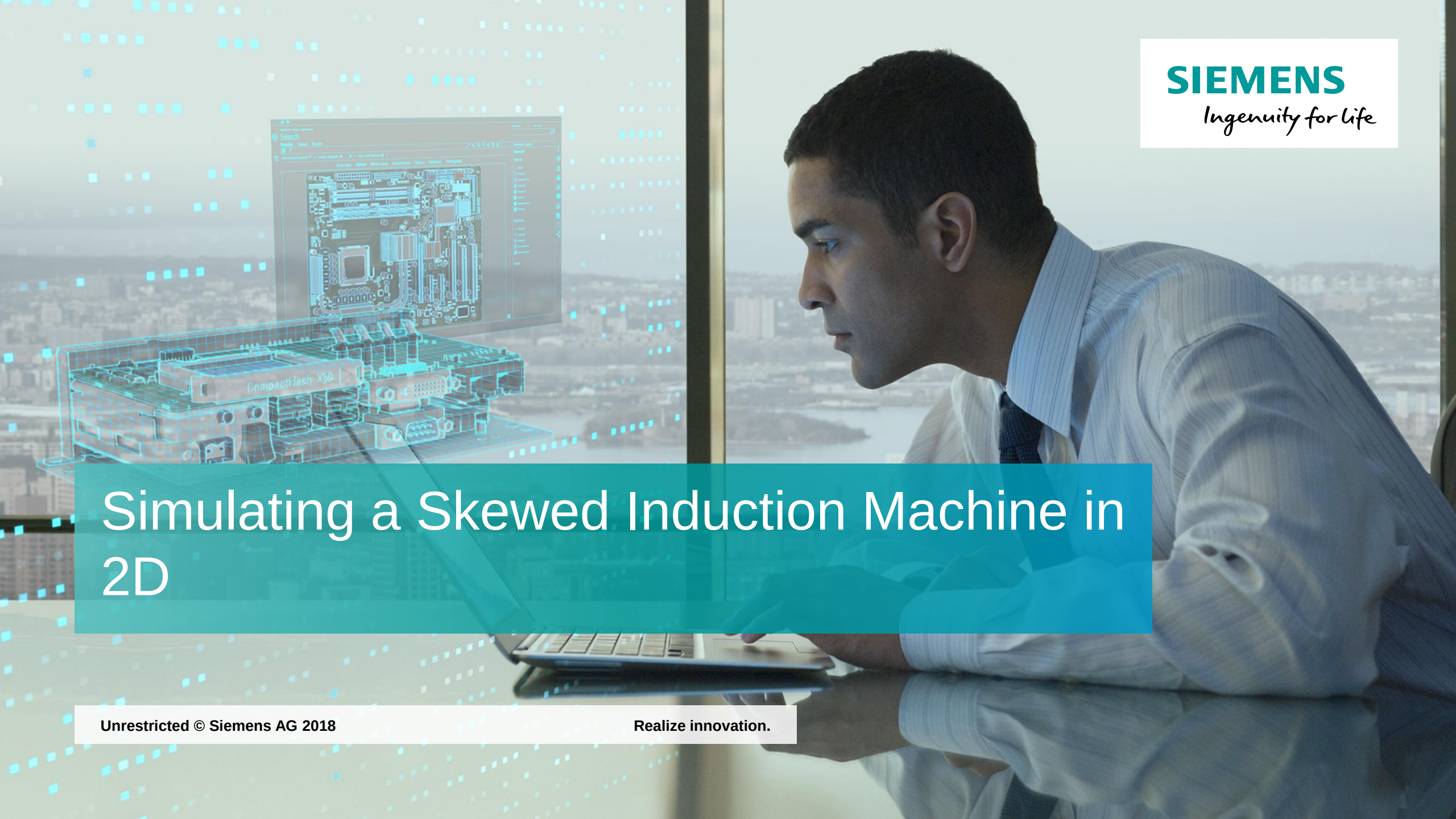

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Simulating a Skewed Induction Machine in 2D

