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FEA and Numerical Analysis and Comparison of Connecting Rods From A car and A Motorcycle.

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Introduction

The focus of this study was to complete a comparative analysis of two connecting rods, one from a Triumph Daytona 675R the other from a Ford Sigma 1.6L to show how each design has been optimised for its specific use. Starting with real-world test data to build a simulated profile of the forces acting through each rod to create two studies, a finite element study was used to build a profile of how the forces act over the entire rod, while numerical analysis was used to provide a more detailed view of key areas on the connecting rods.

Simulated Profile.

In order to conduct the two different approaches to analysis the forces acting through the connecting rods needs to be calculated; this is carried out by using real-world pressure data to calculate numerous operating factors. The desired results give the "Rod Force" which is found by dividing the net force acting on the rod by the cosine of the angle at which the rod is connected to the crank. [1]

$$\textit{Rod force} = \frac{\textit{Gas Force} - \textit{Inertia Force}}{\cos \textit{Rod Angle}}$$

Finite Element Analysis

Using physical measurements to create a 3D model of both connecting rods in a computer aided design suite (Solidworks) and the operating forces calculated in the simulated profile, a finite element study can be carried out which provides an accurate representation of how the connecting rod is likely to behave overall when subjected to the highest calculated motion loads.
All physical measurements were collected using a digital Vernier calliper rated to an accuracy of 0.01mm, masses were also collected where possible using a digital scale rated to an accuracy of 0.01g.

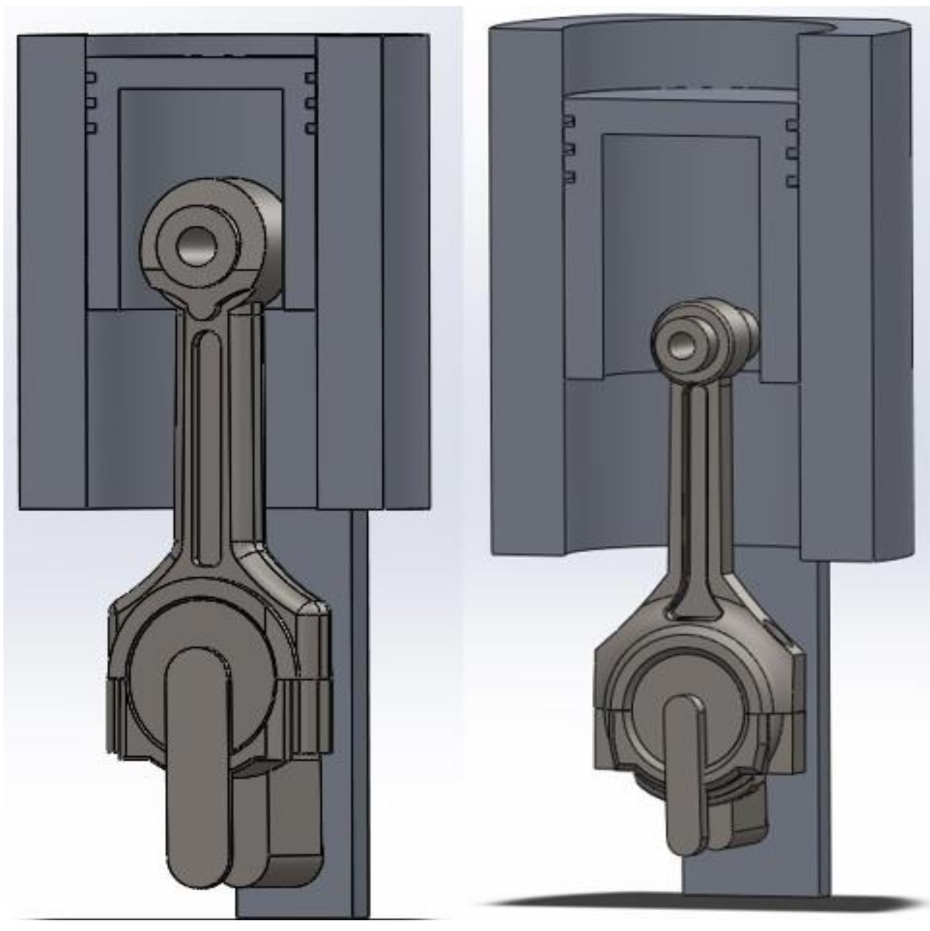

Figure 1. Cylinder Model Assemblies. Left: Ford Connecting Rod. Right: Triumph Connecting Rod.

