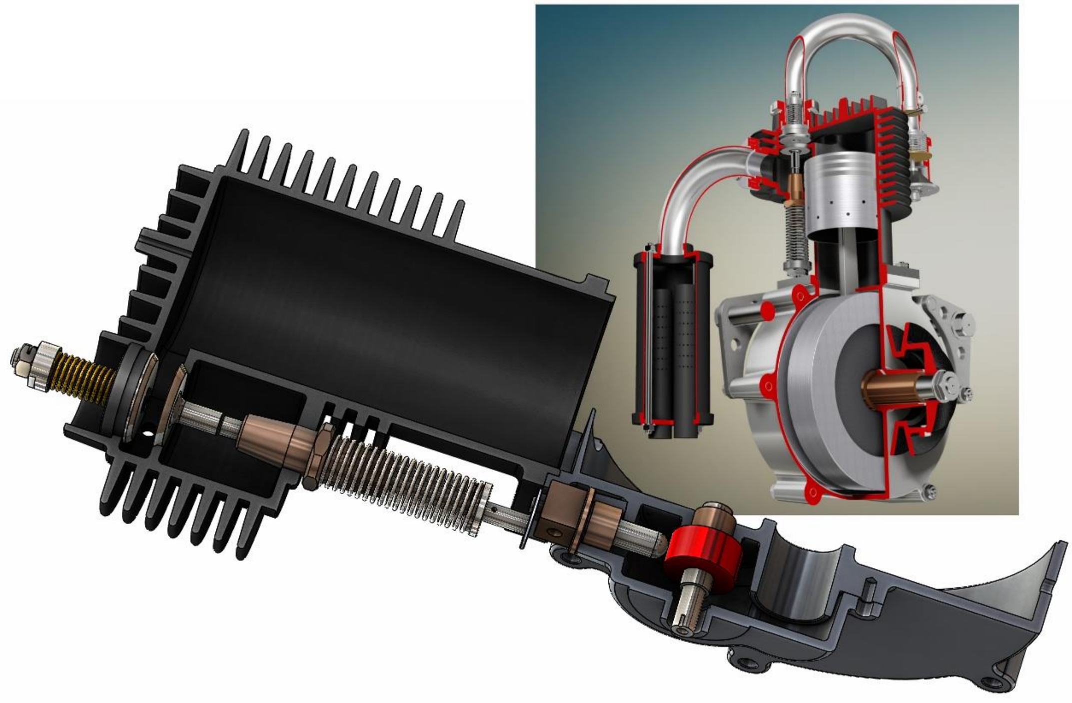
DYNAMIC SIMULATION



Objective

The aim of this short paper is to introduce Dynamic Simulation and how it is of use in the real world.

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Introduction

As a mechanical engineer it is essential that we have confidence in a design before we go ahead and start cutting metal. One of the most powerful tools at my disposal to ensure that we arrive at a working product is Dynamic Simulation.

The aims of this short paper are to:

- introduce you to Dynamic Simulation
- show you how Dynamic Simulation if of great practical use
- demonstrate how it can save you both time and money when developing a product

What is Dynamic Simulation?

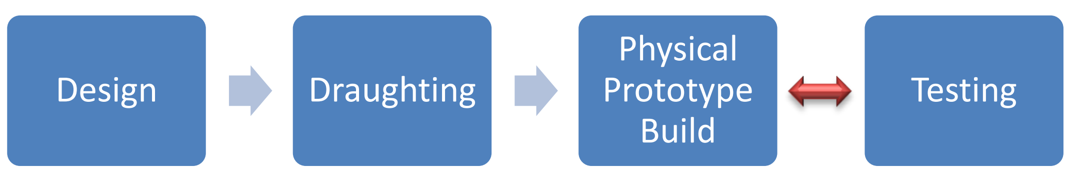
Dynamic Simulation is simply when we investigate how a mechanical assembly behaves in response to some form of change.

Now any modern commercially available computer aided design (CAD) software allows us to translate 2D sketches into 3D models. With these 3D models we can then answer an awful lot of questions that are important for any design, namely:

- *Do all of the parts fit together correctly?*
- *Do any of the parts have interference issues?*
- *How much does the entire assembly weigh?*
- *What does the assembly look like? etc.*

However standard CAD software does <u>not</u> help us understand how a mechanical design will operate in real life when the parts are in motion.

Because of this drawback a lot of companies will jump from a finished CAD assembly into manufacturing drawings and then onto a physical prototype for testing. This can be a slow and expensive way to work if errors are found.



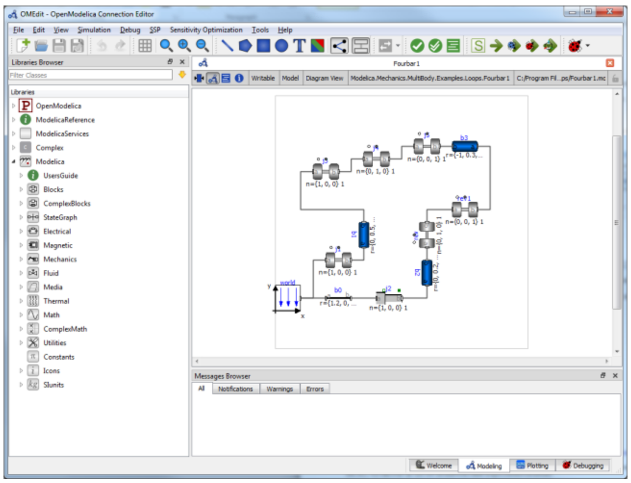
A faster and more economical approach is to perform testing on a virtual CAD assembly. If we find that we don't have the behaviour that we expected then we can easily make changes to the design until we arrive at a virtual prototype that gives us the confidence to start draughting.