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Simulating a Skewed Induction Machine in 2D

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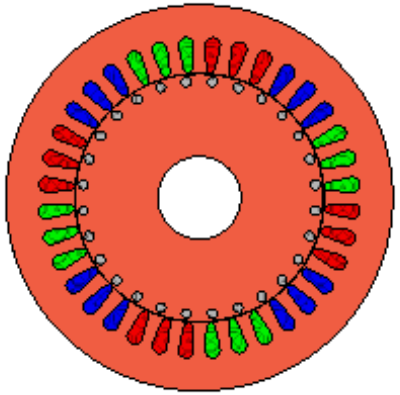
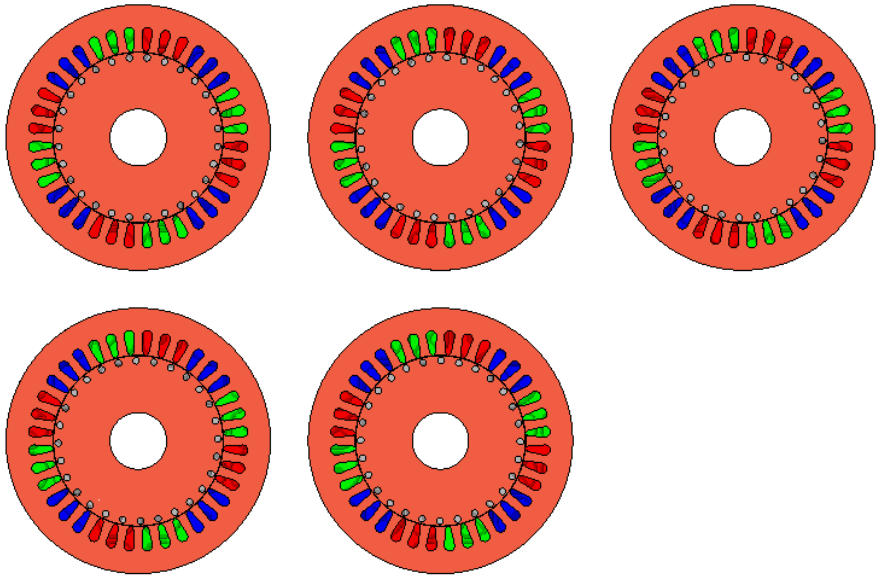


Induction motors often have skewed rotor bars in order to minimize the torque ripple and cogging effect. Skewing also eliminates high-order harmonics in the stator current waveform which can potentially be harmful. By definition, skewing is a three-dimensional feature and usually requires lengthy 3D simulations. Fortunately, Simcenter MAGNET's unique mesh capabilities make it possible to accurately model skew using the powerful 2D solver and a multi-slice approach. The key point is that a number of slices of the machine need to be solved in parallel in order to obtain the right induced currents in the rotor bars. This approach is implemented in the time domain analysis presented here. The transient with motion solver is first used to study high-order harmonics in the stator current waveform at constant speed and then to simulate load driven operation with an applied external load.

MULTI-SLICE APPROACH



The idea is to have N different slices with disjoint meshes in the same Simcenter MAGNET model. Each slice's thickness corresponds to the machine's total thickness divided by N. Each slice has its own moving rotor, stator coils and rotor bars. In order to solve for the current distribution in all five slices in parallel while forcing the current in each stator slot and rotor bar to be the same from one slice to the other, the equivalent coils belonging to different slices are all connected in series. The only difference between the different slices is the angle of the rotor at start-up. In order to cover a skew angle of 10 degrees with N = 5 slices, there has to be a 2 degree difference between the position at start-up in one slice and that in the next slice.