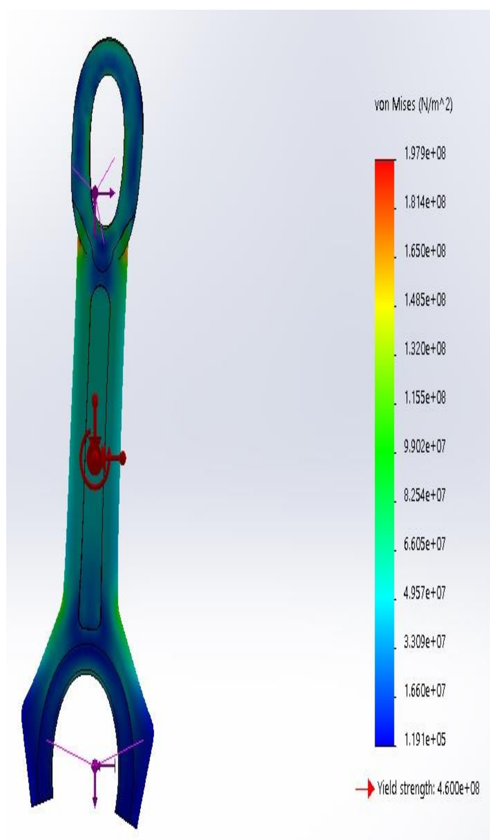

Figure 2 (Left). Ford Connecting Rod FEA Results, Von-misses

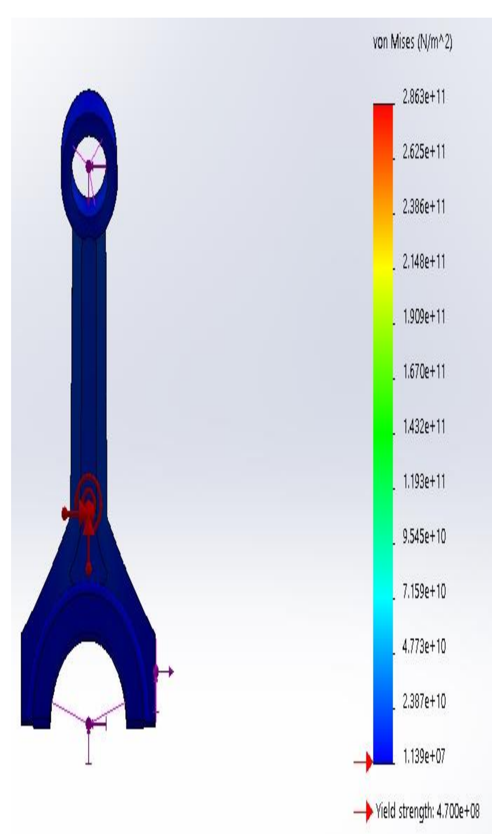

Figure 3 (Right). Triumph Connecting Rod FEA Results Von-misses

Numerical Analysis

At 4 critical locations on the connecting rod assembly stress calculations were carried out to find the fatigue safety factor at each location. The fatigue safety factor or "FSF" gives a simple number to the estimated life of a connecting rod and is found by calculating the ratio of the range of stresses from the combined compressive and tensile stress calculated and the allowable range of stresses permitted by the material ultimate tensile strength. [2].
The allowable range of stresses is calculated with the aid of a Goodman diagram using the trigonometry of similar triangles to find the distance between two points plotted graphically. [3]

$$\textit{Allowable range} = (2 \times \textit{Material endurance limit})\left(1 - \frac{\textit{Mean stress}}{\textit{Material ultimate tensile strength}}\right)$$

$$\textit{Fatigue safety factor} = \frac{\textit{Allowable range of stresses}}{\textit{Actual range of stresses}}$$

The combined stresses are only calculated for the Gudgeon pin and consist of both bending and shear stresses. [3]
At key rod points the compressive and tensile stresses can be found immediately by dividing the force by the cross-sectional area of the point being analysed. [5]

