



Valve-Train Investigation and Comparative Analysis of Two High-Performance Single Cylinder Engines

Callum-James Hill

Dr Owen Williams

School of Engineering

BEng Motorsport Engineering

Introduction

The terminology “valve-train” as applied to an ICE refers to the mechanism for controlling the intake and exhaust gas flow through the cylinder head ports and combustion chamber. The valve-train is one of the most crucially important assemblies when designing an ICE, even more so when designing one to be used in motorsport, due to the harsher working conditions each component will be put under.

Project Aims

A dynamics study, friction model study and a FEA study were completed to analyse and understand the behaviors of a valve-train. To successfully complete this, two valve-trains were considered; a 2014 KTM Moto3 RC250R & a 2017 Yamaha YZ250F (GYTR Cylinder Head). The KTM is used in road racing and the Yamaha used in Enduro, a comparative analysis of the data collected on the two valve-trains was conducted, the aim being to study the different choices made by the manufacturers based upon their racing applications.



Figure 1
2017
Yamaha
YZ250F
(Enduro
21)



Figure 2
2014 KTM
Moto3
RC250R

Methodology

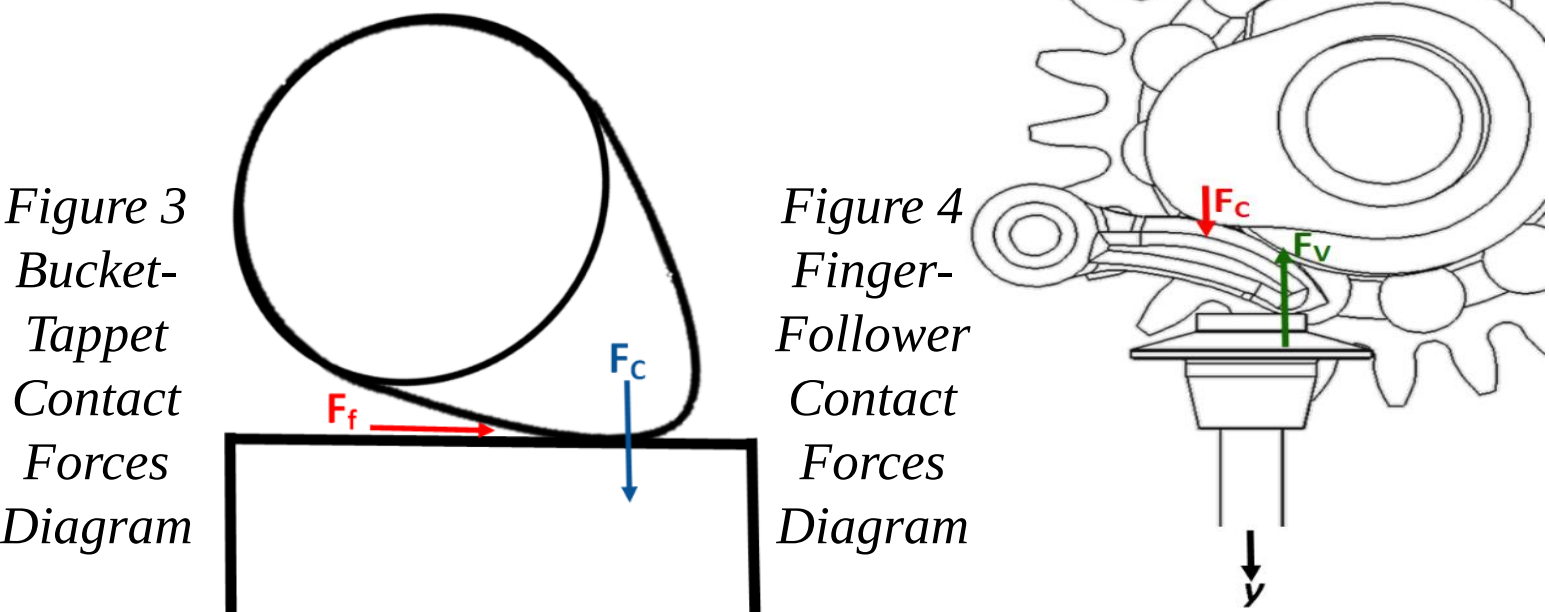
Dynamics Study

The cam lift values were measured with the use of an optical dividing head. From the cam lift data, the valve lift could be determined for each degree of cam angle with the use of a 360 x 360 Matrix. Then the valve’s velocities and accelerations could be determined, using the first and second order derivatives of distance with respect to time;

