Appendix

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A Description of the MATLAB® Environment

In this appendix, the design of the MATLAB code is presented. Function calls and returns are defined together with data needed for intended execution. A simple chart of how the program functions is shown in figure A.1.

A.1 Invoking Script

main Main script that loads parameters and constants via the **input** function. Script initiates function for computing the initial conditions, **CalcInit**, and differential equation solver, **ParSolve**, in correct order. Script also invokes **PlotPath** for generating plots.

A.2 Parameter and Constant Loading

[P,C]=input(name) Function for loading machine parameter profile using profile name. Current supported machine profiles are **name**='TEXTOR' and **name**='custom'. Custom parameters are editable in the **input** function. Function invokes the **Constants** function for loading physical constants. Contents of structure **P** is described in section A.8.

[C]=Constants() Function for loading physical constants. Contents of structure **C** is described in A.8.

A.3 Computation Routines

A.3.1 Coordinate transformations

Both routines uses ϕ as the toroidal angle, θ as the poloidal angle and r as the distance from the magnetic center or center of the toroidal cross section.

[ϕ, θ, r]=**CarToTor**(x, y, z, **P**, **C**) Routine for transforming Cartesian coordinates to toroidal coordinates. Requires geometric data in structure **P** for computing toroidal coordinates.

[x, y, z]=**TorToCar**(ϕ, θ, r, **P**, **C**) Routine for transforming toroidal coordinates to Cartesian coordinates. Requires geometric data in structure **P** for computing Cartesian coordinates.

A.3.2 Toroidal Unit Vectors

[$\vec{e}_\phi$, $\vec{e}_\theta$, $\vec{e}_r$]=**CalcVec**(x, y, z, **P**, **C**) Function for computing the toroidal unit vectors at a given point (x, y, z). Invokes the **CarToTor** routine and therefore requires parameter structure **P**. Returned unit vectors is in column form.

A.3.3 Magnetic Field

[$\vec{B}$]=CalcB(x**,** y**,** z**, P, C)** Function for computing the magnetic field at a given point inside the torus described by geometric data in parameter structure **P**. Returned magnetic field vector is in column form. Invokes the **CalcVec** routine.

A.3.4 Initial Conditions

[K_0]=CalcInit(P, C) Routine used for computing the initial condition of a particle. Invokes the **CalcB** routine and uses data in parameter structure **P**. Parameter structure **P** is also nessesary for supplying underlying functions with data. Returned vector K_0 is in array form and consists of the initial position and initial velocity, $K_0 = [x_0, y_0, z_0, v_{x0}, v_{0y}, v_{0z}]$.

A.4 Differential Equation System

[∂K]=ParDyn(K) Equation system that formulates the differential equation supplied by the Lorentz force and Newtons second law of motion. Invokes the **CalcB** routine.

A.5 Differential Equation Solver Function

[T, Y]=ParSolve(K_0**, P, C)** Function for simplified calling of the native MATLAB ODE-solver **ode45**. Editable to change the settings of the solver, e.g. relative tolerance.

A.6 Projecting Function

[YGC]=PosToGC2(Y, P, C) Function for computing the position of the Guiding center instead of the absolute particle position. Invokes the **CalcB**-routine in order to recalculate the magnetic field at every point. Returned array, **YGC**, is scaled by the guiding center granularity changed in the **input** function.

A.7 Plotting Functions

[FH,FN]=PlotPath(T, Y, YF, YGCF, P, C) Function for plotting three dimensional plots of particle path and two dimensional plot of particle path. **YF** is boolean flag for plotting the true particle path and YGCF is boolean flag for plotting the guiding center particle path. Both can be invoked simultaneously for true and guiding center path in same plots. Function returns figure handles, **FH**, and figure names, **FN**, for saving of plots.

A.8 Structures & Program Algorithm

The data contained within structure **P** is machine construction data and initial condition data. Se table A.1.

level				Remark
P	Simulation	Name		Name of simulation [string]
		Time		Simulation time [s]
		Granularity		Number of true path points skip between guiding center points.
P	Particle	Mass		Particle mass [kg]
		Charge		Particle Charge [C]

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level				Remark
P	Initial	Energy		Particle thermal energy [eV]
		PitchAngle		Particle initial pitch angle [rad]
		ToroidalAngle		Particle initial toroidal angle position [rad]
		PoloidalAngle		Particle initial poloidal angle position [rad]
		Radius		Particle initial radius distance [m]
P	Torus	MajorRadius		Major radius of machine torus [m]
		MinorRadius		Minor radius of machine torus [meter]]
P	Coil	Toroidal	NumberOfCoils	Number of toroidal field coils
			WindingPerCoil	Number of windings per toroidal field coil
			Current	Current driven through the toroidal field coils [A]
P	Current	Plasma		Driven plasma current [A]

Table A.1: Contents of parameter structure **P**.

