Applying Virtual Reality Techniques to Finite Element Solutions

M. Schöning, and K. Hameyer
Institute of Electrial Machines, RWTH Aachen University
D-52056 Aachen, Germany
marc.schoening@iem.rwth-aachen.de

***Abstract*— Electrical machine design resorts more and more to numerical simulation techniques instead of prototyping, so as to reduce development time and costs. In order to replace prototypes advantageously, numerical simulations must be accurate. This is achieved by using the discretisation techniques like the Finite Element Method combined with a fine mesh. This results in a large amount of computed data, that need to be post-processed adequately to allow making a correct interpretation of the results and taking the right decisions. Virtual reality environments are suited to match these demands. They offer the possibility of exploring efficiently and in detail the computed results of complicated geometries. In this paper, a post-processing software exploiting virtual reality capabilities is demonstrated and application examples are shown.**

I. INTRODUCTION

Numerical simulations of electrical devices are becoming increasingly important nowadays. The Finite Element package iMOOSE [1] allows for simulating complex geometries with high precision and resolution in space and time. The post-processing of the mass of numerical data generated by a 3D-magnetic field computation is a not an easy matter. Various ways of visualization like 2D plots or graphs have been well known for long, but results obtained from the computation of three-dimensional fields in complex geometries are still difficult to evaluate at present. This paper demonstrates how the principles of virtual reality can be used to enhance design capabilities. With this technique, users can dive into a virtual representation of 3D field lines and follow their path through the magnetic circuit, acquiring so an intuitive understanding of how the machine really works. Designers can also use the same technique to spot the location of some design problem and find out the possible causes of observed malfunctioning of the developed system. Virtual reality environments are suited for teaching purposes as well.

II. COMPUTER GRAPHICS SOFTWARE

The post-processing software named iMOOSE.trinity.vr uses the graphical package VTK [2] for the visualisation of Finite Element solutions. The Visualization Toolkit (VTK) is an open source software system for 3D computer graphics, image processing, and visualisation. VTK consists of a C++ class library, and several interpreted interface layers including Tcl/Tk, Java, and Python. It supports a wide variety of visualisation algorithms for scalar, vector and tensor quantities with different textures, and advanced modeling techniques such as implicit modeling, polygon reduction, mesh smoothing, cutting, contouring, and Delaunay triangulation. In addition, dozens of imaging algorithms have been directly integrated to allow the user to mix 2D imaging / 3D graphics algorithms and data. VTK combines a powerful structure, object-oriented programming, platform independence and it is freely available. The object oriented design of this software is characterised by general, easy to use data structures, whose versatility encourages a modular use of algorithms acting as filter objects. The working principle of VTK is based on visualisation pipelines (see Fig. 1). Prior to use the filter algorithms provided by VTK, the results of the Finite Element computations must be converted into VTK data structures. The main obstacle to using VTK for the visualisation of Finite Element solutions is the discontinuity of the fields at material transitions in electromagnetic devices or in the presence of shocks in Fluid dynamics. Finite Element packages can handle discontinuous solutions of first or second order whereas the data structures of VTK can only handle first order continuous solutions. Those discontinuities are however physically relevant and must therefore appear in the solution plot. When dealing with electromagnetic fields, the association between material boundaries and discontinuities can be utilised to comply with the standards of VTK. Since all physical characteristics are continuous inside a material domain, the solution in a first or second order element is continuous and discontinuities only occur at the boundaries between elements belonging to different material domains. In consequence, the mesh is partitioned into several submeshes, one for each material domain, when converting the iMOOSE data into the VTK data. Boundary nodes are duplicated so that discontinuous solutions at Finite Element nodes of the original mesh translate into continuous solutions over the different submeshes. The toolkit VISTA [3] is used to display the VTK visualisation data in a virtual reality environment. VISTA covers all aspects of

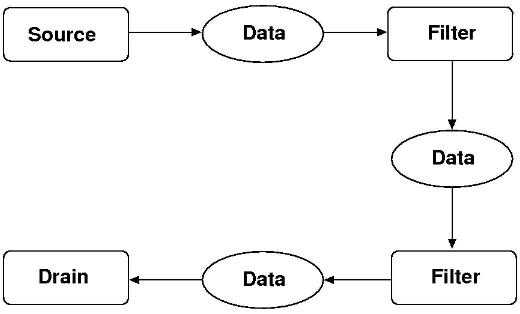

Fig. 1. Visualisation Pipeline of VTK

Marc Schöning, Institute of Electrical Maschine, RWTH Aachen University.

