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Dynamic Modelling of the High Temperature Superconducting Maglev System Using Different *E-J* Constitutive Laws

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Introduction—In an attempt to figure out which common *E-J* constitutive laws of the HTS bulk is more desirable in the numerical modelling. In this paper, for the permanent magnet guideway (PMG)-HTS bulks maglev system, the dynamic modelling results and efficiencies of **three different *E-J* constitutive** laws include the power law model (**PLM**), the flux flow and creep model (**FFCM**), and the flux flow model (**FFM**) **are compared**.

The finite element method with ***H* formulation** of Maxwell\`s equations and **coupled with heat transfer module** is considered. The **ALE formulation** is applied to achieve the relative motion between the PMG and the HTS bulks so as to simulate the variable magnetic field under dynamic operation of the vehicle. The **levitation force**, the **AC loss** and the temperature variation of the bulks under **different high-speed conditions** are discussed. The results indicate that **the PLM has the advantages of reliability and higher efficiency compared to the other two constitutive laws.**

Equations

- ***E-J* constitutive laws compared.**
  - ✓ **The power law model (PLM):**

$$E = E_c \frac{J}{J_c}\left(\frac{|J|}{J_c}\right)^{n-1}$$

  - ✓ **The flux flow and creep model (FFCM):**

$$E = \begin{cases} 2\rho_c J_c \sinh\left(\dfrac{U_0}{kT}\dfrac{|J|}{J_c}\right)\exp\left(-\dfrac{U_0}{kT}\right)\dfrac{J}{|J|} & 0 \le |J| \le J_c \\ \rho_c J_c + \rho_f J_c\left(\dfrac{|J|}{J_c}-1\right)\dfrac{J}{|J|} & |J| > J_c \end{cases}$$

  - ✓ **The flux flow model (FFM):**

$$E = \begin{cases} 0 & 0 \le |J| < J_c \\ \rho_f J_c\left(\dfrac{|J|}{J_c}-1\right) & |J| \ge J_c \end{cases}$$