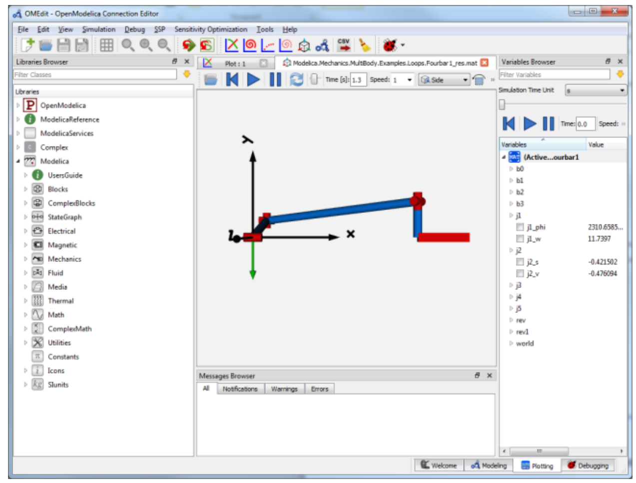
Software

I use Autodesk Inventor Dynamic Simulation[1] as standard but I was initially trained to use Solidworks Motion. As with most Solidworks versus Inventor issues there is only a very small difference between the two and they can be considered to be essentially the same tool.

www.solidworks.com www.autodesk.eu/products/inventor/overview

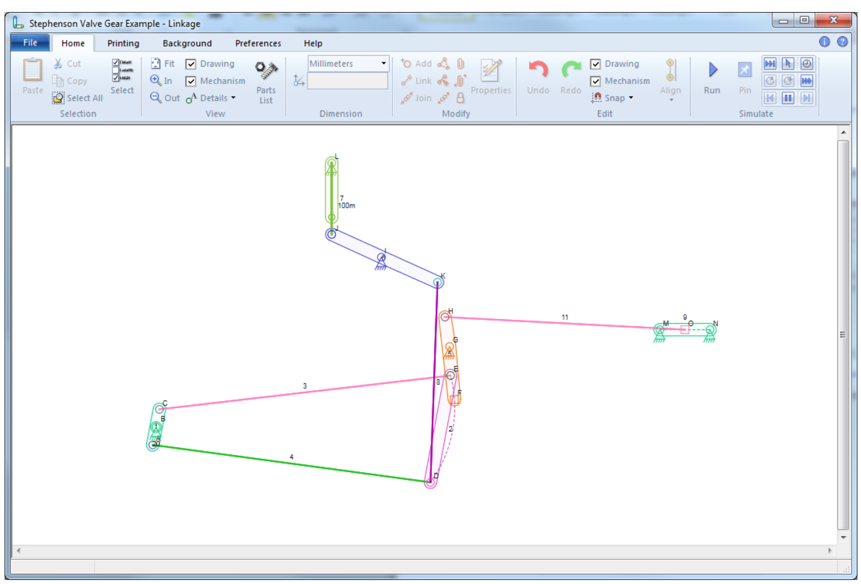
For an additional sanity check when working I will normally also use the dynamic capabilities found within Modelica to ensure that I have arrived at the same result by walking two different paths.





Learn more at: www.openmodelica.org

One other piece of software that I have found to be incredibly useful for this line of work is a small program called "*Linkage*". For quickly drawing up and checking a mechanism this is by far and away the best approach.



Learn more at: www.linkagesimulator.com

1. Please be aware that it is very easy to bring in and use neutral file formats (STEP, IGES, etc.)

Practical Applications

To help you understand how Dynamic Simulation can be used in the real world I have created a number of examples for the five most common types of problems I encounter, namely:

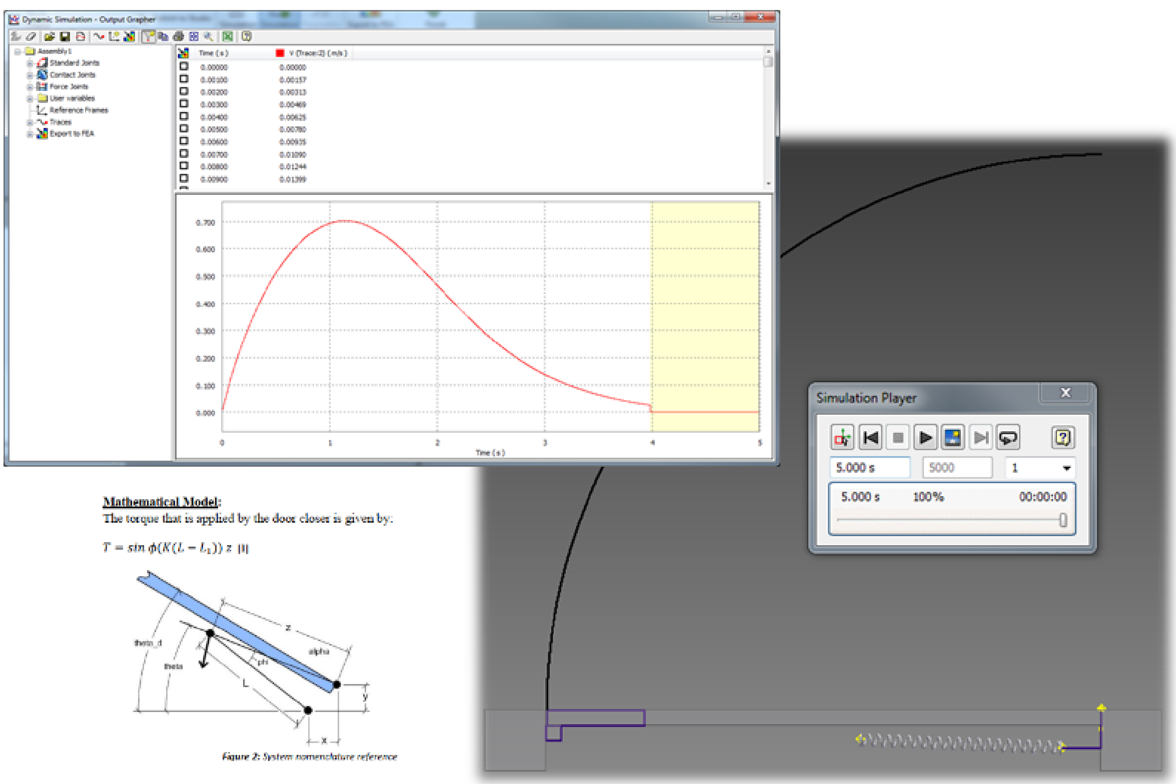
1. *Motion Analysis*
2. *Establishing Cycle Times*
3. *Checking for Collisions*
4. *Checking Hand Calculations*
5. *Establishing Loadings*

1. Motion Analysis

Acceleration, velocity and distance are three key parameters that we are often interested in learning more about.