VALIDATION

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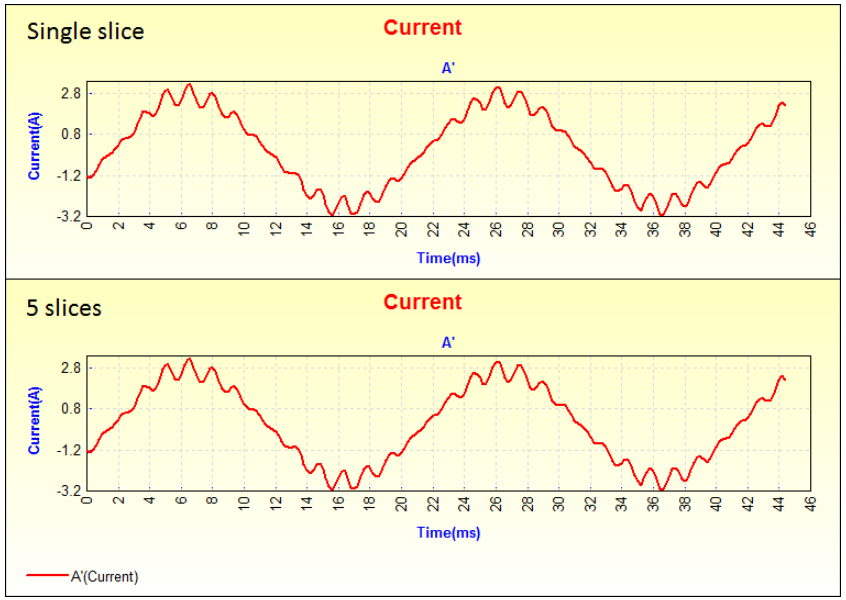
To confirm that the model is properly set up, the results obtained with an unskewed multi-slice model (i.e. having the same start-up position in all slices) are first compared with results obtained with a standard 2D model (a single slice having the same thickness as the real device). As expected, both models produce the same stator currents displayed here for a constant speed of 8550 deg/s corresponding to 5% slip. Note that the initial current in each of the coils was strategically calculated using Simcenter MAGNET's Time-Harmonic solver in order to skip the initial slow start-up transients and go straight into steady state.