The data contained within structure **C** are constants of nature. Se table A.2.

level			Remark
C	Electron	Mass	m_e [kg]
		Charge	$-e$ [colomb]
C	Proton	Mass	m_p [kg]
		Charge	e [C]
C	Vacuum	SpeedOfLight	c [$\mathrm{m\,s^{-1}}$]
		Permeability	μ_0 [$\mathrm{V\,s\,A^{-1}\,m^{-1}}$]
		Permittivity*	$(\mu_0 c^2)^{-1}$ [$\mathrm{F\,m^{-1}}$]

Table A.2: Contents of parameter structure **C**.

A.8.1 Program Algorithm

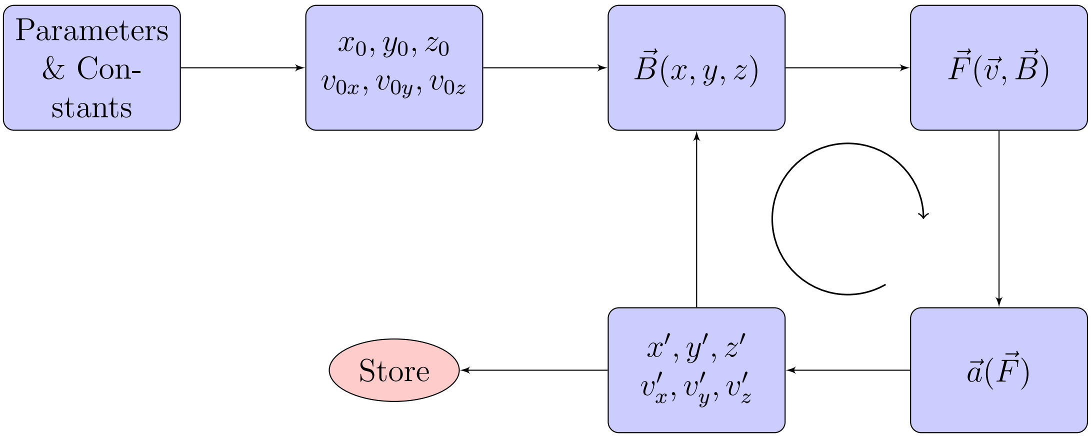

Figure A.1: Flowchart of how the program perform its functions. Circulating arrow represents differential equation solver.

B Visit to Forschungszentrum Jülich

As a part of this Bachelor thesis, a trip to the research center *Forschungszentrum Jülich* (FZJ) in Germany were conducted in the end of February. During two days of the stay, a series of visits were planned at different units of the research center in order to give a broader perspective of the field of fusion research.

Wednesday february 27: Flight to Germany and transport to hotel in Jülich.

Thursday february 28: A visit to the TEXTOR facility after a short introduction to FZJ. An engineer showed a scale model of the TEXTOR Tokamak and introduced the principles behind the design and function of the Tokamak experiment.

At the TEXTOR control room some of the fundamental problems of fusion was introduced, e.g. plasma disruptions, together with video photography of plasma within the Tokamak, and after that a tour of the device itself was conducted. The device has been used to perform a lot of materials research, but also installed with a Dynamic Ergodic Divertor (DED), a magnetic coil system used to control the transport of energy, heat and particles in the plasma boundary.

After lunch, a visit to the so called *hot cells* facility were conducted. A hot cell is a chamber containing radioactive material and protects the handler from the radiation. At the facility, there was not only handling, but also experiments related to fusion conducted. Note that D-T fusion generates high energy neutrons, the materials in the wall of the reactor becomes radioactive.

Lastly, a small talk on the work around modelling fusion were conducted. A small presentation of the ERO code, a 3D modelling program used to study the erosion and deposition in fusion machines, were given. The talk also explained how models are improved using *benchmarking*: Improvement using comparison with experimental results.

Friday march 1: During the morning, the different candidates for wall materials in fusion devices were introduced at the materials research laboratory. The different materials Tungsten, Carbon Fibre Composite (CFC) and Beryllium were discussed and their different advantages and disadvantages were presented. The problem of thermal shock, caused by plasma disruptions, and the neutron bombardment effect were presented and how the affect the wall materials.

After lunch, a visit to the plasma facilities were conducted. At the facility the different effects of plasma on different wall materials were presented and the TOMAS, PADOS and PSI-II experiments were shown. PSI-II is a new plasma generator and an experiment used to find a suitable Plasma Facing Material (PFM) for a future fusion power plant by the year 2035.