Example: Door Closer Assembly

The goal is to design an assembly that will allow a heavy door to close without slamming. In order to achieve this aim I set up a trace on the edge of the door to plot the angular velocity. The Dynamic Simulation then allowed me to tune both the spring and rotary damper parameter values until I achieved the closing behaviour that was desired.



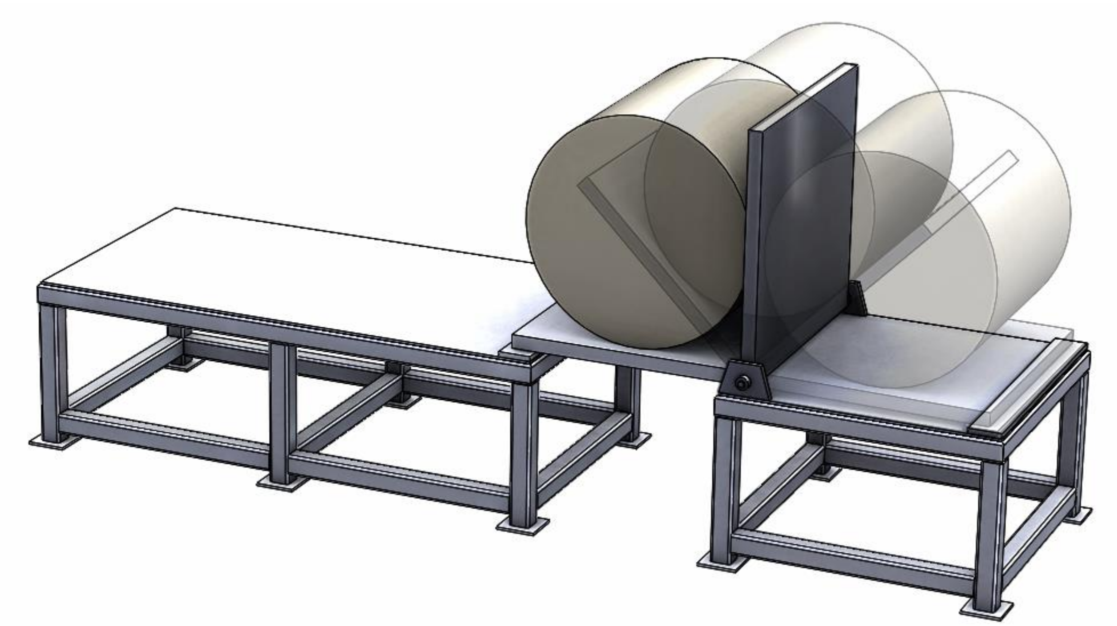
***Conclusion*:**
Dynamic Simulation is a fantastic way to double check hand calculations which gives us the confidence that our understanding of the situation is correct.

2. Establishing Cycle Times

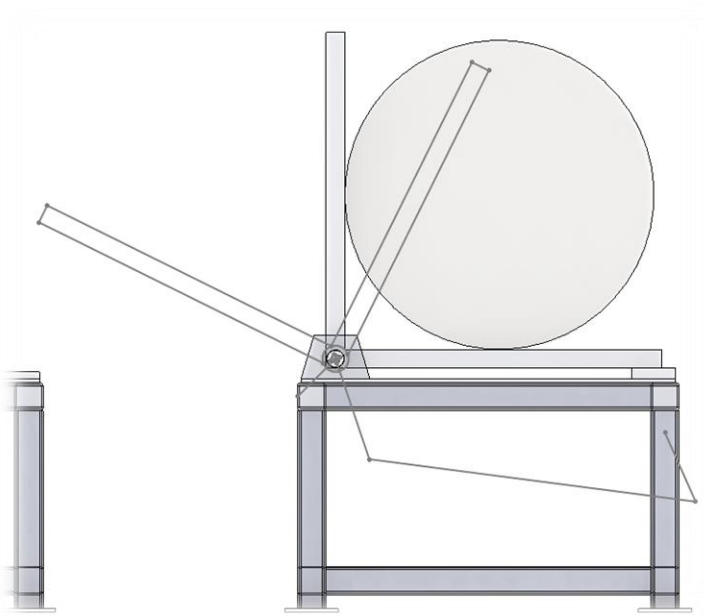
Often it is critical to understand how long it will take to perform a specific task.

Example: Paper Roll Conveyor

For this example our goal is to move a 500kg roll of corrugated paper from the off-loading station towards a paper rolling machine.

