A Tale of Two Geometries

A Comparison of model geometries for magnetics modeling

A DYNE ANALYTICS Research And Development Team Report

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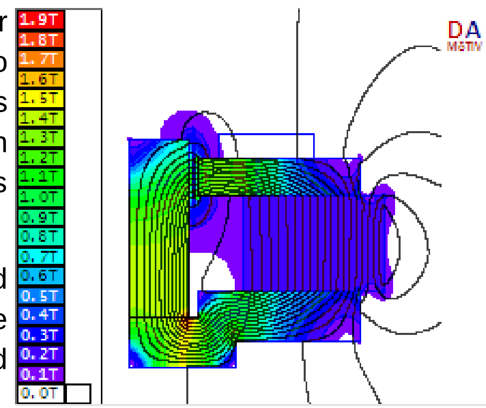
Key Takeaways:

- MōTIV is highly Accurate, as compared to ANSYS' Maxwell
- MōTIV is considerably faster and easier to define geometry and analysis configuration
- MōTIV's block geometry is as accurate as most "complex" geometry requirements

ABSTRACT

MōTIV is a purpose-built loudspeaker magnetics modeler, designed for rapid design and simulation. It allows quick entry of geometries thanks to a simplified but complete set of components and dimension. While this geometry appears overly-simplified at first blush, an in-depth comparison of this geometry with a highly contoured and optimized design shows little absolute difference, and no appreciable real-world difference.

Additionally, a comparison of the results of MōTIV and an advanced modeling tool such as ANSYS' Maxwell yields no appreciable difference in results between these two tools for evaluation of magnetic field simulation.



Flux profile of base geometry, image captured from MōTIV

Reason For This Report

Modern FEA tools allow modeling of a wide variety of shapes and geometries; many believe that an FEA simulation of anything but a highly-optimized, geometrically complex model will not result in an accurate set of results. As such, the approach used by MōTIV, where a highly simplified geometry is used, could be suspect in terms of accuracy about the magnetic flux within the motor.

This report is designed to address this potential concern. To this end we will make two comparisons between MōTIV's simplified geometry and some highly contoured/optimized versions.

The first comparison will be our standard ring motor design, and a typical "finalized" version with radii, chamfers, and fillets as would be typically added.

The second comparison will be a highly optimized cup motor design, with angled parts, lots of smoothing and radii and chamfers. We will approximate this design with MōTIVas closely as possible.

We will show the resulting BL curves and plot the difference in BL over stroke for these two comparisons, to show MōTIV's approach of highly simplified geometry has accurate and acceptable results..

Inside this report:

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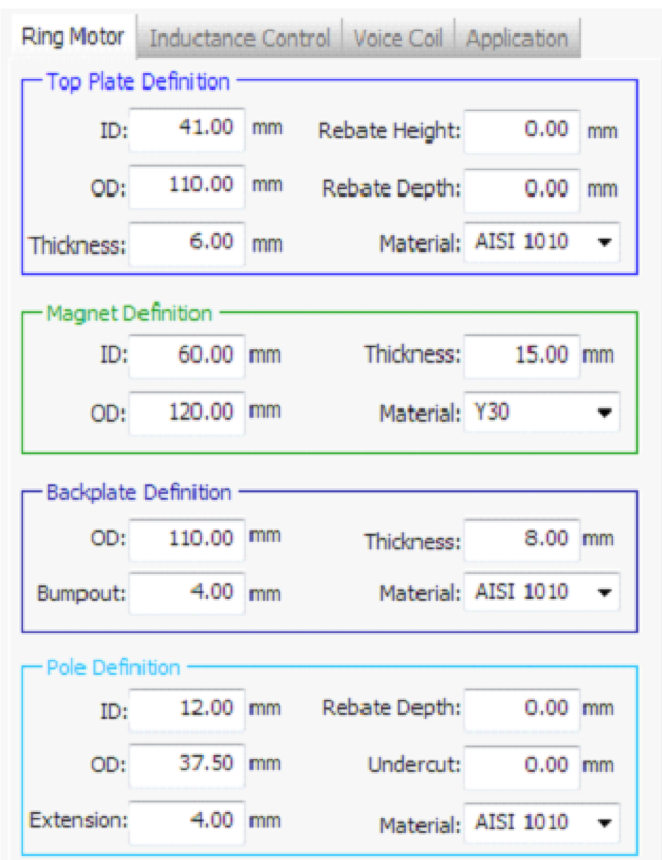
MōTIV Approach