EFFECT OF SKEWING ON STATOR CURRENTS

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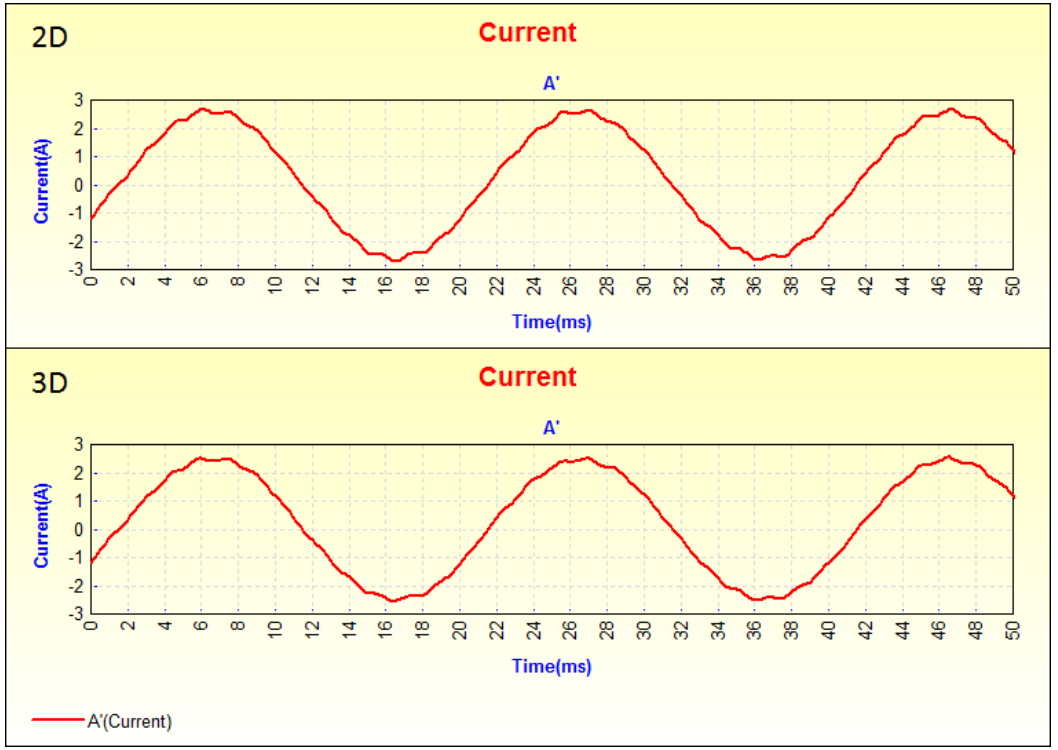
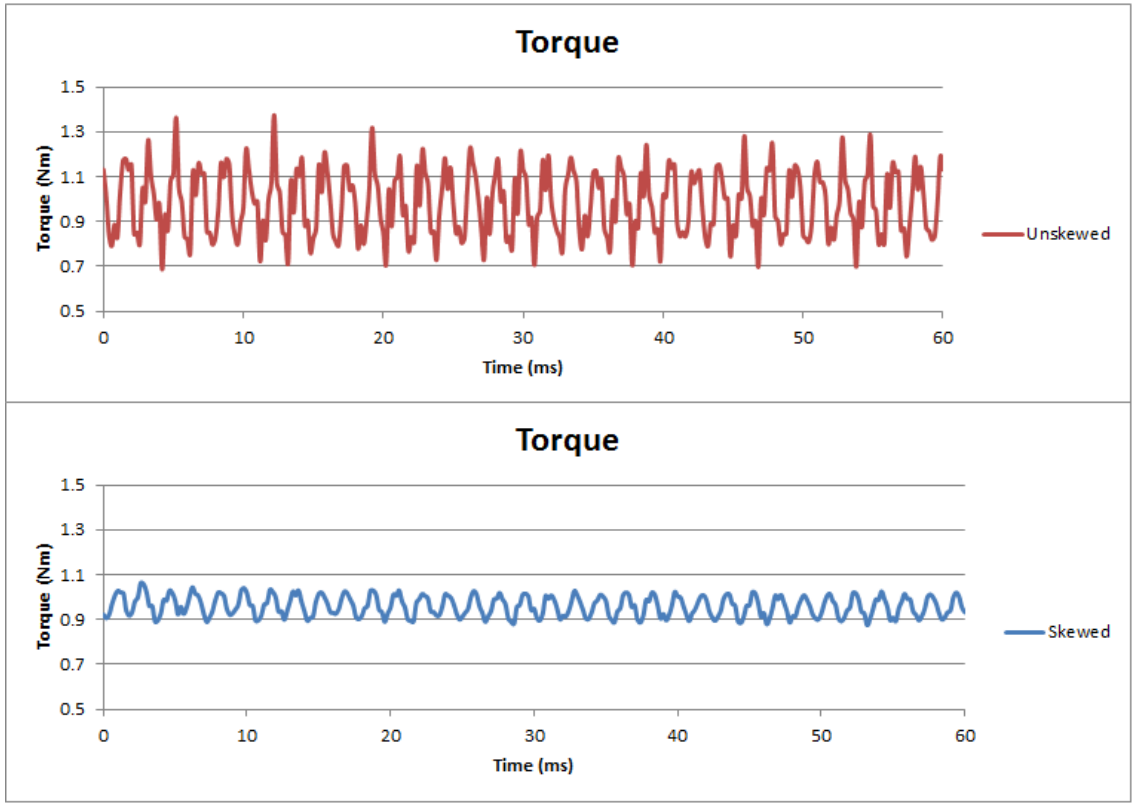


After introducing a skew angle of 10 degrees using 5 disjoint slices, the current waveform becomes smoother as expected. The same 10 degree skew angle was also modeled in 3D. The calculated current waveform is very similar to that obtained in 2D, which confirms that the multi-slice approach is accurate and that N = 5 is sufficient in this case.