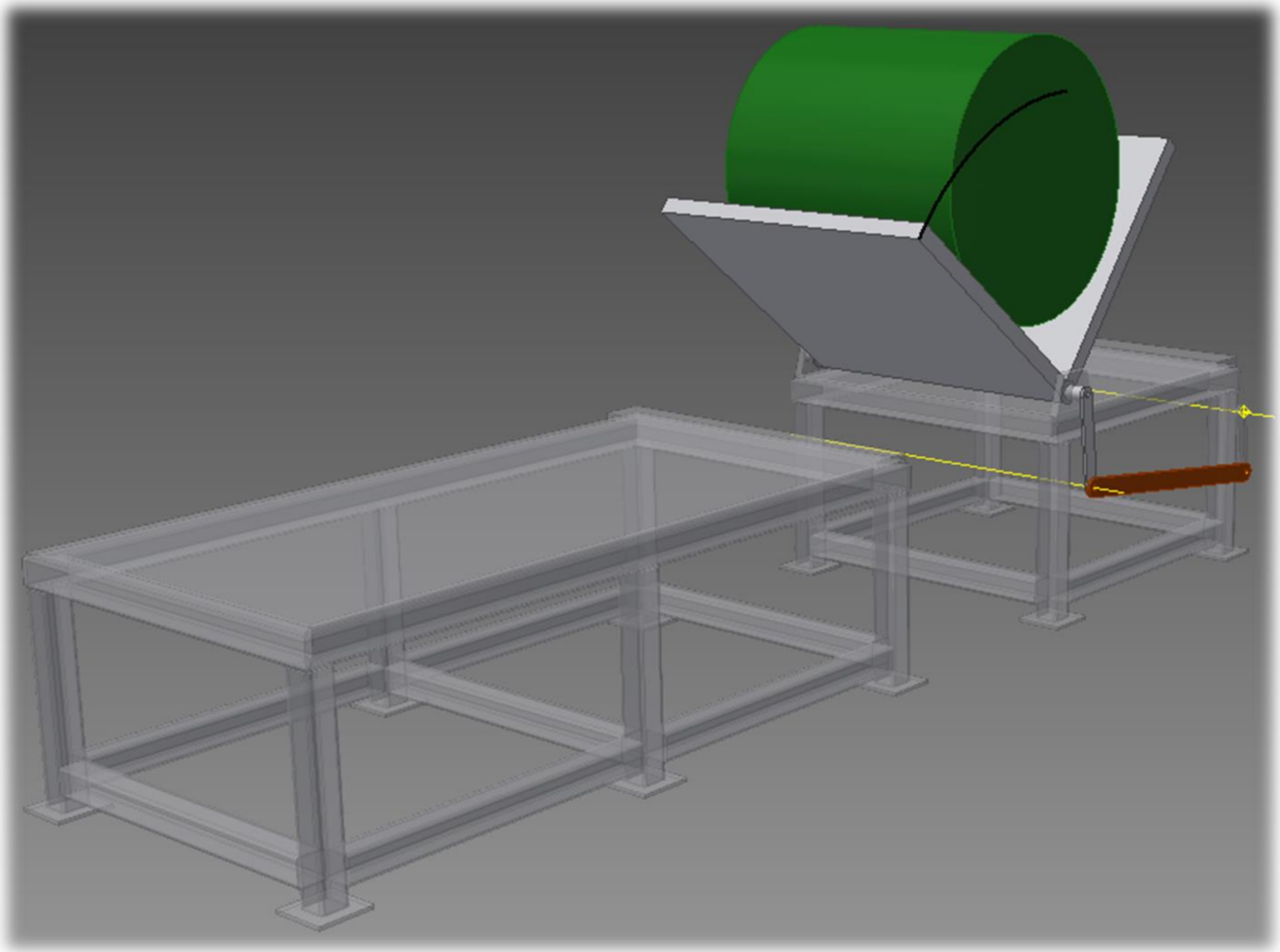


I start with a simplified 3D CAD model of the assembly and then sketch up a linkage that I believe will rotate the paper roll through the defined range of motion that is required.



I then export the Solidworks CAD data into Autodesk Inventor and set up a Dynamic Simulation where I experiment with the speed at which we will drive the linkage.

I find from experimentation that an angular velocity of $15\ \mathrm{deg/s}$ will safely flip the position of the roll in 12.7 seconds.



***Conclusion*:**
Dynamic Simulation can help us answer complicated questions but very often I find that its main use is that it ensures we are provoked into asking additional questions that might not have been considered.

Take the example above, after performing the simulation we see that we need to establish:

- *(a) the reaction forces created by the 500kg roll as it drops down the small step onto the long table*
- *(b) the torque required to drive the linkage*
- *(c) the loading that is imposed on the paper holder*
- *(d) etc.*

All of these questions can be answered by performing further Dynamic Simulation studies.

Remember that hunting problems down and running tests on a virtual mechanical prototype costs an awful lot less than doing it in real life…

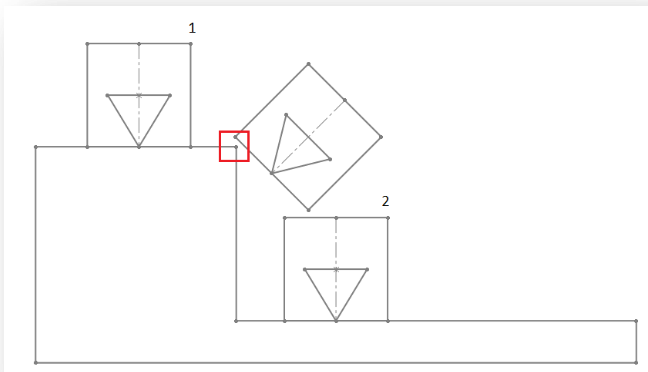
3. Checking for Collisions

A very common mechanical design problem is checking that we won't have any embarrassing collisions when we operate the design in real life.

Example: Rail Monitoring Equipment

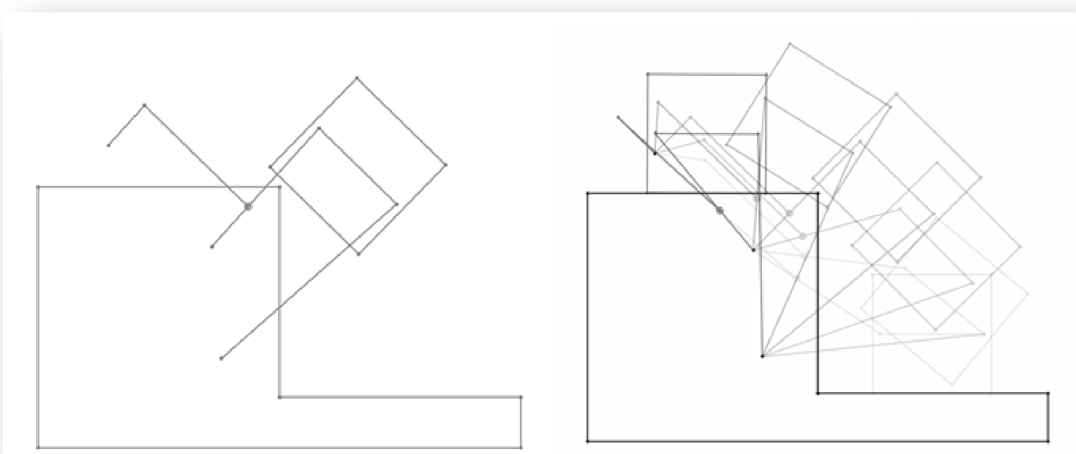
We have a box that contains railway monitoring equipment and we want to be able to move it from its stored position (*ref: 1*) down towards the track where it will then hover above the rails (*ref: 2*).