MōTIV was designed to provide a rapid yet accurate means of development and design of voice-coil based loudspeaker motors. DYNE specifically chose to avoid the first-look-obvious approach of importing a standard/portable uses a simplified but complete model geometry to speed entry of motor parameters as well as speed finite element analysis.

The reasoning behind eschewing the import of CAD drawings was three-fold:

1. Editing in CAD requires multiple switches between programs and repeated saving of models in both applications
2. Specification of components/materials would require constant redefinition within MōTIV
3. Import of DXF or IGES files is not guaranteed to be accurate and consistent from modeling package to modeling package

Thus DYNE decided to create a simplified motor geometry model for both ring style (magnet outside the voice coil ID) and cup style (magnet inside the voice coil ID) designs. This approach allows for rapid definition of diameters via direct entry of dimensions. Additionally, since the geometry is completely defined within MōTIV, definition of materials and regions is easily automated.



MoTIV Motor Definition Form

MōTIV Geometry Entry

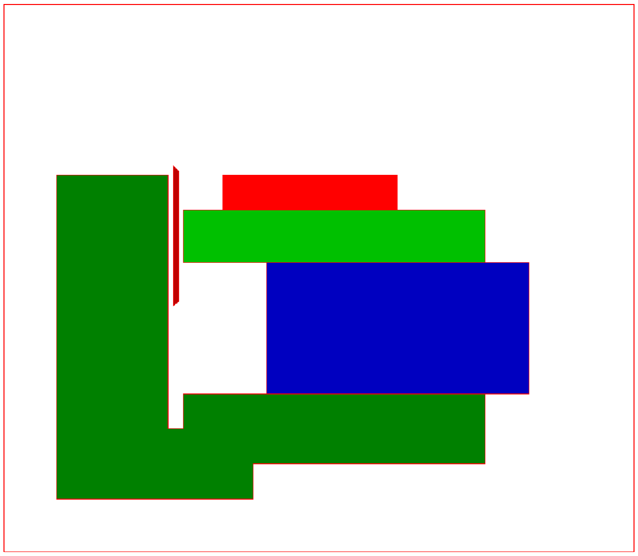
As is seen in the image to the left, MoTIV uses a highly simplified method of specifying the dimensions of a ring style loudspeaker motor. For this paper, we chose to simulate the default ring motor geometry; however, there is no reason to suspect that other geometries would have a significantly different result than what we achieved with this design.

The base design is a very standard overhung ring motor as would commonly be used on mid-sized woofers and midbasses. It utilizes normal Y30 grade ferrite magnet, AISI 1010 grade steel (approximately 0.1% carbon content), a 6mm thick top plate, 8mm thick back plate which is bumped out by 4mm for voice coil clearance, and a vented pole piece with small extension.

Not shown here is the definition of the voice coil; however, the voice coil is only required for post-processing when the simulated B field is used to build the BL curve. As such, we will define the voice coil for each design to be consistent in dimensions, material, and geometry such as number of turns.

