A frequency-robust solver for eddy current problems

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In many practical applications in computational electromagnetics, the excitation is time-harmonic. Due to the time-harmonic excitation, we can switch from the time domain to the frequency domain. At least in the case of linear problems, this allows us to replace the expensive time-integration procedure by the solution of a linear system for the amplitudes belonging to the sine- and to the cosine-excitation. The fast solution of the corresponding linear system of finite element equations is crucial for the competitiveness of this method. J. Schöberl and W. Zulehner (2007) proposed a new parameter-robust MinRes preconditioning technique for saddle point problems. This method allows us to construct a frequency-robust preconditioned MinRes solver.

The application of this MinRes preconditioning technique to linear time-harmonic eddy current problems in electromagnetics is not straight forward. Due to the non-trivial kernel of the curl operator we have to perform an exact regularization of the frequency domain equations, in order to provide a theoretical basis for the application of the MinRes preconditioner.

Furthermore we have to find appropriate parameter robust preconditioners for the inversion of the diagonal blocks in (1).

$$\frac{1}{\omega}\begin{pmatrix} \omega\mathbf{M}_{\sigma,h}+\mathbf{A}_h & 0 \\ 0 & \omega^2(\omega\mathbf{M}_{\sigma,h}+\mathbf{A}_h) \end{pmatrix} \tag{1}$$

The multigrid preconditioner by Arnold, Falk and Winther (2000) and the domain decomposition preconditioner by Hu and Zou (2004) are candidates for σ being constant and σ being piecewise constant respectively.

Finally, we discuss the application of this solver to linear eddy current problems with non-harmonic excitation and to non-linear problems in the framework of the multiharmonic technique.

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