Results: with different *E-J* constitutive laws

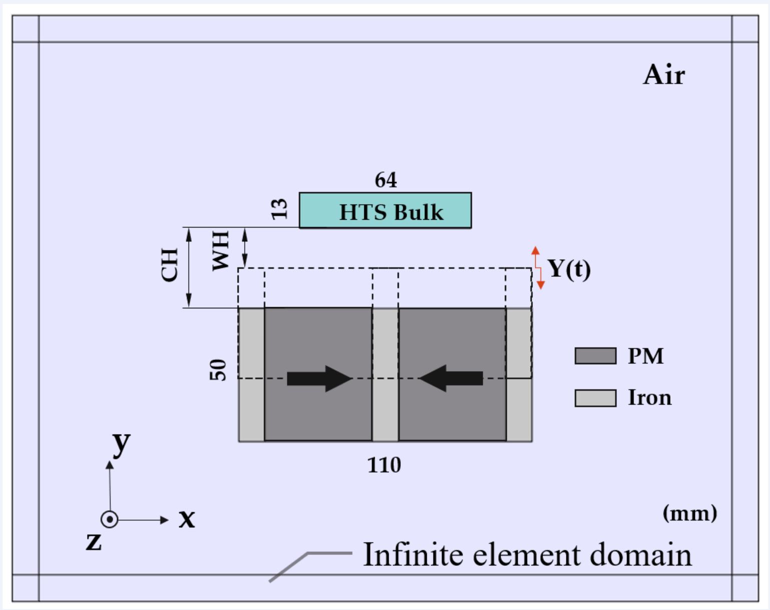
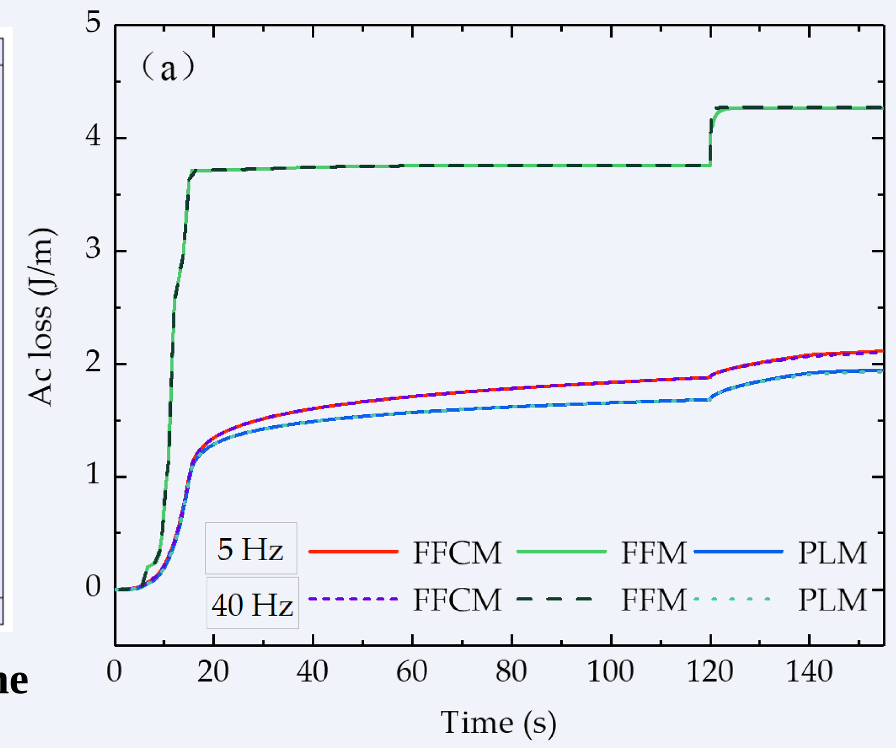
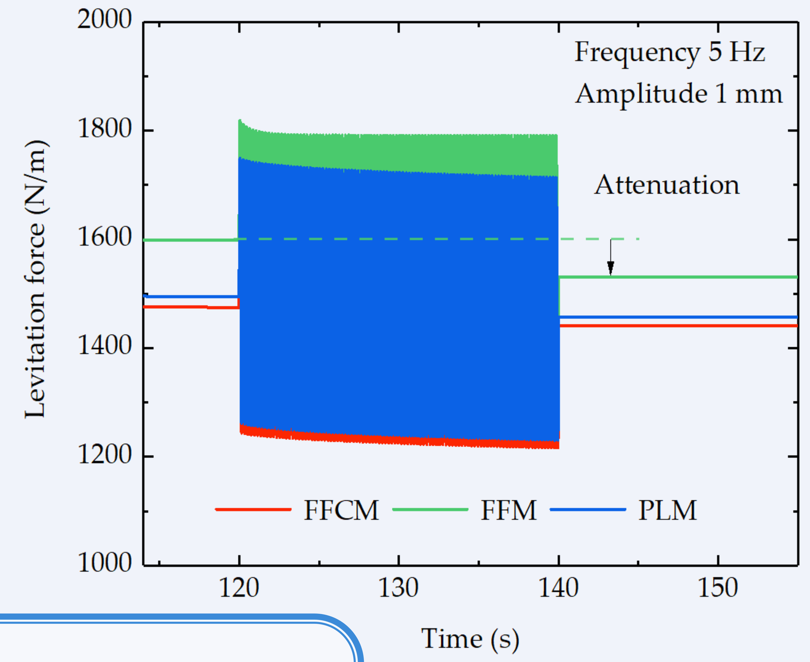
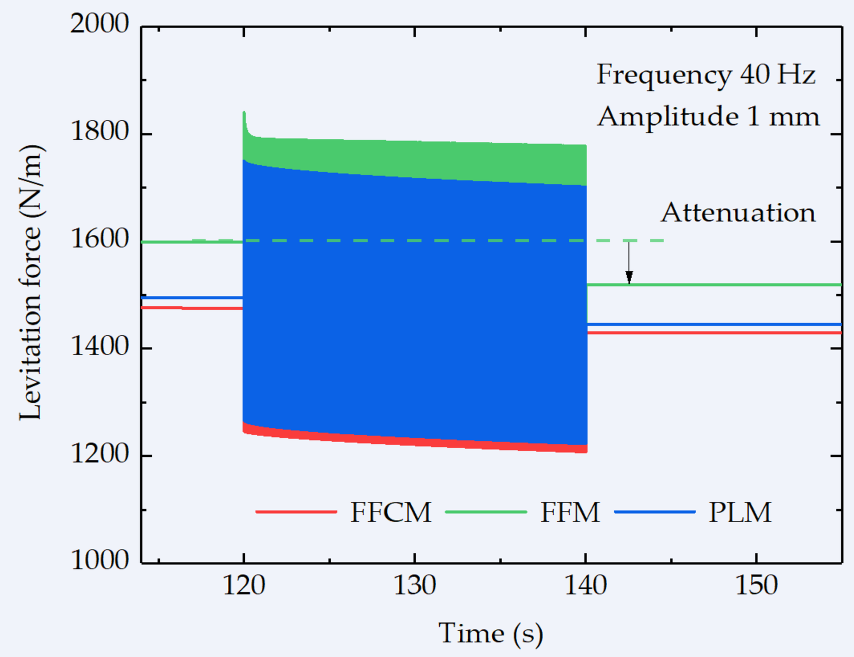