MōTIV Ring Motor Geometry

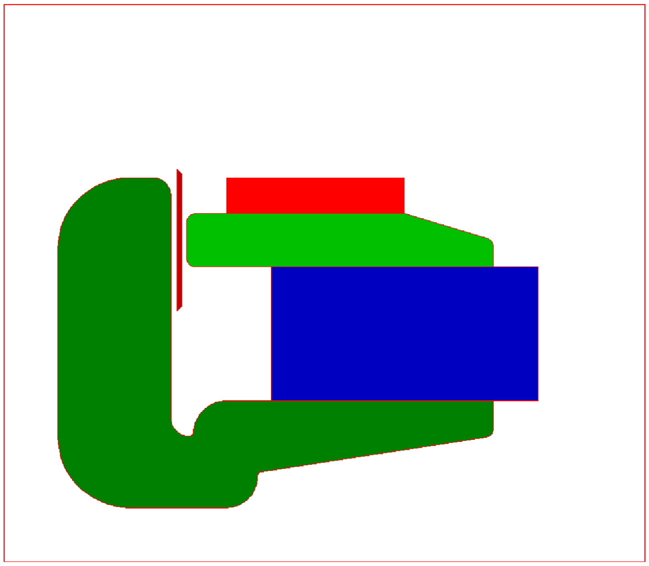
As is seen in the image to the right, MōTIV uses a highly simplified method of specifying the dimensions of a loudspeaker motor. For this paper, we chose to simulate the default ring motor geometry; however, there is no reason to suspect that other geometries would have a significantly different result than what we achieved with this design.



The base design is a very standard overhung ring motor as would commonly be used on mid-sized woofers and midbasses. It utilizes normal Y30 grade ferrite magnet, AISI 1010 grade steel (approximately 0.1% carbon content), a 6mm thick top plate, 8mm thick back plate which is bumped out by 4mm for voice coil clearance, and a vented pole piece with small extension. A DXF drawing file is available for download if you wish to conduct your own comparisons and simulations with alternative tools.

Maxwell Ring Motor Geometries

We performed two Maxwell simulations: one with the simplified geometry above (as used in MōTIV), and one with the highly optimized geometry shown below. This was done to not only show the minimal differences in magnetic flux between the two models, but also highlight the accuracy of MōTIV as compared to Maxwell.



As is seen in the image to the left, the base dimensions are maintained; the ID and OD of each component is maintained, as is the thickness, extensions, bumpouts, etc. The specific changes we applied for the Maxwell model are as follows:

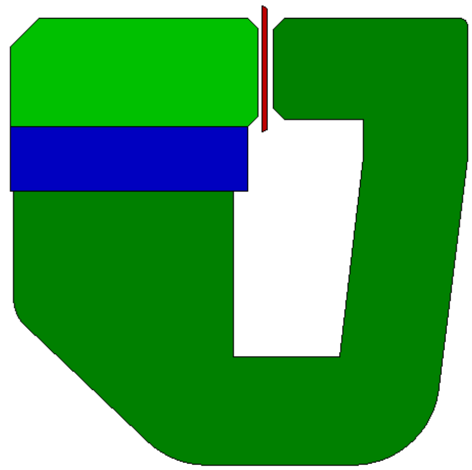
- The pole vent uses an 8mm radius
- A 2.5mm fillet is used between the pole and back plate
- The face of the top plate has 1mm radii
- The outside, top edge of the pole has a 1mm radius
- The bumpout has 3mm radii on all edges
- The backplate is chamfered to a 4mm outside height
- The top plate is chamfered to a 3mm outside height.

This model is what one would expect to see after a motor is "put on a diet" to remove excess steel, as well as adding smoothing for airflow and turbulence issues. Visually the differences are quite obvious and rather extreme and should accentuate any errors in simulation due to the simplified geometry.

MAXWELL CUP MOTOR GEOMETRY

The motor used for our cup motor geometry comparison is a highly optimized, 4” voice coil design used for high power, high output professional audio use. This motor is currently in production for a premier manufacturer, and represents their state of the art design on their top end products.