Figure 4.
Goodman Diagram Example

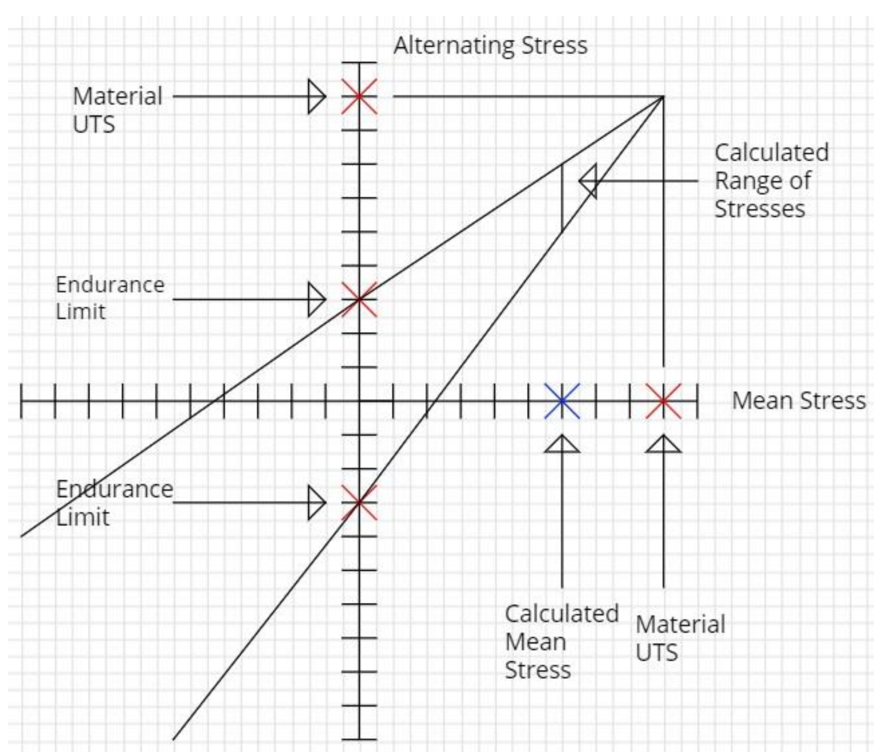

Table 1. Sample of the Simulated Profile Built Up.

Simulation Sample								
Gas Force	Rod Angle	Rod Angle	Displacement	1st order	2nd order	Inertia Force	Net Force	Rod Force
N	Radians	Degrees	M	N	N	N	N	N
1330.068	3.67E-17	2.1E-15	0	10975	1349.535	14987.00414	-13656.9	-13656.9
1322.225	0.002611	0.149612	0.000356591	10973.33	1348.713	14983.97179	-13661.7	-13661.8
1312.79	0.005222	0.299178	0.001414974	10968.31	1346.247	14974.87658	-13662.1	-13662.3
1309.604	0.00783	0.448653	0.00314153	10959.96	1342.142	14959.72403	-13650.1	-13650.5
1301.761	0.010437	0.597991	0.005482049	10948.27	1336.401	14938.5233	-13636.8	-13637.5

Results

Figure 5. Fatigue Safety factors

Fatigue Safety Factor		
Location	Triumph	Ford
Gudgeon Pin	1.0388	4.2683
Point A	0.9024	2.4438
Point B	1.5783	2.6606
Point C	3.2637	2.6709

Figure 6. Rod Forces and Loads

Rod Forces and loads			
Force	Triumph	Ford	Units
Compressive	35645.1	32947.7	N/mm^2
Tensile	16939.4	13662.1	N/mm^2
Buckling	108.676	351.795	KN

Conclusion

The connecting rod used by Ford shows optimisation to increase longevity and durability while the rod used by Triumph is designed to handle increased inertia loads due to higher operating speeds. This is evident by the lightening of the rod and the extra care taken to reduce stress concentrations due to surface imperfections which is not present on the Ford connecting rod.
The car is designed for increased durability due to the majority of people using cars as their primary mode of transportation as opposed to motorcycles like the Triumph Daytona which was designed as a sports bike for recreational use. [6]

References

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Acknowledgements
With special thanks to Karen Slade for proofreading all of the work submitted throughout this course. Thanks also to Maddison slade, Phillipa James, Phoebe Lillis, Alexis "Lexie" Kushmaul and Sean Russ for their unending help and support throughout