VeraCAD Technology Chat	
Title:	**Using Mass Distribution with Spine Line**
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Using Mass Distribution with Spine Line

This article explains why the cross-section area is not exact and cannot be verified by any CAD-System, if the mass distribution is calculated with a spine line.

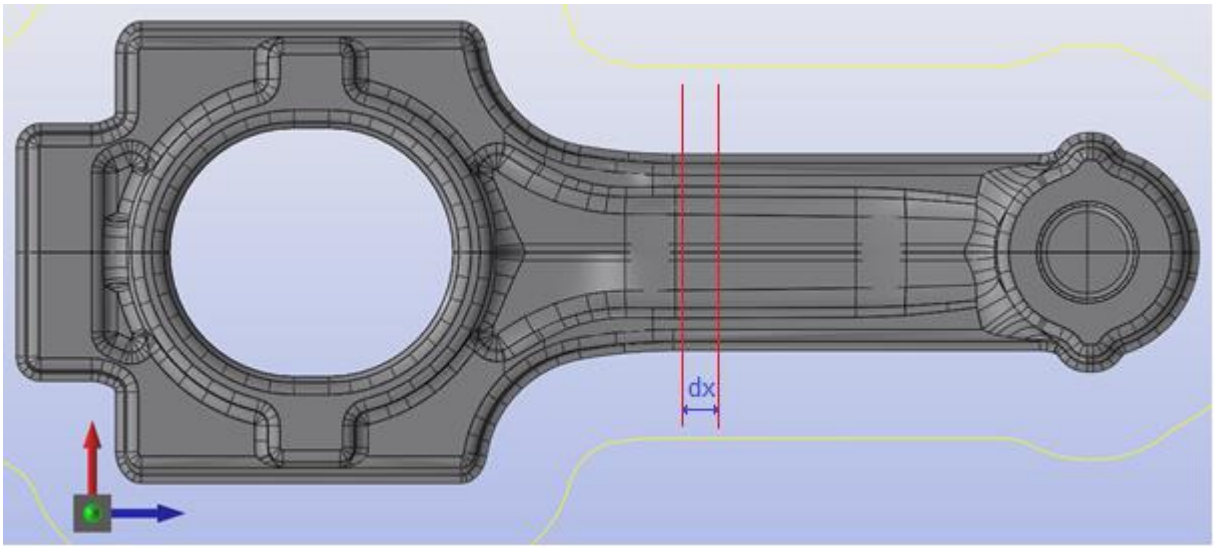
Plane crosscuts perpendicular to a main direction

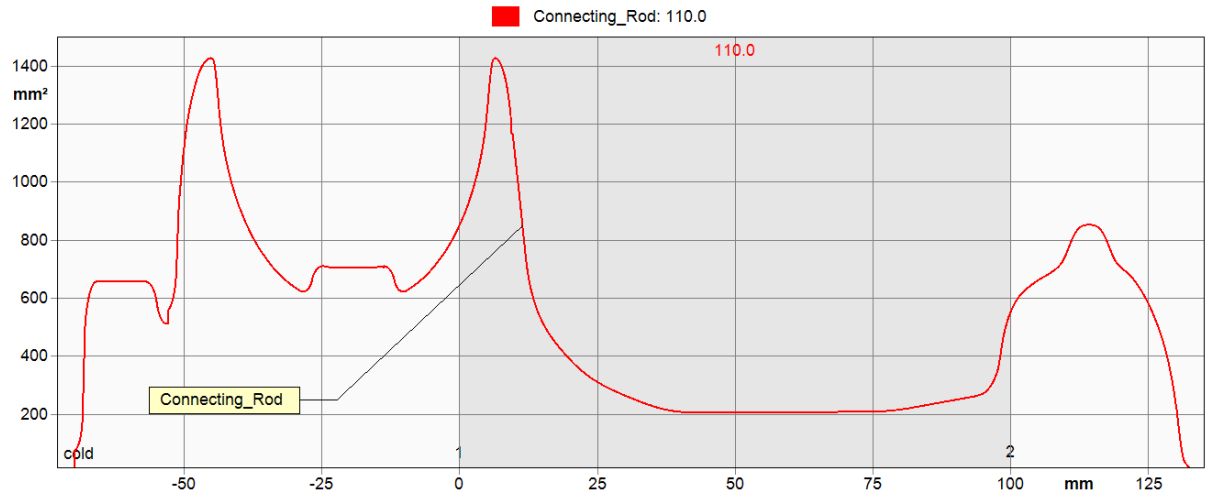
Normally a mass distribution diagram is calculated by calculation plenty of crosscuts perpendicular to a main direction. If main direction is X-Axis, the cross-cuts will be in YZ-plane. VeraCAD uses 2048 crosscuts. This number is a fixed value in the software.
The cross-section area is calculated precise and can be verified by a CAD-system. The volume between 2 crosscuts can be easily calculated by the truncated cone formula.

$$dV = \frac{1}{3}(A_1 + \sqrt{A_1 * A_2} + A_2)\, dx$$

Here dV is the volume between the 2 cross-sections and dx is the distance between the 2 parallel planes. It is very important to remark, that the 2 planes are parallel and the distance is constant. Therefore the Integral over all cross-section areas will give us the correct total volume. For total volume we can do the following calculation.