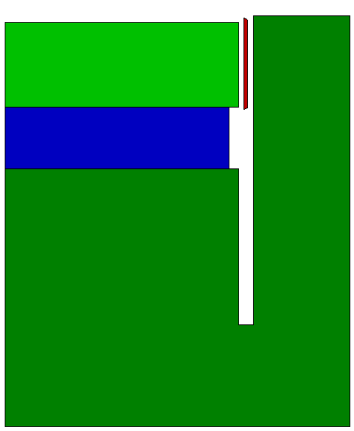
The design features a large disc of neo (blue), and some highly optimized steel to provide smooth pole vent airflow. It was optimized to yield as low loss as possible, but still allow for a compact and lightweight design. Direct entry of this geometry is not possible within MōTIV, so this represents a real-world challenge to try to create an equivalent MōTIV design and show the results are equivalent.



MōTIV CUP MOTOR GEOMETRY

For geometry entry for B and BL modeling, it is critical to get the size of the magnet the same, the gap height and width as close as possible, and the total flux path length the same. So for the simplified MōTIV design we did just that: same magnet, same gap width, an effectively-same-height (compensate for the bevels) gap, and set the flux path length through the cup to be the same. The resulting geometry within MōTIV is seen below; it is quite different from the original geometry!

The two magnets are set to the same ID, OD, and thickness, as well as the same material. This sets the potential flux in the motor to be the same.



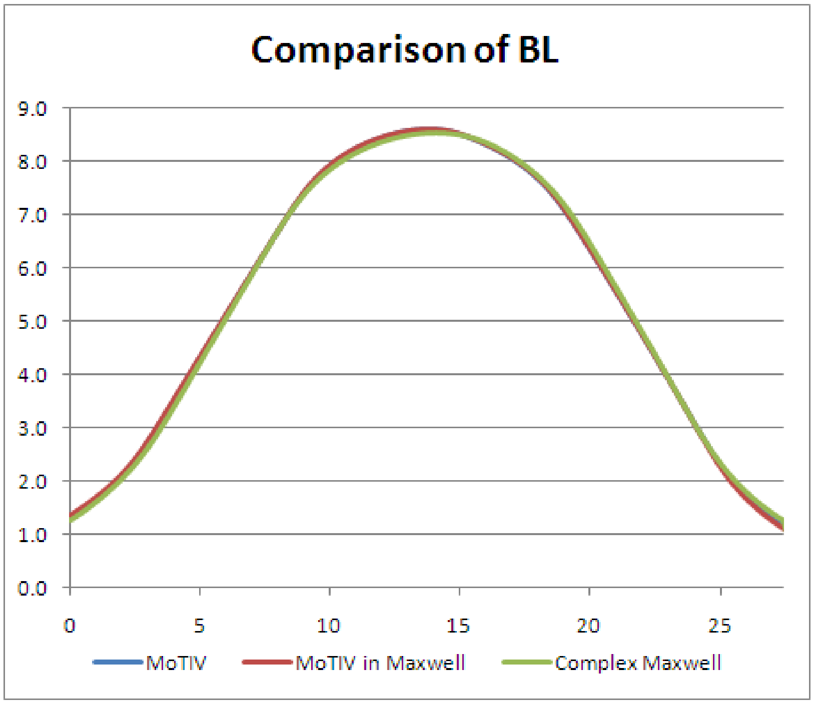
The cap is flush against the ID of the magnet, and extends over the front of the magnet as required in the original geometry. The height of the cap is set to be one bevel height “short” of the original design, so as to compensate for the top and bottom bevels of the original design.

The cup depth (what we call the riser) was set to specifically allow the same rearward excursion. This also forces the flux path length to be equivalent.

The result is extremely simple and direct; the only “trick” used was the compensation of the bevel, and that was a straight geometric compensation of two 45 degree chamfers. No other differences in dimensions or other changes were used.

