vs. Crank Angle

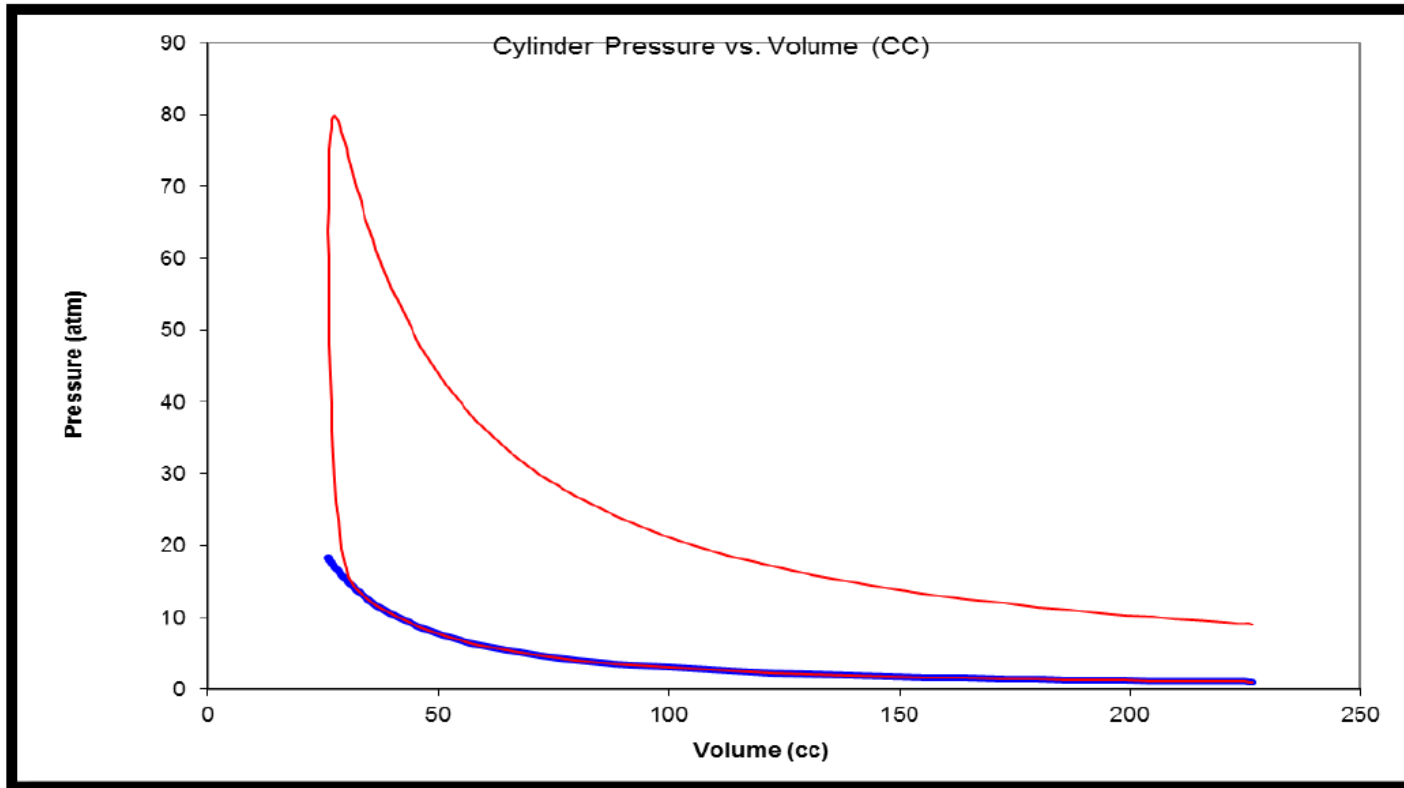


Figure 2: Cylinder Pressure vs. Volume (CC)



### 1.3 Gas Torque vs. Crank Angle

In a different excel sheet, the other parameters are calculated. Firstly, the gas pressure is converted from Bar to Pascal. Then the Gas Force (N) is calculated using equation 1. Followed by Piston Position (m) using equation 2. The approximate Gas Torque (Nm) is the product of Gas Force and Piston Position. To obtain the Exact Gas Torque, equation 3 is used.