$$v = \frac{dy}{dt} \quad a = \frac{dv}{dt} = \frac{d^2y}{dt^2}$$

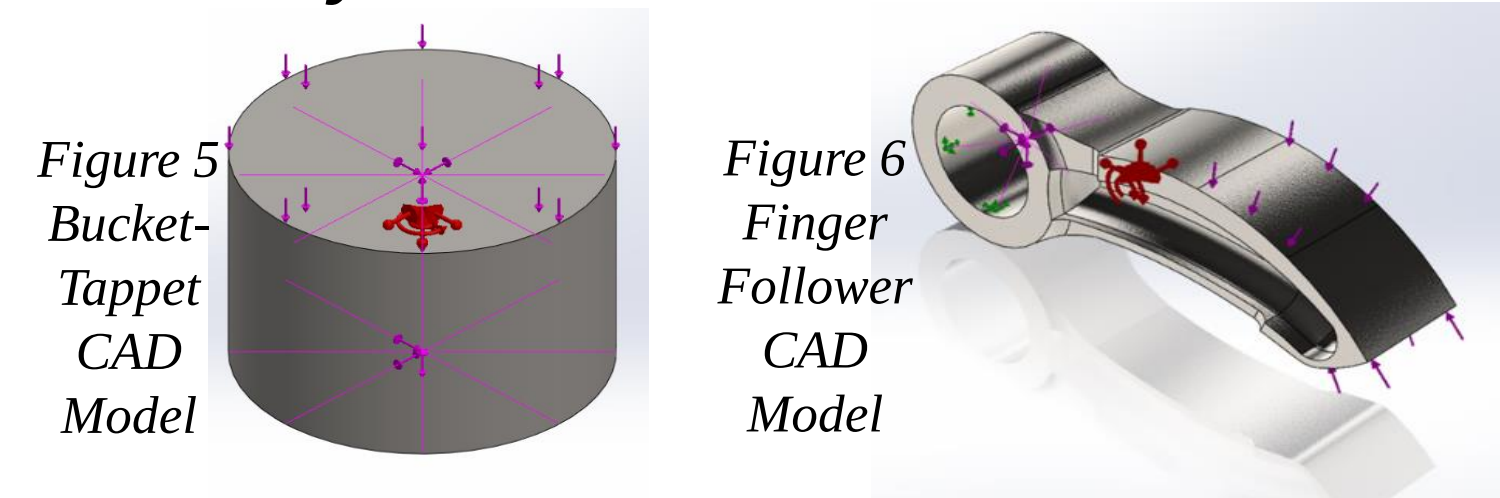
First Derivative Second Derivative

Friction Model



One of the more significant differences between the two valve-trains is the valve actuation systems. The Yamaha uses uncoated steel bucket-tappets with a friction coefficient of 0.16 as opposed to the KTM which uses finger followers covered with a thin-film DLC coating and a friction coefficient of 0.05. The contact forces from the cam-lobes for each valve-train had to be calculated using different methods, as the bucket-tappets have a flat surface whereas the followers have a curved surface. Then the rest of the friction model was carried out so that the power losses through friction within the two valve-trains could be calculated.