The previous approach used a series of complicated multi-stage assemblies to move the box backwards and then down.



The idea of using a simple motor driven linkage is proposed but we need to understand how much clearance must be provided in order that the box does not clip the edge of the step.

I start the work by designing a new linkage in Solidworks and then use sketch blocks[2] to allow a quick visual inspection.

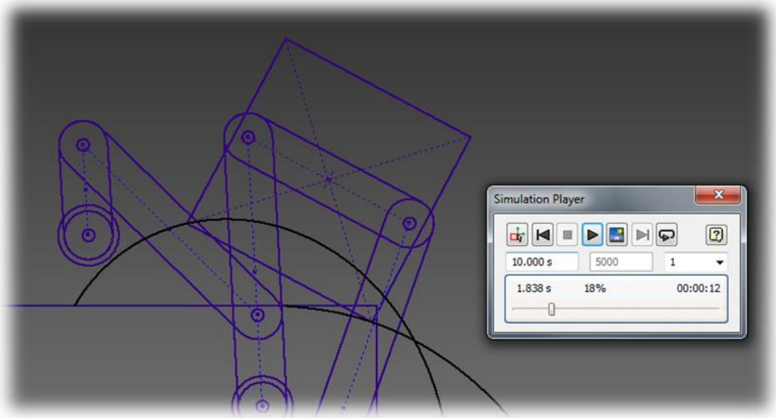


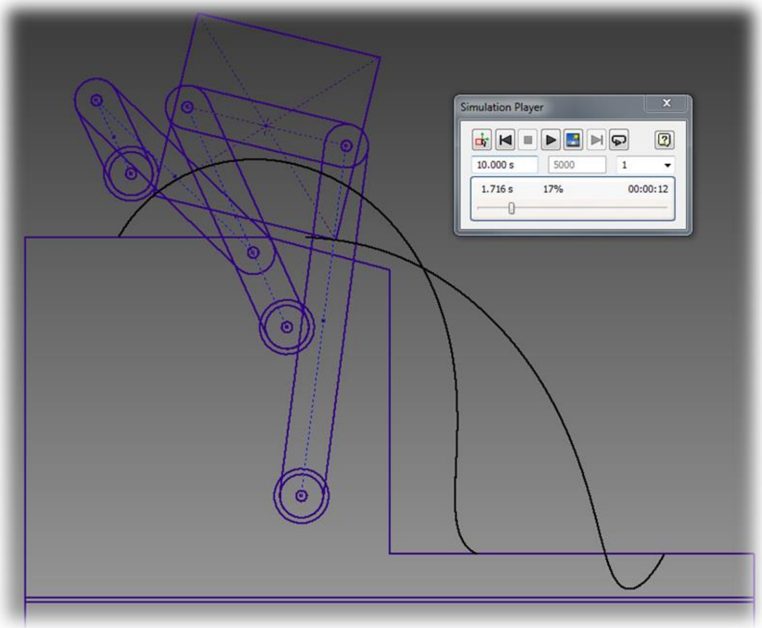
I find that we have the precise motion that is required but it looks like the base of the box will indeed scrape the edge of the step.

2. A sketch block is simply a sketch that has had its dimensions frozen in order that we can then drag it around on the screen

The question then becomes exactly how much clearance do we need to provide? To answer this question I export the Solidworks sketch into Autodesk Inventor and use it to perform a Dynamic Simulation.

By placing a trace on the front and back edge of the box and driving the linkage with a virtual motor we can see by just how much we have a problem.





Adding a very small chamfer[3] to the top edge the step completely fixes the problem and gives us the confidence that we won't have any issues in real life.

3. Note that whilst the chamfer was added by eye in this example for expediency I could easily have exported all of the X and Y coordinates of the two path traces into Excel if the problem had demanded a greater level of accuracy

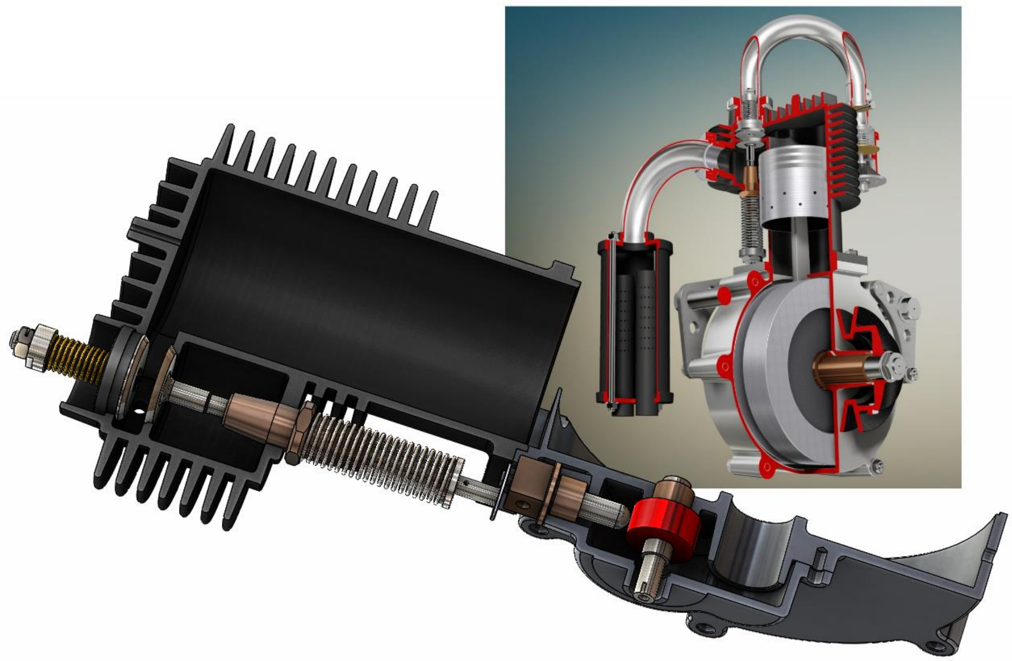
***Conclusion*:**
It can be seen that by creating a virtual mechanical prototype we have a very powerful method for accurately checking clearance issues within complicated assemblies.