#### Gas Force (N)

$$F_g = \frac{\pi}{4} \cdot P_g \cdot B^2 \quad \text{Equation 1}$$

#### Piston Position (m)

$$x = r \cdot \left( \sin \theta + \left( 1 + \frac{r}{l} \cos \theta \right) \right) \quad \text{Equation 2}$$



## Approximate Gas Torque (Nm)

$$Tg_{21a} = \text{Piston Postion (m)} \cdot \text{Gas Force (N)}$$

## Exact Gas Torque (Nm)

$$\text{Zetta, } \phi = \text{atan} \left( \frac{r \sin \theta}{l \sqrt{1 - \left(\frac{r}{l} \sin \theta\right)^2}} \right)$$

$$\hat{x} = r \cdot \cos \theta + l \cdot \sqrt{1 - \left(\frac{r}{l} \sin \theta\right)^2}$$

$$Tg_{21e} = F_g \cdot \tan(\phi) \cdot \hat{x}$$

Equation 3



## Excel Input

Deg	Vol	Pfired(Bar)	P(Pa)	Gas Force (N)	Piston Position (m)	Approximate Gas Torque (Nm)	Zetta	x	Exact Gas Torque (Nm)
-180	226.2	0.997732562	99773.3	406.227	0.0735	29.85770064	-3.05287E-17	0.0735	-9.14503E-16
-175	225.8	0.999770275	99977	407.057	0.074655134	30.38888575	-0.021788954	0.073593	-0.652824897
-170	224.8	1.005916664	100592	409.559	0.075976802	31.11701182	-0.043412192	0.0738713	-1.314247615
-165	223.1	1.016272523	101627	413.776	0.077455658	32.04927491	-0.064705249	0.0743328	-1.992927729
-160	220.7	1.03100935	103101	419.776	0.079081352	33.19644403	-0.08550616	0.0749739	-2.697649328
-155	217.7	1.05037479	105037	427.661	0.080842567	34.57317464	-0.105656687	0.07579	-3.437385817
-150	214.1	1.074700636	107470	437.565	0.082727074	36.19845598	-0.125003514	0.0767747	-4.221136798
-145	209.8	1.104413768	110441	449.563	0.084721791	38.09521364	-0.143399415	0.0779207	-5.059156659
-140	204.9	1.140050612	114005	464.172	0.086812842	40.2960969	-0.160704371	0.0792193	-5.960721542
-135	199.5	1.182275869	118228	481.364	0.088985636	42.83449074	-0.176786639	0.0806606	-6.936527652
-130	193.5	1.231906519	123191	501.571	0.091224937	45.755805	-0.191523755	0.0822337	-7.997630951
-125	187.0	1.289942429	128994	525.201	0.093514956	49.11410989	-0.204803473	0.0839268	-9.155783958
-120	180.0	1.357605304	135761	552.750	0.09583944	52.97520753	-0.216524624	0.085727	-10.42355109
-115	172.7	1.436388239	143639	584.826	0.098181768	57.41925644	-0.226597892	0.0876207	-11.81443113
-110	164.9	1.528118824	152812	622.174	0.100525061	62.54409965	-0.234946504	0.0895935	-13.34298026
-105	156.9	1.635039607	163504	665.707	0.102852284	68.46949012	-0.241506817	0.0916304	-15.02492231
-100	148.6	1.75991078	175991	716.548	0.105146367	75.34245986	-0.246228817	0.0937159	-16.87722195
-95	140.0	1.906141292	190614	776.086	0.107390314	83.34414087	-0.249076497	0.0958343	-18.91807882
-90	131.4	2.077955995	207796	846.041	0.109567331	92.69841377	-0.250028143	0.0979694	-21.16677258
-85	122.6	2.280507941	228061	928.550	0.111660945	103.6828211	-0.249076497	0.1001049	-23.64324448
-80	113.8	2.520645855	252065	1026.282	0.113655127	116.6422099	-0.246228817	0.1022247	-26.36723166
-75	105.1	2.806246299	280625	1142.564	0.115534418	132.0055039	-0.241506817	0.1043125	-29.3566624
-70	96.6	3.147615709	314762	1281.553	0.117284048	150.3057259	-0.234946504	0.1063524	-32.62495572
-65	88.2	3.557455222	355746	1448.419	0.118990063	172.2026673	-0.226597892	0.108329	-36.17582277