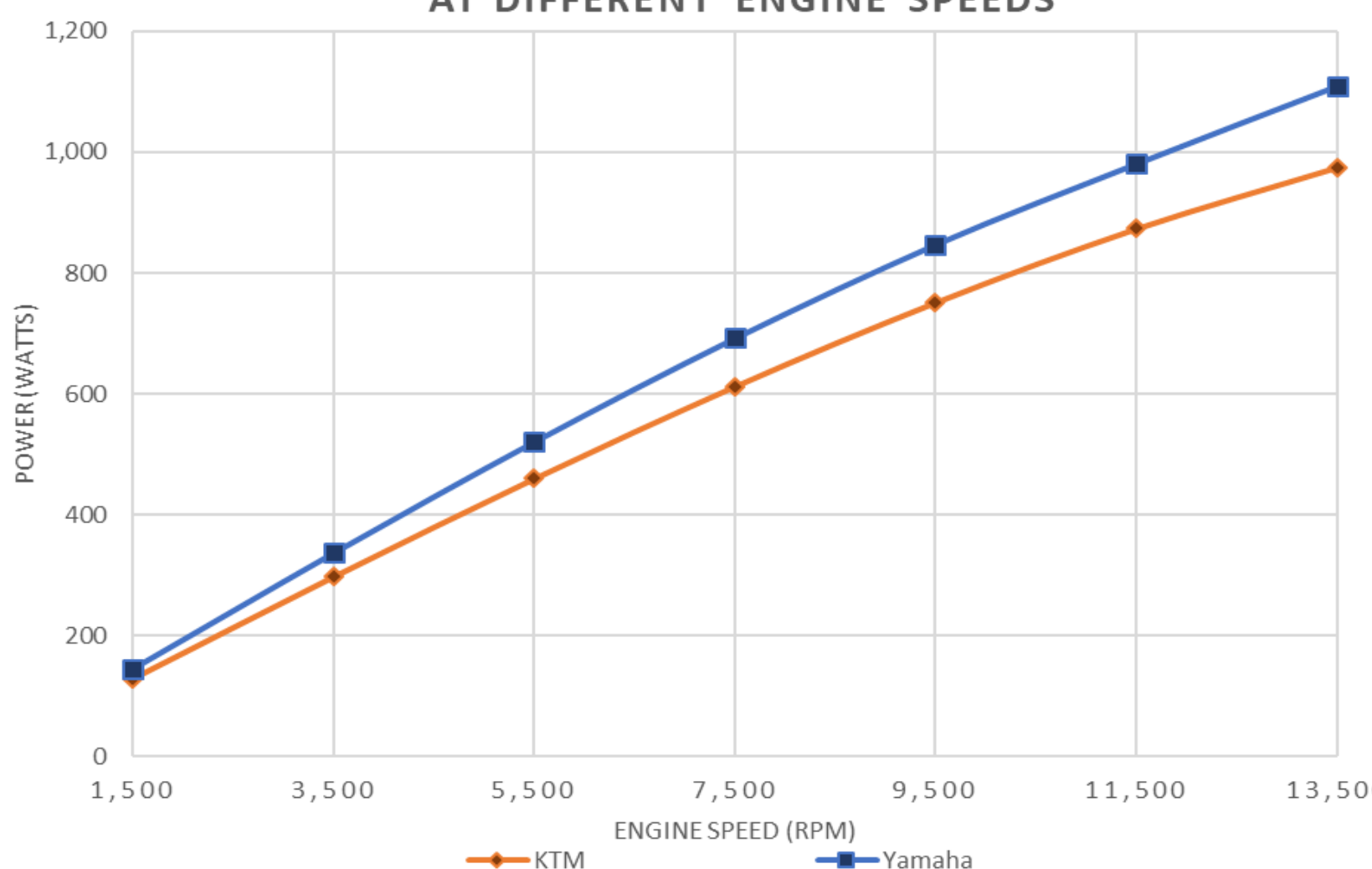
FEA Study



With the use of the SolidWorks software package, all the relevant valve-train components were modelled, and a motion simulation was run at maximum speed for each engine. Then an FEA study was carried out on the YZ250F’s bucket-tappet and the KTM’s finger follower generating all the forces acting upon either component. Calculating the stresses and displacements experienced during the camshaft’s revolution.

Results

Graph 1 Valve-Train Power Losses Through Friction
FRICTION POWER LOSSES WITHIN THE VALVE TRAIN
AT DIFFERENT ENGINE SPEEDS