RESULTS: RING MOTOR

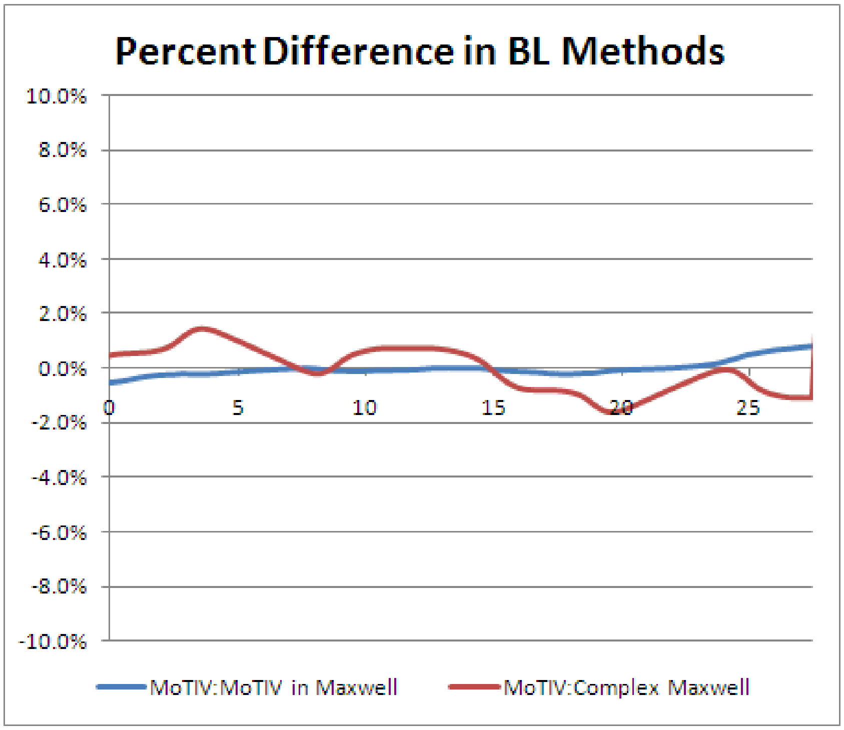
After we ran the FEA engines, we calculated the BL for each result set; this was done with the same voice coil dimensions for each curve.



We calculated three BL curves: MōTIV, the MōTIV block geometry in Maxwell, and the complex Maxwell geometry. The BL curves were then overlaid on each other and provided in the graph to the left. There are actually 3 traces there; the straight MōTIV curve is completely hidden by the other two curves.

As can be seen, there is no appreciable difference in the BL curve for the three different simulations; not only does this showcase the accuracy of the MōTIV FEA engine as compared to a highly-respected application like Maxwell, but it also shows that the MōTIV approach of a greatly simplified geometry is a perfectly valid and accurate approach to generation of the model itself.

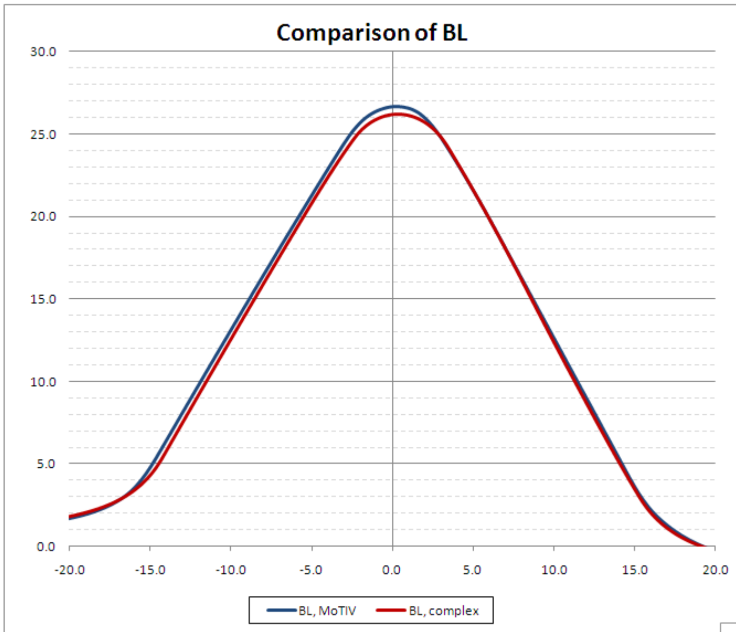
To further show the differences between the approaches, we plotted the percent difference between the three results: between the simplified geometry in MōTIV and as run within Maxwell, and then between the MōTIV results and the complex geometry as used within Maxwell. The results are shown to the right, in percent versus position.