Figure 3: Excel Input Example



### 1.3.1 Piston Position vs. Crank Angle

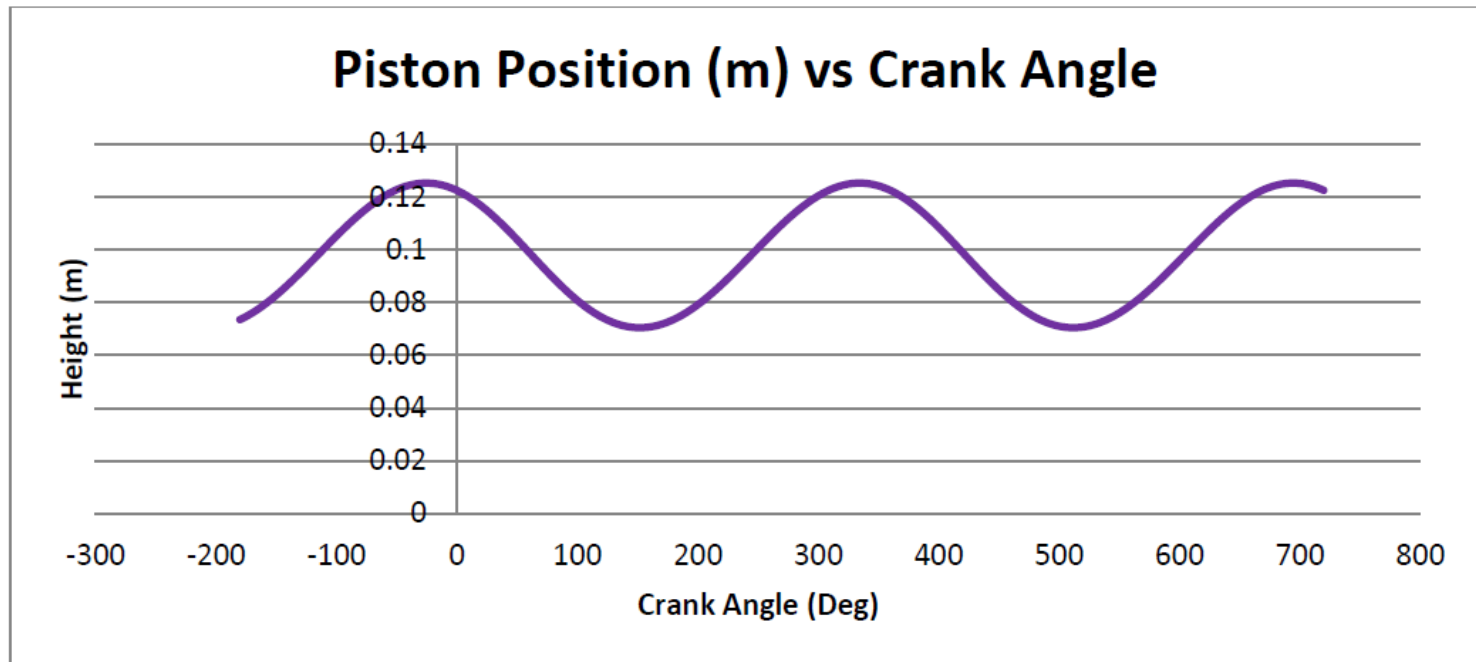


Figure 4: Piston Position vs. Crank Angle Graph obtained from Excel Output