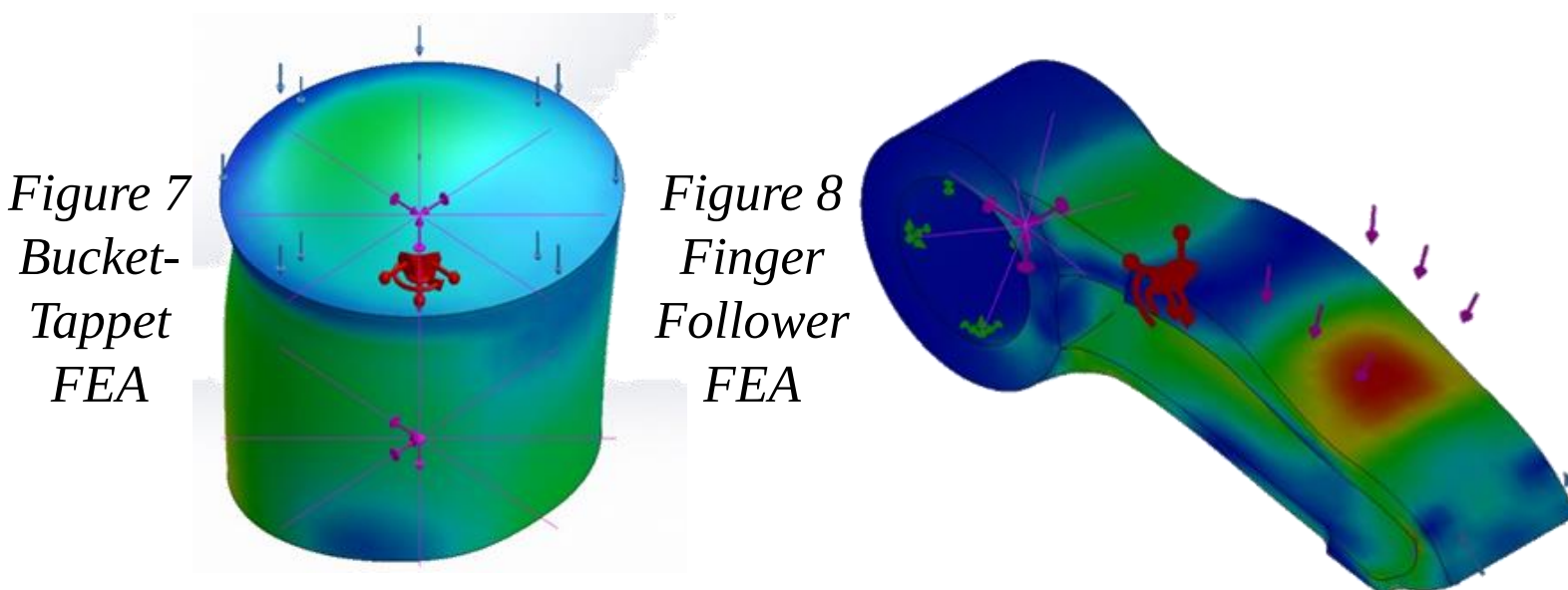


Frictional power losses account for around 80% of the friction within the valve-train and 20% of total engine friction. Graph 1 shows these power losses for both valve-trains, demonstrating the losses increase with engine speed.

Table 1 Valve-Train Power Losses Through Friction

	Overall Valve-Train Power Loss in HP			
RPM	7,500	9,500	11,500	13,500
KTM	0.8210	1.0076	1.1712	1.3072
Yamaha	0.9279	1.1353	1.3145	1.4594

Table 1 shows the power losses through friction at high engine speeds. On average the Yamaha is losing 12.54% more power compared to the KTM. this shows that a DLC coating and assists in reducing losses in turn enhancing engine performance, even if only slightly.



At maximum engine speed, the finger follower was experiencing a significantly higher amount of contact force in comparison with the bucket-tappet, 94.8% more force in fact. The maximum stress experienced by the bucket-tappet is only 6.4% of its UTS and the maximum stress the KTM’s finger follower experienced was only 10.39% of its UTS.

Conclusions

The study outlined the importance of the valve-train within the internal combustion engine, and how it can be designed to reduce emissions and increase performance, by reducing mass and by reducing power losses as a result of friction. Finally, The comparative analysis of the two valve-trains demonstrated how vast the differences between the two engines are, ranging from the cam-profiles to the valve actuating systems

Acknowledgements

I would like to thank my supervisor Dr Owen Williams for his guidance. Also, I would like to thank SymCircus Motorsport for donating the KTM engine and fellow student David Migliorati N'Doua for allowing me to use the YZ250F valve-train components.

Finally, I would like to thank my family and my girlfriend for the continued support throughout my studies.

References

- Kano, M. I. (2007). Superlubricity of Diamond/Glycerol Technology Applied to Automotive Gasoline Engines. Superlubricity.
- Enduro 21. (n.d.). Team Miglio Yamaha Race Bikes Stolen. Retrieved from Enduro 21: <https://enduro21.com/index.php/40-general/1172-team-miglio-yamaha-race-bikes-stolen>