

dlength

Calling `tlength(nderiv)` to calculate the length cost function w/o its derivatives on all degrees of freedom. When $nderiv = 0$, it only calculates the 0 – order length cost function, which is $/tlength = \sum_{i=1, Ncoils} \frac{1}{2}(L_i - L_o^i)^2/$. When $nderiv = 1$, it will calculate both the 0 – order and 1st – order derivatives in array `t1L(1:Ncoils,0:Codf)`. When $nderiv = 2$, it will calculate all the 0 – order, 1st – order and 2nd – order derivatives `t2L(1 : Ncoils, 0 : Codf, 1 : Ncoils, 0 : Codf)`.

[called by: `costfun`.]

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1.1 Total length cost function

1. The length of each coils can be calculated through,

$$L_i = \int_{icoil} \sqrt{\dot{x}(t)^2 + \dot{y}(t)^2 + \dot{z}(t)^2} dt \approx \sum_{kseg=0, Ndcil-1} \sqrt{xt(kseg)^2 + yt(kseg)^2 + zt(kseg)^2} \frac{2\pi}{NDcoil} \quad (1)$$

The results of user discretized method and `NAG:D01EAF` adaptive routine can be compared through subroutine `descent`.

2. And then the cost funtion on length is

$$ttlen = \sum_{i=1, Ncoils} \frac{1}{2} Lw_i (L_i - L_o^i)^2 \quad (2)$$

where Lw_i is the weight of length of each coil, while there is another weight on the length cost function `weight_ttlen`

1.2 First dirivatives

Since the length of coils has no relationships with the current in the coil, the first derivatives of `ttlen` on currents are all zero. An the derivatives on the geometry variables can be represented as,

$$\frac{\partial ttlen}{\partial x_n^i} \equiv (L_i - L_o^i) \frac{\partial L_i}{\partial x_n^i} \quad (3)$$

Here i is denoted to the i^{th} coil and x_n means the n^{th} DoF. And

$$\frac{\partial L_i}{\partial x_n^i} \equiv \int_{icoil} \frac{\dot{x}}{\sqrt{\dot{x}(t)^2 + \dot{y}(t)^2 + \dot{z}(t)^2}} \frac{\partial \dot{x}}{\partial x_n^i} dt \quad (4)$$

1.3 Second derivatives

The second derivatives of length cost function are only related to geometry variables of the same coil. That is,

$$\frac{\partial^2 ttlen}{\partial x_n^i \partial x_m^i} \equiv \frac{\partial L_i}{\partial x_m^i} \frac{\partial L_i}{\partial x_n^i} + (L_i - L_o^i) \frac{\partial^2 L_i}{\partial x_n^i \partial x_m^i} \equiv \int_{icoil} \frac{1}{\sqrt{\dot{x}(t)^2 + \dot{y}(t)^2 + \dot{z}(t)^2}} \frac{\partial \dot{x}}{\partial x_n^i} \frac{\partial \dot{x}}{\partial x_m^i} - \frac{\dot{x}' \dot{x}}{(\sqrt{\dot{x}(t)^2 + \dot{y}(t)^2 + \dot{z}(t)^2})^3} dt \quad (5)$$