ma02aa

Constructs Beltrami field in given volume consistent with flux, helicity, rotational-transform and/or parallel-current constraints.

[called by: dforce.] [calls: packab, df00ab, mp00ac.]

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1.1 sequential quadratic programming

- 1. Only relevant if LBsequad=T. See LBeltrami for details.
- 2. Documentation on the implementation of NAG: E04UFF is under construction.

1.2 Newton method

1. Only relevant if LBnewton=T. See LBeltrami for details.

1.3 "linear" method

- 1. Only relevant if LBlinear=T. See LBeltrami for details.
- 2. The quantity μ is <u>not</u> not treated as a "magnetic" degree-of-freedom equivalent to in the degrees-of-freedom in the magnetic vector potential (as it strictly should be, because it is a Lagrange multiplier introduced to enforce the helicity constraint).
- 3. In this case, the Beltrami equation, $\nabla \times \mathbf{B} = \mu \mathbf{B}$, is linear in the magnetic degrees-of-freedom.
- 4. The algorithm proceeds as follows:

1.3.1 plasma volumes

- (a) In addition to the enclosed toroidal flux, $\Delta \psi_t$, which is held constant in the plasma volumes, the Beltrami field in a given volume is assumed to be parameterized by μ and $\Delta \psi_p$. (Note that $\Delta \psi_p$ is not defined in a torus.)
- (b) These are "packed" into an array, e.g. $\mu \equiv (\mu, \Delta \psi_p)^T$, so that standard library routines , e.g. NAG: C05PCF, can be used to (iteratively) find the appropriately-constrained Beltrami solution, i.e. $\mathbf{f}(\mu) = 0$.
- (c) The function $f(\mu)$, which is computed by mp00ac, is defined by the input parameter Lconstraint:
 - i. If Lconstraint = -1, 0, then μ is not varied and Nxdof=0.
 - ii. If Lconstraint = 1, then μ is varied to satisfy the transform constraints; and Nxdof=1 in the simple torus and Nxdof=2 in the annular regions. (Note that in the "simple-torus" region, the enclosed poloidal flux $\Delta \psi_p$ is not well-defined, and only $\mu = \mu_1$ is varied in order to satisfy the transform constraint on the "outer" interface of that volume.)
 - iii. If Lconstraint = 2, then $\mu = \mu_1$ is varied in order to satisfy the helicity constraint, and $\Delta \psi_p = \mu_2$ is <u>not</u> varied, and Nxdof=1. (under re-construction)

1.3.2 vacuum volume

- (a) In the vacuum, $\mu = 0$, and the enclosed fluxes, $\Delta \psi_t$ and $\Delta \psi_p$, are considered to parameterize the family of solutions. (These quantities may not be well-defined if $\mathbf{B} \cdot \mathbf{n} \neq 0$ on the computational boundary.)
- (b) These are "packed" into an array, $\mu \equiv (\Delta \psi_t, \Delta \psi_p)^T$, so that, as above, standard routines can be used to iteratively find the appropriately constrained solution, i.e. $\mathbf{f}(\mu) = 0$.
- (c) The function $f(\mu)$, which is computed by mp00ac, is defined by the input parameter Lconstraint:
 - i. If Lconstraint = -1, then μ is not varied and Nxdof=0.
 - ii. If Lconstraint = 0,2, then μ is varied to satisfy the enclosed current constraints, and Nxdof=2.
 - iii. If Lconstraint = 1, then μ is varied to satisfy the constraint on the transform on the inner boundary \equiv plasma boundary and the "linking" current, and Nxdof=2.

- 5. The Beltrami fields, and the rotational-transform and helicity etc. as required to determine the function $f(\mu)$ are calculated in mp00ac.
- 6. This routine, mp00ac, is called iteratively if Nxdof > 1 via NAG: C05PCF to determine the appropriately constrained Beltrami field, \mathbf{B}_{μ} , so that $\mathbf{f}(\mu) = 0$.
- 7. The input variables mupftol and mupfits control the required accuracy and maximum number of iterations.
- 8. If Nxdof = 1, then mp00ac is called only once to provide the Beltrami fields with the given value of μ .

1.4 debugging: finite-difference confirmation of the derivatives of the rotational-transform

- 1. Note that the rotational-transform (if required) is calculated by tr00ab, which is called by mp00ac.
- 2. If Lconstraint=1, then mp00ac will ask tr00ab to compute the derivatives of the transform with respect to variations in the helicity-multiplier, μ , and the enclosed poloidal-flux, $\Delta \psi_p$, so that NAG: C05PCF may more efficiently find the solution.
- 3. The required derivatives are

 $\partial \Delta \psi_n$

$$\frac{\partial t}{\partial \mu} \tag{1}$$

$$\frac{\partial t}{\partial t} \tag{2}$$

to improve the efficiency of the iterative search. A finite difference estimate of these derivatives is available; need DEBUG, Lcheck=2 and Lconstraint=1.

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SPEC subroutines;