### 1.3.2 Approximate Gas Torque vs. Crank Angle

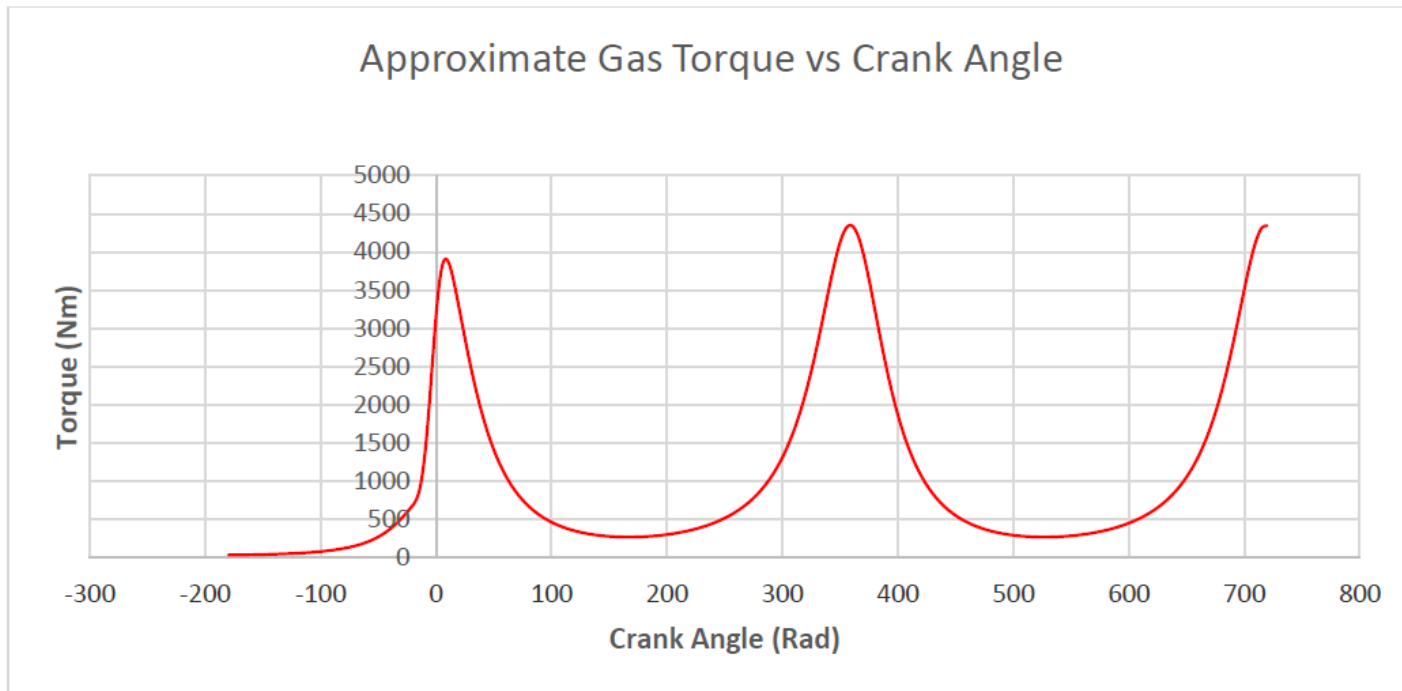


Figure 5: Approximate Gas Torque vs. Crank Angle Graph obtained from Excel Output