4. Sizing Parts

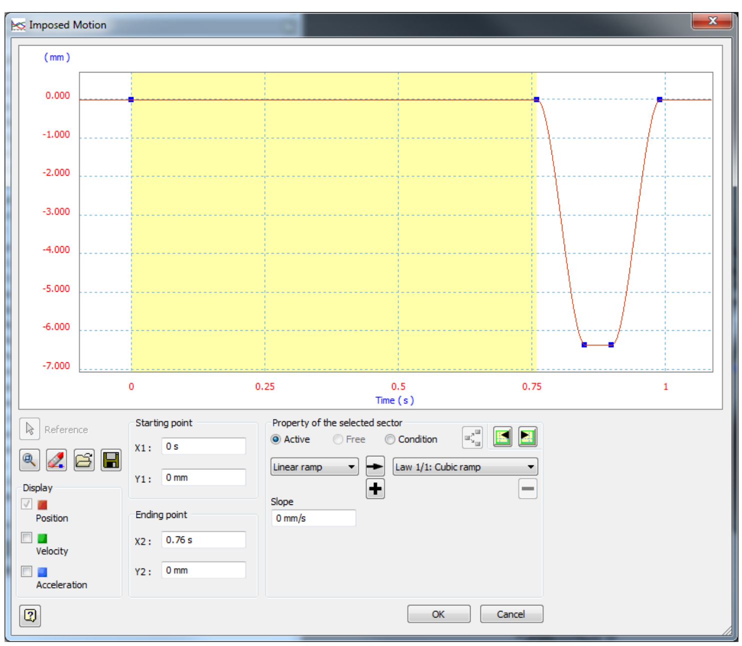
Helping to ensuring that motors, actuators, gears, springs and cams are all designed correctly is where I think that Dynamic Analysis really comes into its own.

Example: Motorcycle Engine

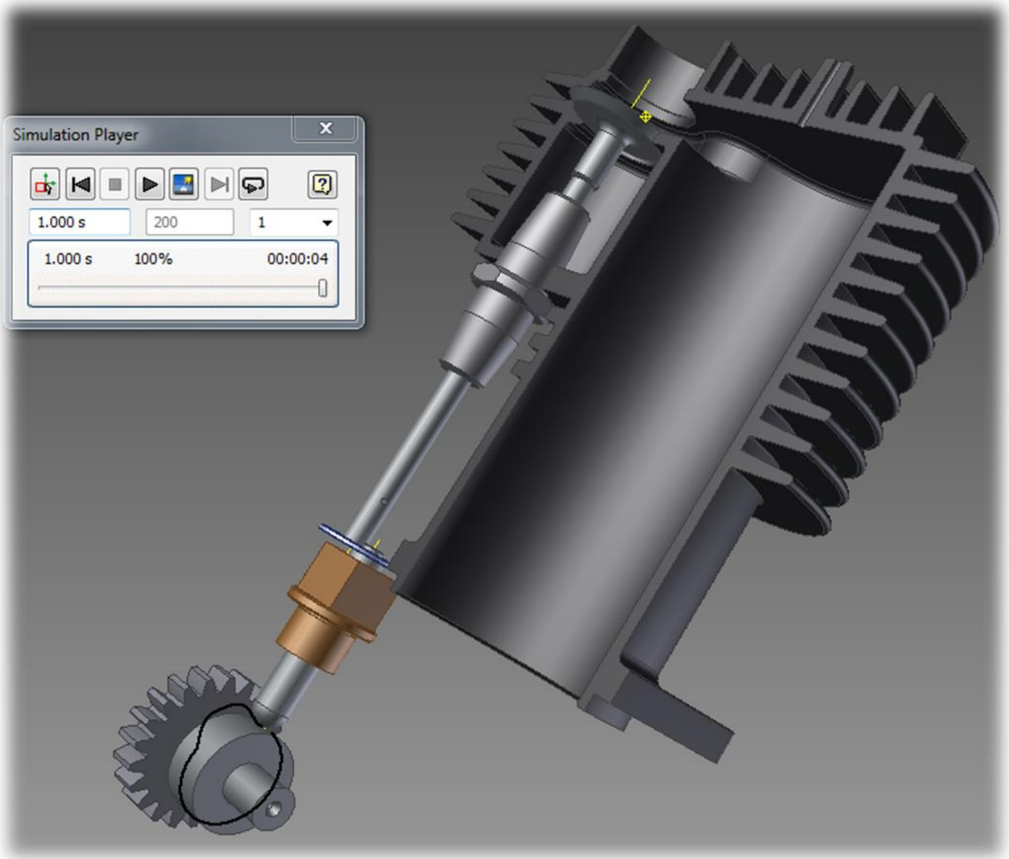
Shown below is a motorcycle engine that has an exhaust valve that needs to be lifted ¼ inch for a short duration on every fourth rotation of the crankshaft by way of a small exhaust cam.



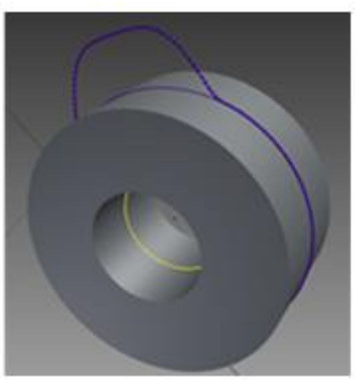
In order to design the exhaust cam I imported the simplified assembly from Solidworks into Autodesk Inventor and then used the input grapher to impose a controlled vertical lift of 6.35mm onto the exhaust valve in accordance with the timing of the crankshaft.