EFFECT OF SKEWING ON THE TORQUE RIPPLE



Skewing also has the effect of reducing the torque ripple. Note that running the rotor at 8550 deg/s produces a torque of about 0.95 Nm.

LOAD DRIVEN OPERATION

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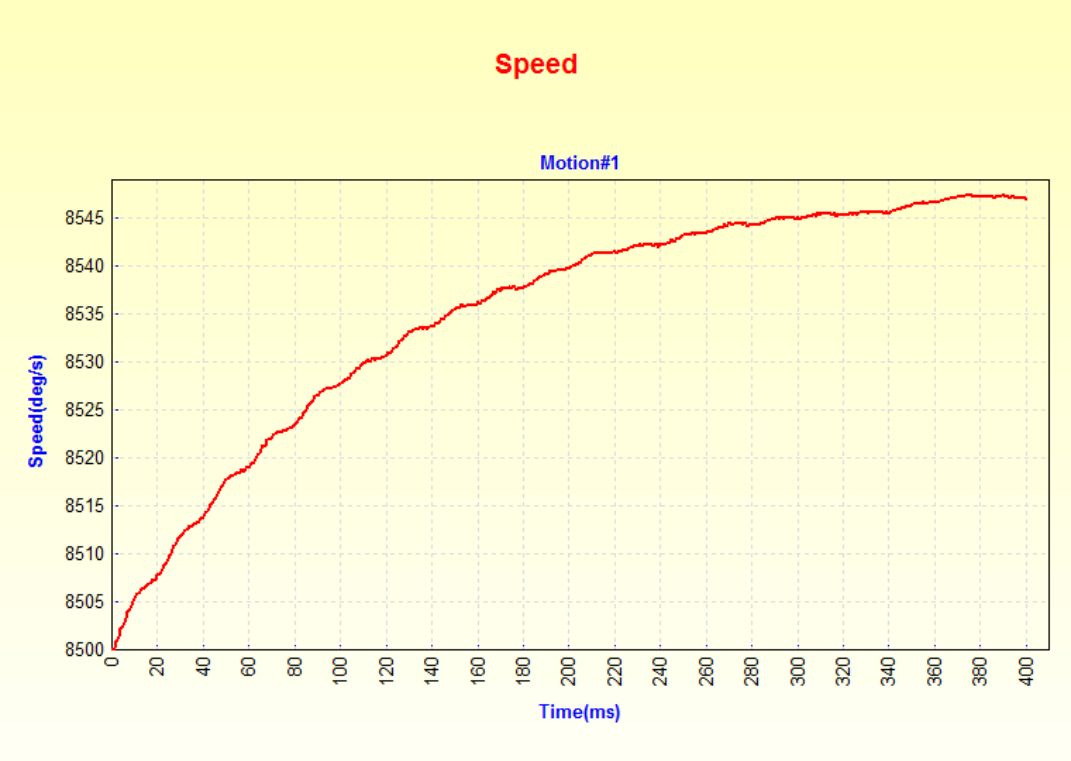

The machine can also be operated in load-driven mode. Each slice contributes to the total magnetic torque. A Visual Basic script is used here to ensure that the speed is the same in all N slices. This graph shows that with an external load of 0.95 Nm, the speed settles around 8550 deg/s as expected.

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RERERENCE

Direct Modeling of Induction Motors with Skewed Rotor Slots Using 2-D Multi-Slice Model and Time Stepping FEM, F. Wei-nong and J. Jian-zhong, Journal of Shanghai University, Vol. 4, No. 2, pp. 133-139, 2000.