### 1.3.3 Exact Gas Torque vs. Crank Angle

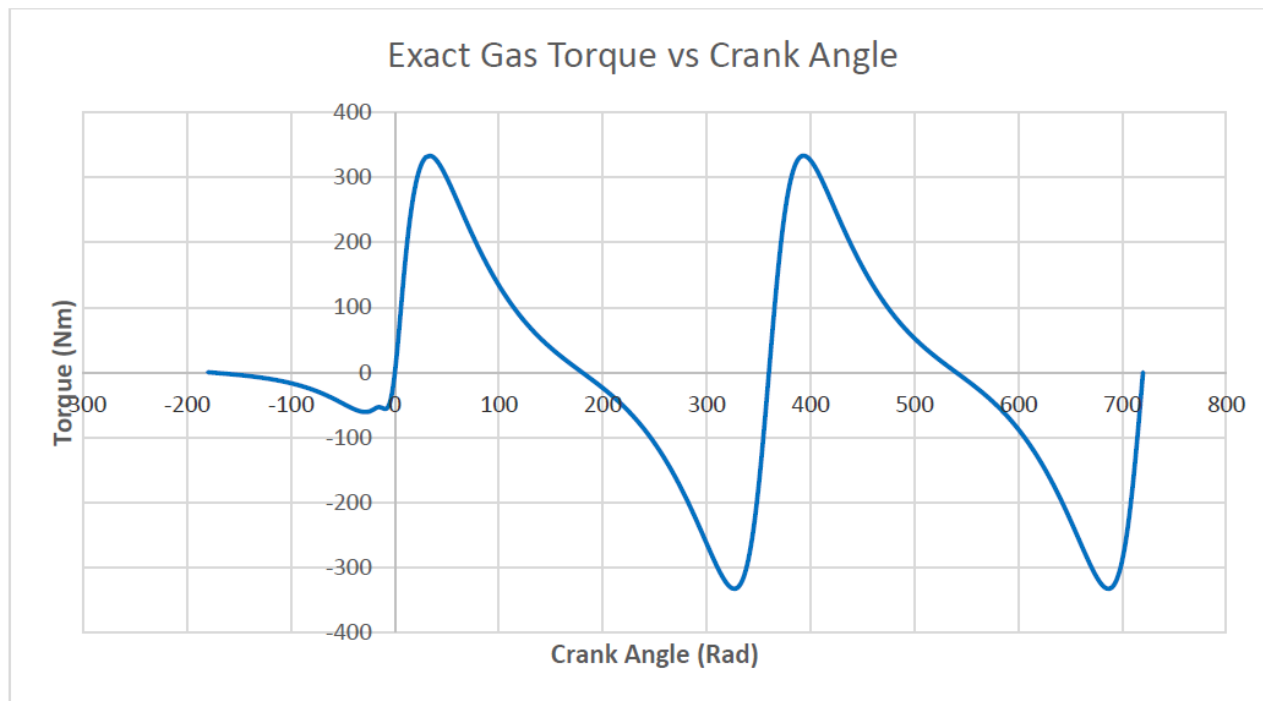


Figure 6: Exact Gas Torque vs. Crank Angle Graph obtained from Excel Output

## 1.4 Inertia Torque

### 1.4.1 Piston Head Design & Mass Properties

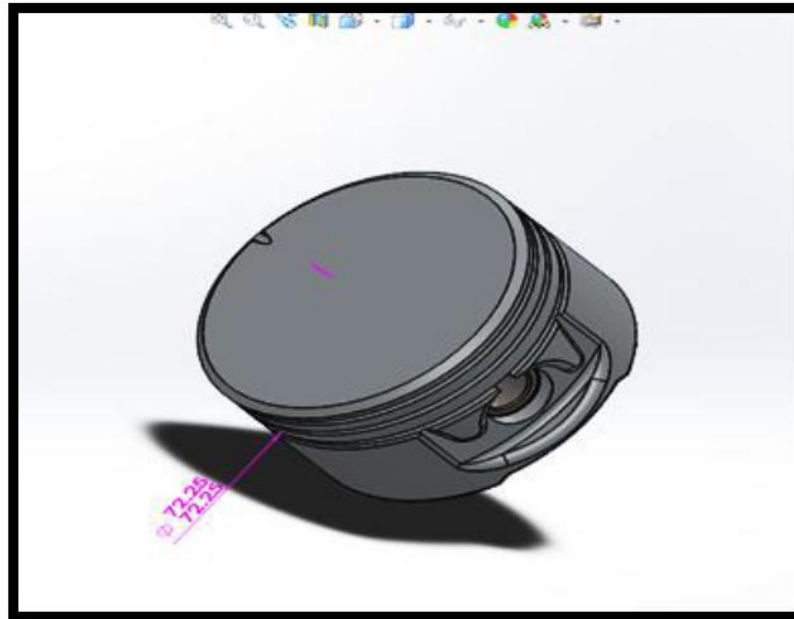


Figure 7: Piston Head Design using Solidworks

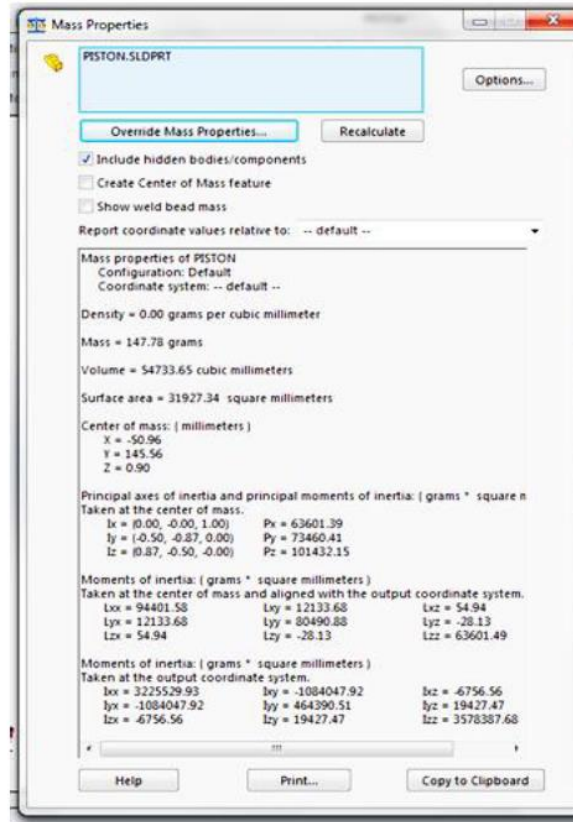