As shown, there is very little difference between the methods of simulation. The differences are less than 0.5% on average between MōTIV and Maxwell when using the same simplified geometry, and less than 0.8% between MōTIV using its simplified geometry and Maxwell using the highly optimized geometry.

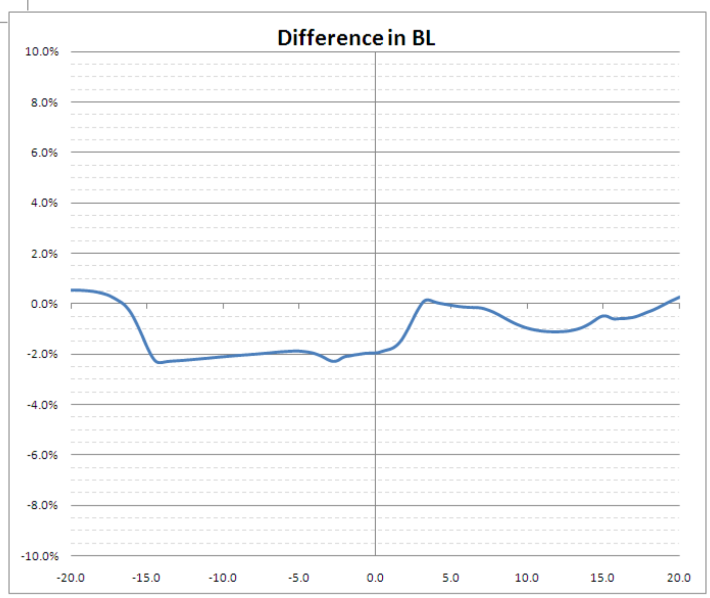
Our simplified geometry works, and works VERY well for ring style motors.

RESULTS: CUP MOTOR



As with the ring motor, we calculated (with the same voice coil) and plotted the BL curve for the two designs: the complex original design and the simplified MōTIV geometry. The results are shown to the left.

The results are quite remarkable; with such a radical difference in fundamental geometry MōTIV is capable of accurately predicting the resulting BL curve of the motor. There is very little difference over the entire usable stroke of the motor. And the definition and creation of the MōTIV motor is quite faster, easier to change (no need to redefine chamfers or radii based upon some other change), and as we see—just as accurate.



And as we did for the ring motor comparison, we also see the percent difference in BL between the two cup motor geometries in the graph to the right. The difference in BL for each point—referenced to the peak MōTIV BL—is graphed over the full stroke.

As shown, there is very little difference between the methods of simulation. The differences are less than 1% on average between MōTIV and it's simplified geometry and Maxwell using the highly optimized geometry. Additionally, the peak difference is just 2%, well within most production tolerances in terms of overall accuracy. As we saw with ring motors, our simplified geometry works for cup motors

CONCLUSIONS

As we have shown, the actual geometry details that are often of concern can be safely ignored for most FEA simulation purposes. Features such as chamfers, radiusing, fillets, and other small-scale details do not have a significant or appreciable effect on the BL curve as simulated. Thus the use of a highly simplified and easy-to-modify model is a suitable approach. Differences will be typically less than 1% over range of motion, and worst-case spot differences will be less than 2%, which is typically below manufacturing tolerances and consistency of materials.

The approach chosen by DYNE Analytics, to create as very rapid means of entering and modifying motor geometries, is a fundamentally sound and accurate approach.