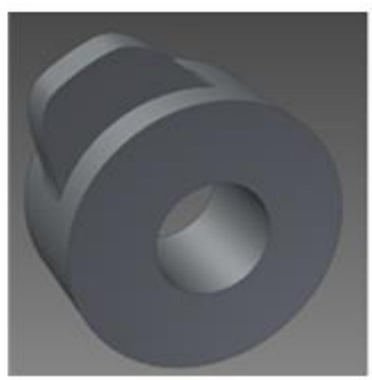


Then by placing a logging trace on the end of the tappet rod and using the tappet gear as a datum I was able to run a simulation and generate a cam profile.



This profile was then exported out as a sketch in order to create a new exhaust cam prototype ready for testing.





Conclusion:

It is not just cam profiles that can be designed and checked using Dynamic Simulation, lots of mechanical components can be evaluated using this approach.

By having the ability to arrive at an answer by a completely different approach is incredibly useful for checking traditional hand calculations.

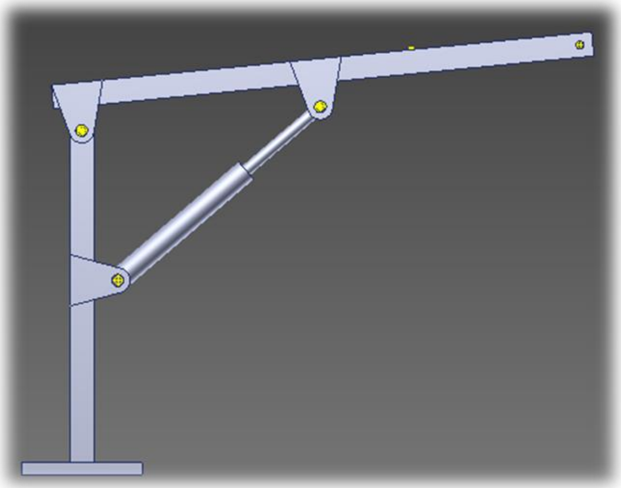
5. Establishing Loadings

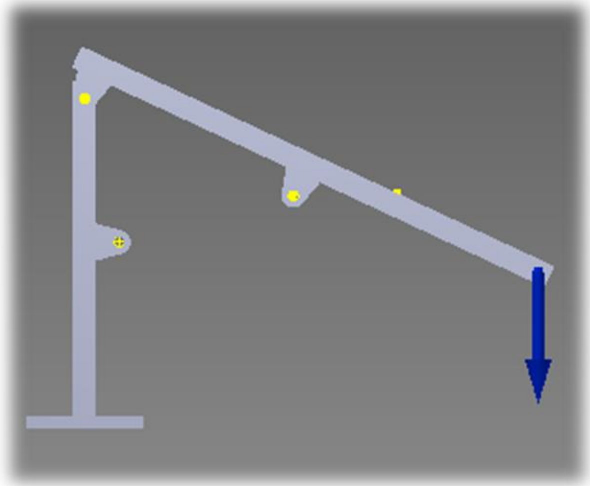
A lot of mechanical design problems involve designing parts that are subjected to loads that change over time. It is very important that we understand how loadings impact upon a part.

<u>Example</u>: Small Hoist

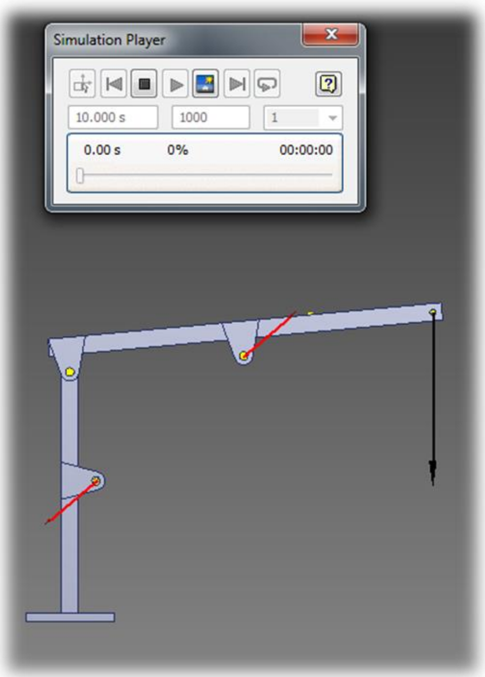
A small hoist needs to be able to lift 100 kg through 65 degrees and we are tasked with ensuring that the design is safe.

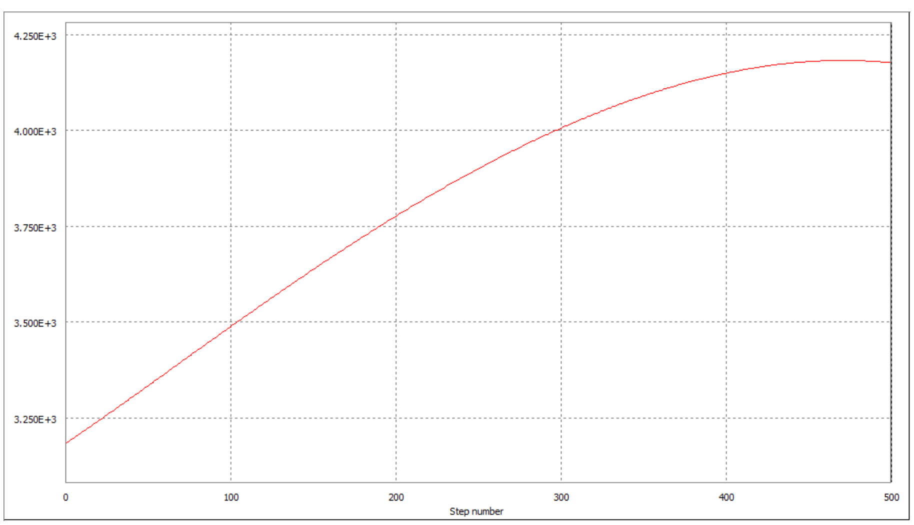
I begin by creating a CAD assembly in Autodesk Inventor and then start the Dynamic Simulation by hiding the hydraulic actuator and applying the 100kg load.