Figure 8: Mass Properties of Piston Head = 147.78g



## 1.4.2 Connecting Rod Design & Mass Properties

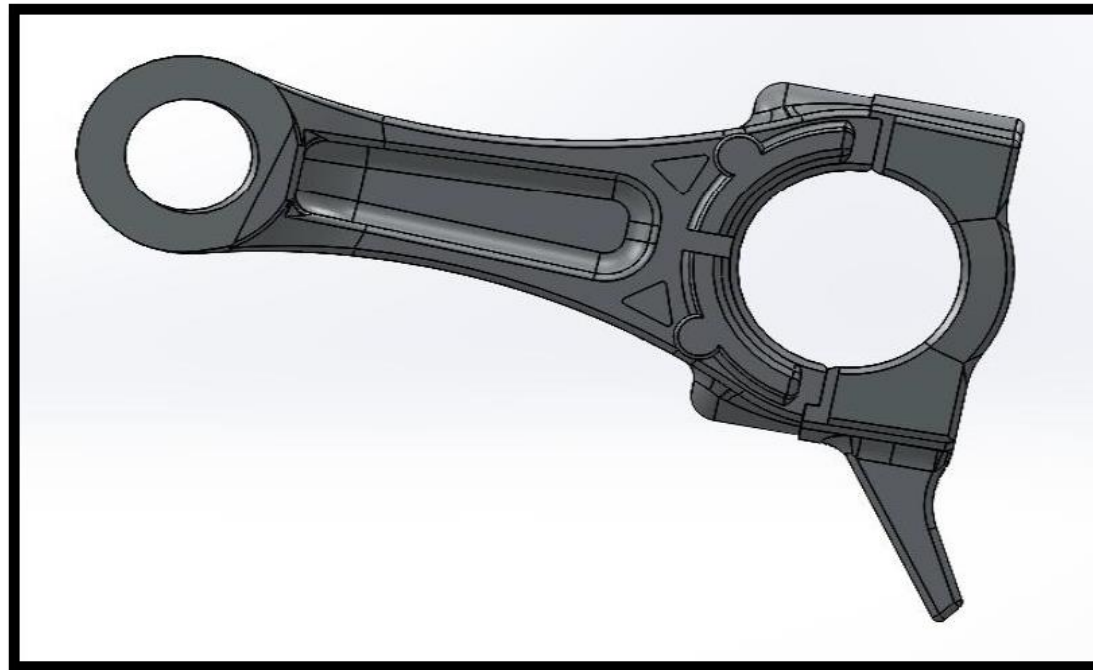


Figure 9: Connecting Rod Design using Solidworks

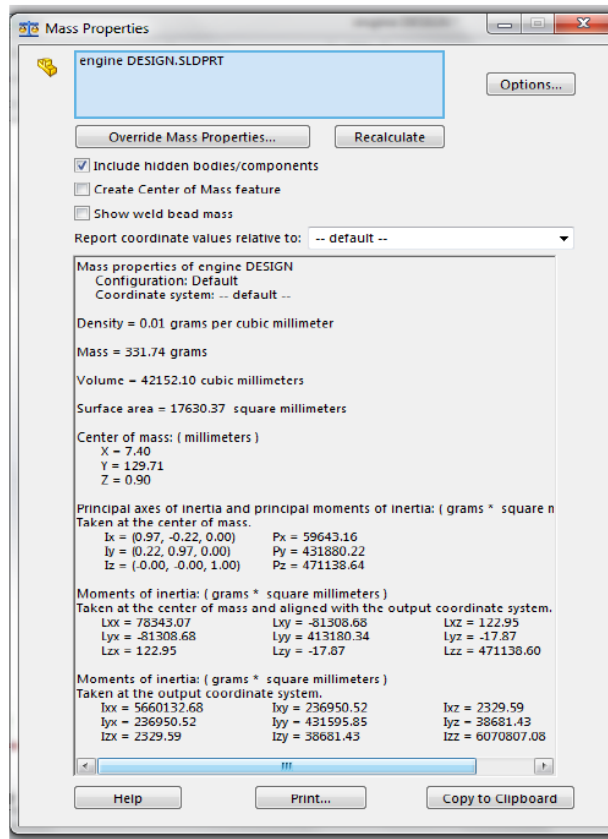


Figure 10: Mass Properties of Connecting Rod = 331.74g



### 1.4.3 Crank Shaft Design & Mass Properties

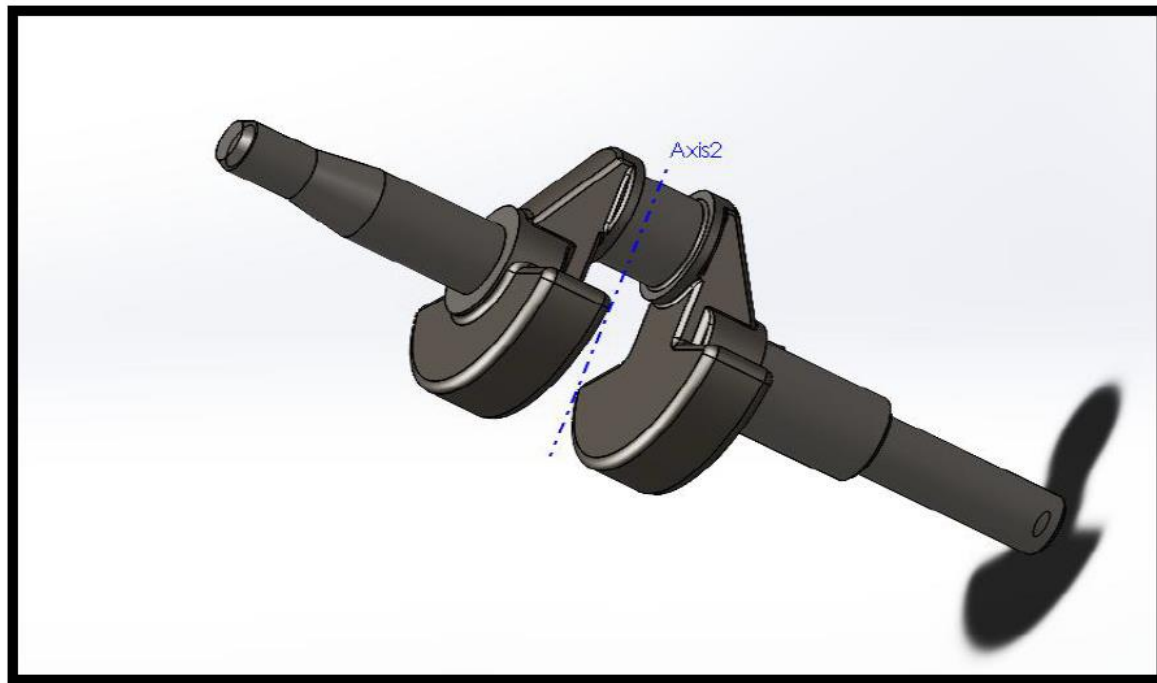