$$V_{tot} = \int A_x\, dx$$

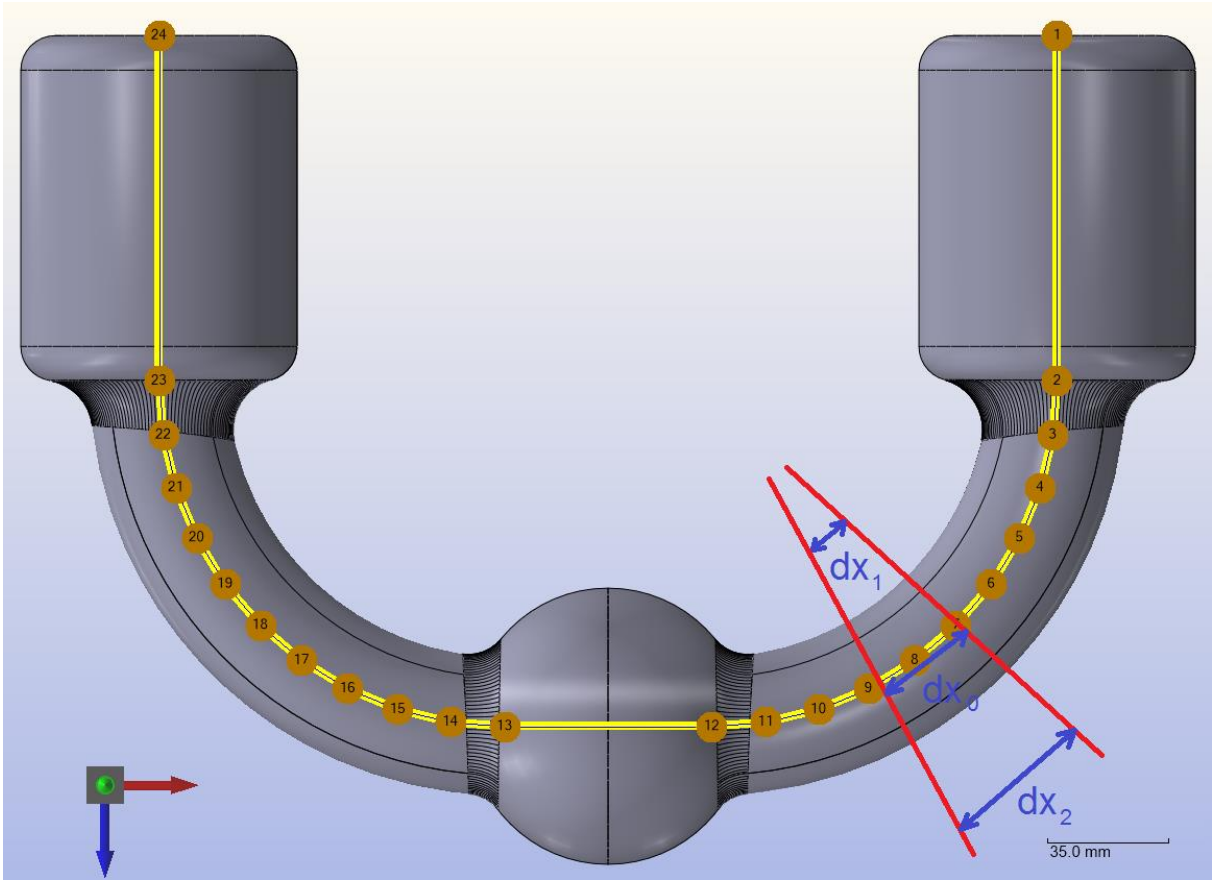




Mass distribution of connecting rod with 2048 crosscuts perpendicular to X-Axis

Mass distribution using a spine line

If the part is bended, a centerline or spine-line is used.



Taking into account the spine line, cross-sections cannot be cut perpendicular to the spine line. On one hand the cutting plane would intersect the forging piece more than once in some cases, on the other hand the cutting planes are no more parallel. A cross-section and volume calculation with the above formulas is not possible.