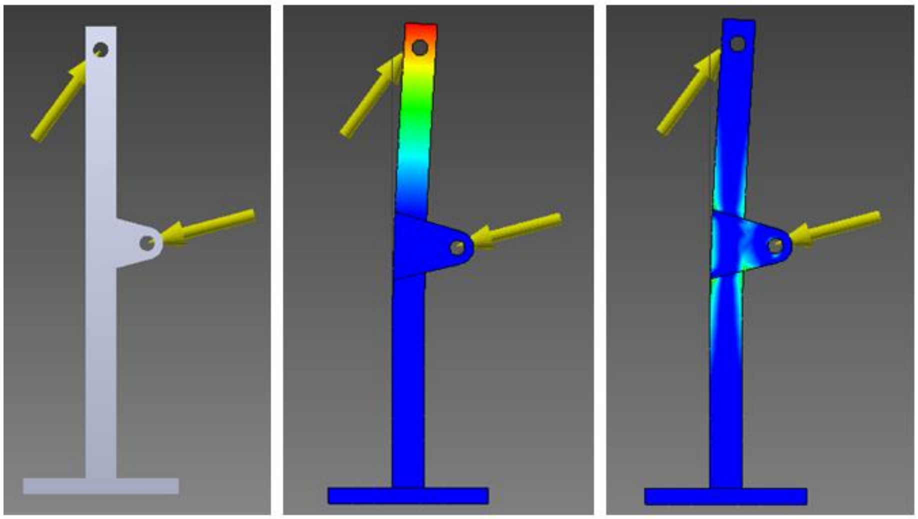
Using the '*unknown force*' tool I can plot the force required to raise the load. This approach allows me to understand which hydraulic actuator needs to be purchased.

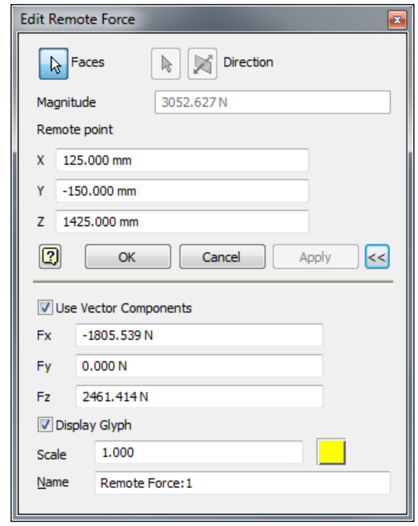


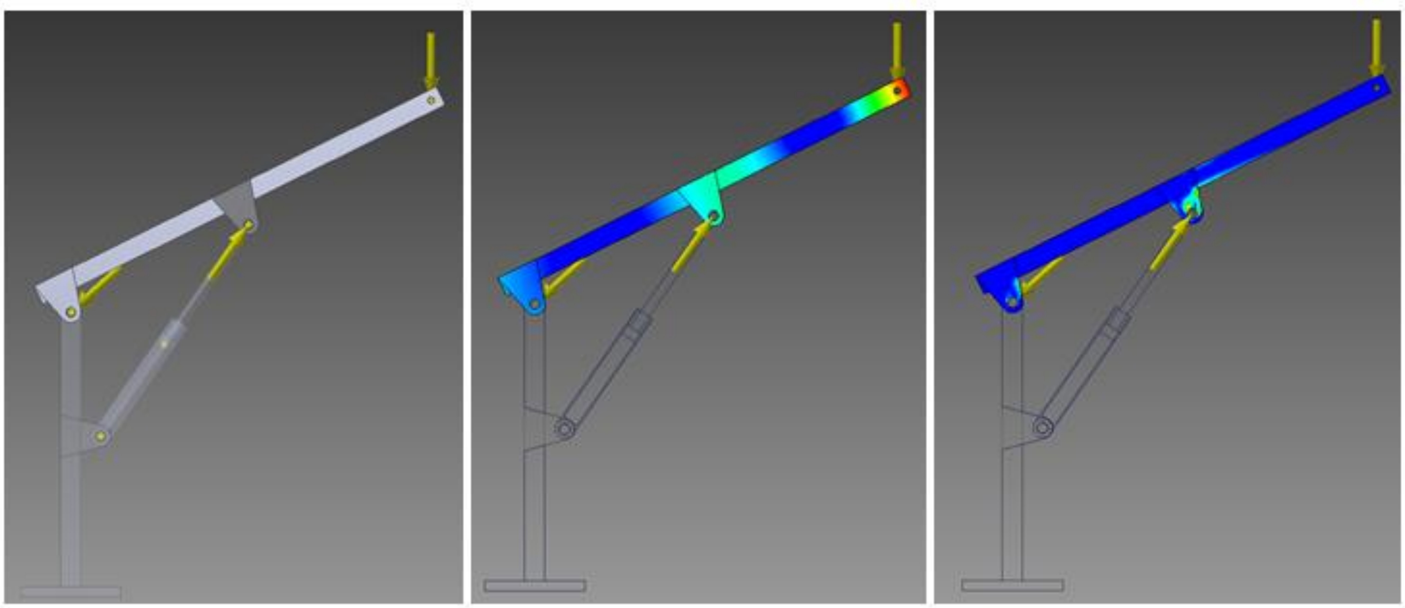


Once I have an understanding of the actuator forces as the hoist is operated I can export out the reaction forces that occur at the joints.

This then allows me to perform a finite element (FEA) analysis study.







Taking this approach with the two welded assemblies I can make a check on both the deflection and stress levels for any particular angle of the hoist that I wish to investigate.

Conclusion:

Dynamic Simulations allow us to accurately establish the loadings that a mechanical assembly will encounter during its operation.

These loadings can then be used to ensure that the parts that we design neither bend excessively nor break.

Thanks for taking the time to read this short paper.
If you have a design problem that you would like to discuss then get in touch today:

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