Figure 11: Crank Shaft Design using Solidworks

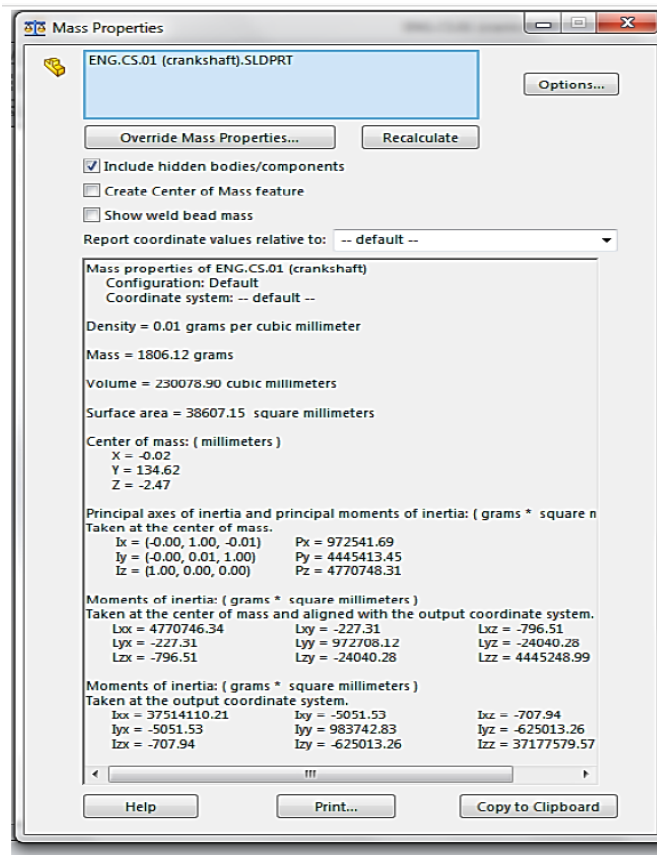


Figure 12: Mass Properties of Crank Shaft = 180612g





#### 1.4.4 Engine Specifications

**Table 2:** Specification for KTM Duke Single Cylinder Four Stroke Oversquare Engine

r	Compression Ratio	8.6
k	Expansion Coefficient	1.35
Pmax	Maximum Pressure (after combustion), p3	78.7456 atm
Patm	Atmospheric Pressure	14.7 psi
Vc	Clearance Volume	0.0263 liters
L	Stroke	49mm
D	Bore	72mm
$\alpha$	Ratio of crank to conn. Rod length	0.25
N	Engine Speed Idle	3000 RPM
Mpiston	Mass of Piston	0.32579 lbs
Mcrank	Effective Mass of Crank Shaft ( 1 cylinder)	3.9818 Ibs
Mconn	Mass of Connecting Rod	0.73136 Ibs



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