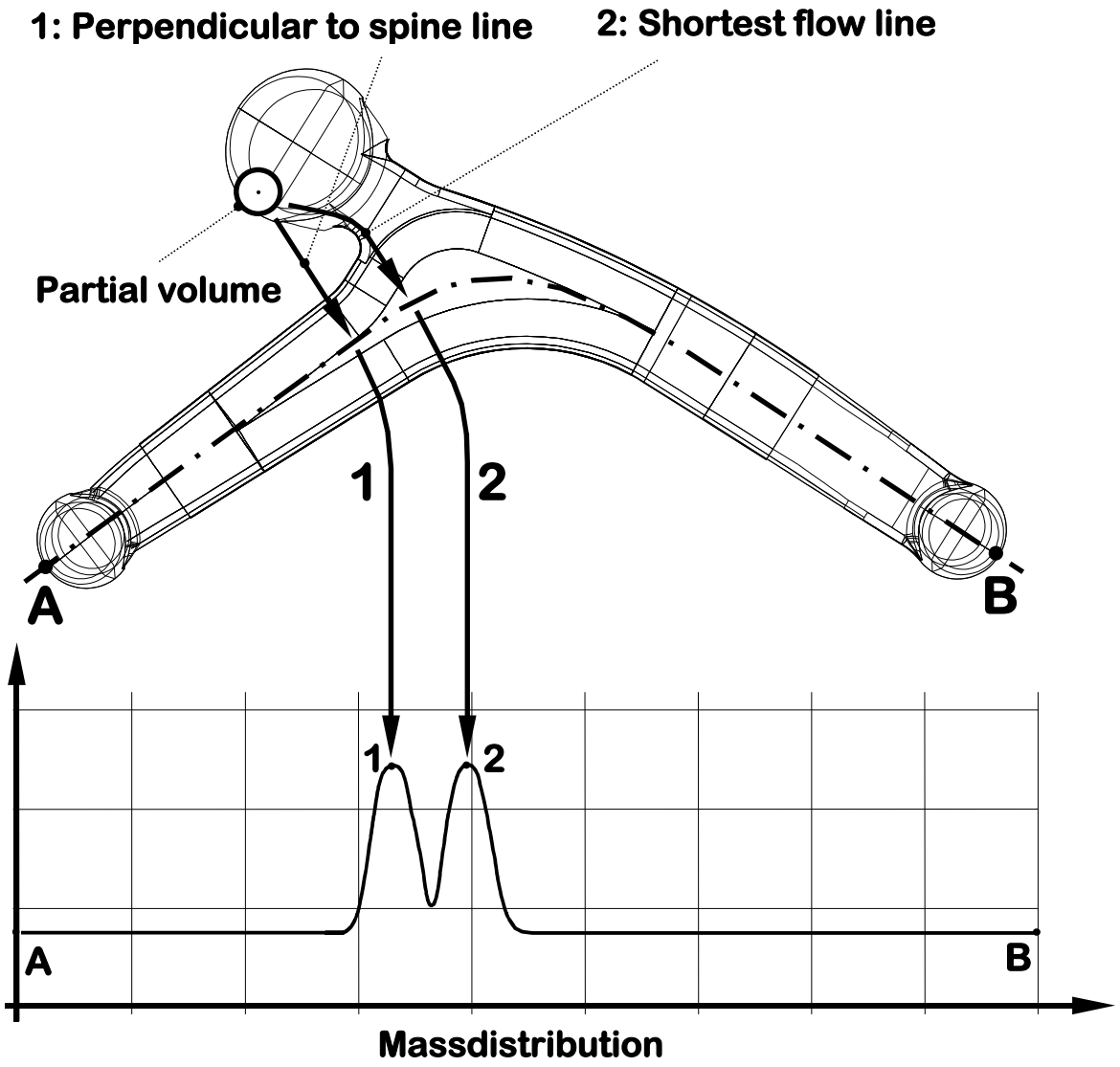
When using a spine line, this line later is unwound and builds the X-axis. The length of the X-axis in mass distribution is the length of the spine line. We expect that the total volume is still exact and can be calculated by simple integration of the mass distribution diagram.
We could measure dx directly on the spine line. Here dx = dx_0.
But if we place the spine-line a little bit to the left or right, another dx would be the consequence (dx_1 or dx_2, see picture above). Because of the total volume is unchanged we can request:

$$V_{tot} = \int A_{x0}\, dx_0 = \int A_{x1}\, dx_1 = \int A_{x2}\, dx_2$$

This can only work, if the cross-section area A_{x0} is not equal A_{x1} and not equal A_{x2}.
It gives us the reason, why the cross-section area in VeraCAD's mass distribution is not the same like a cross-section area measured with a CAD-System. But the cross-section area is very close to that, measured by a CAD-System. In addition it could be equal to that from CAD, if we move the spine-line into correct position (a little bit to the left or right), but nobody will do so.

Which value is correct, if it is not the cross-section area?
We have found an explanation, why the cross-section area cannot be the same like in a perpendicular crosscut. But the volume between the 2 non parallel cross-sections is the same volume, like the Integral in VeraCAD's mass distribution diagram between the two X-values made on the spine-line by the intersection of the 2 non parallel planes.
In other works, VeraCAD does not produce a mass distribution diagram that shows the true cross-section area at a given x-position on spine line, but it shows the true volume between 2 positions x_1, x_2 on the spine-line.
This behavior becomes more clear it we understand how VeraCAD creates the mass distribution in case of using a spine-line, see next section.

How can VeraCAD do the exact volume calculation with the spine-line?
For exact calculation of the mass distribution, VeraCAD breaks the geometry into more than 4.2 million small cubes and calculates the volume for each cube. The projection of these partial volumes onto the spine line is "perpendicular" or uses the option "shortest flow line. The spine line is unwound on the X-axis, while the summed sub-volumes form the Y-axis of the mass distribution (s. picture below).



Comparison of the strategy "Perpendicular to the spine- line" and "Shortest flow line"