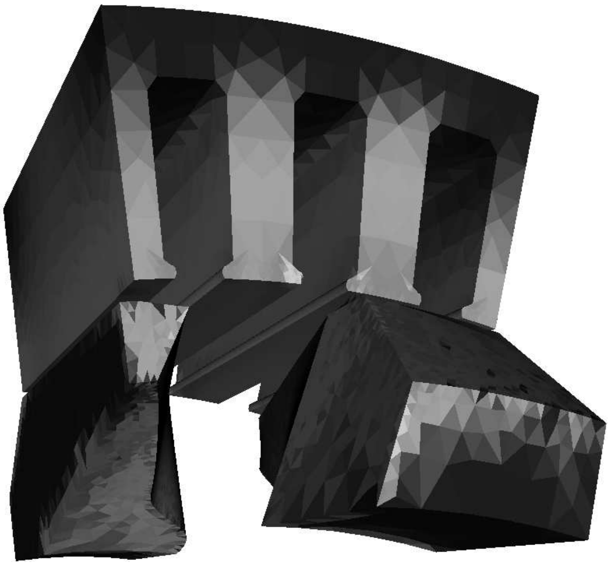

Fig. 2. Flux Density Distribution in Claw Pole Generator.

virtual reality technology. It is scalable in order to integrate all kinds of display systems, ranging from high-end visualisation displays like CAVE-style systems down to standard desktop monitors, and it offers access to a variety of 3D input devices. Special features like force-feedback and three dimensional acoustics are also covered. VISTA is implemented as a library, so that virtual reality applications can be developed rapidly for specific purposes. By using additional hardware, like a holobench or a cave, combined with additional features like force feedback system and head position tracking system, the realistic effect of virtual reality environments can be increased significantly.

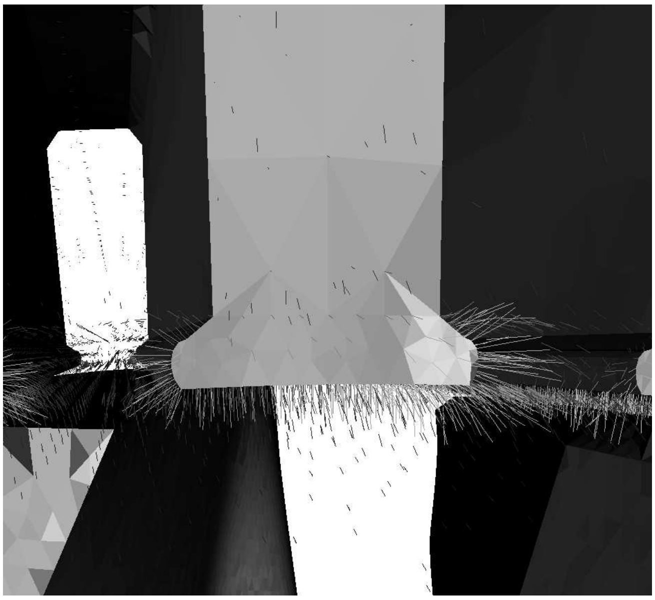

Fig. 3. Field Lines in Air Volume.

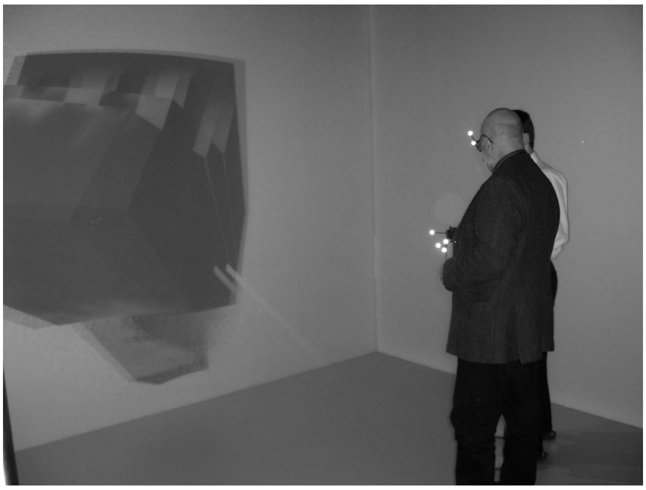

Fig. 4. User in a cave-style system.

III. APPLICATION

By using VTK, various new visualisation methods in the form of filter algorithms are available. This includes the extraction of equipotential surfaces or field lines in 3D models (see Fig. 3). Furthermore, the deformation and the generation of vectors can be controlled very accurately and additional functionalities like smoothing meshes and decreasing the number of shown vectors are available. All visualisations presented here are created utilising the nodal solution data calculated by the iMOOSE solver environment. Fig. 2 illustrates a flux density plot of a claw pole generator. The field lines in the air gap are shown in Fig. 3. This visualisation mechanism can be used to indicate the flux distribution and therefore the flux leakage at every desired position in an simulation model. Combined with Virtual Reality Environments, the flux distribution can be recognised entirely. Fig. 4 shows a user in a cave system, completely immerged in a flux density solution plot of a claw pole alternator.

IV. CONCLUSION

Using Virtual Reality Environments allows for a better understanding of the designed machine even for complicated geometries and field distributions. Thereby, the iterative design process can be expedited. Furthermore, Virtual Reality can be used for teaching purposes or presentations for non experienced people, giving them a better idea of research objectives. Further details will be presented in the full paper.

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