Figure1: Geometrical configuration of the HTS maglev system



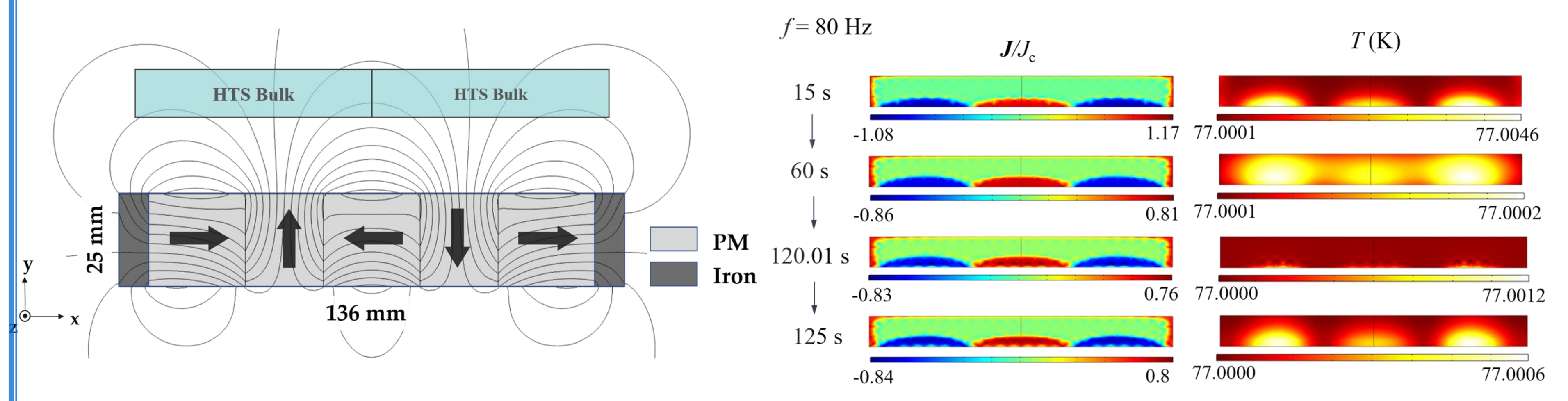




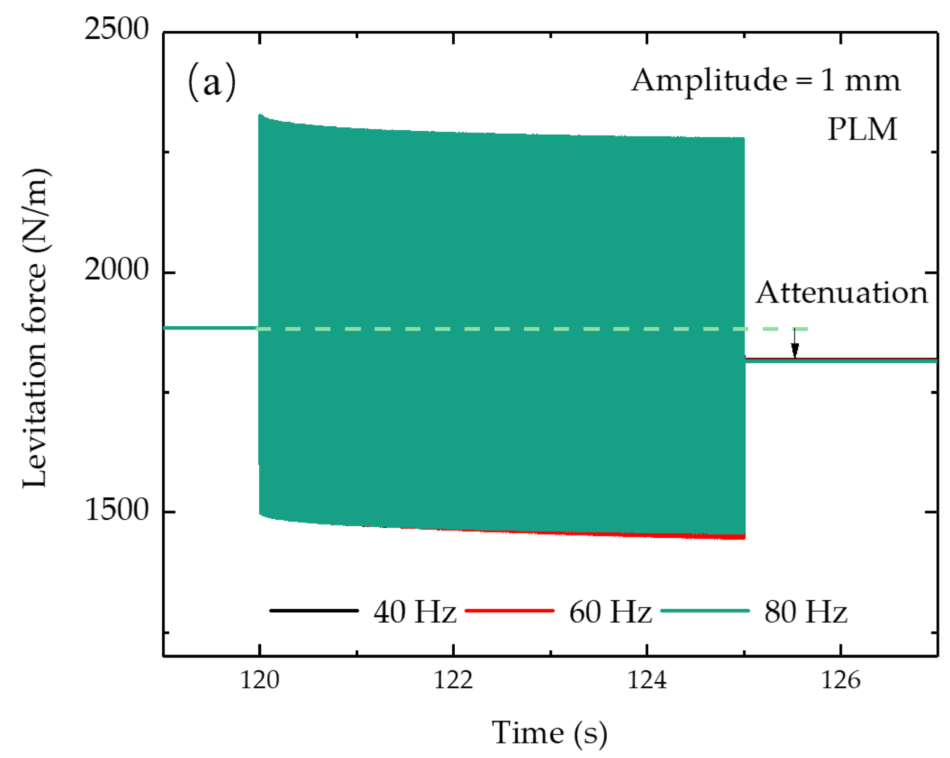
☐ **Calculation efficiency of different *E-J* constitutive laws under vibration frequencies of 5 Hz and 40 Hz.**

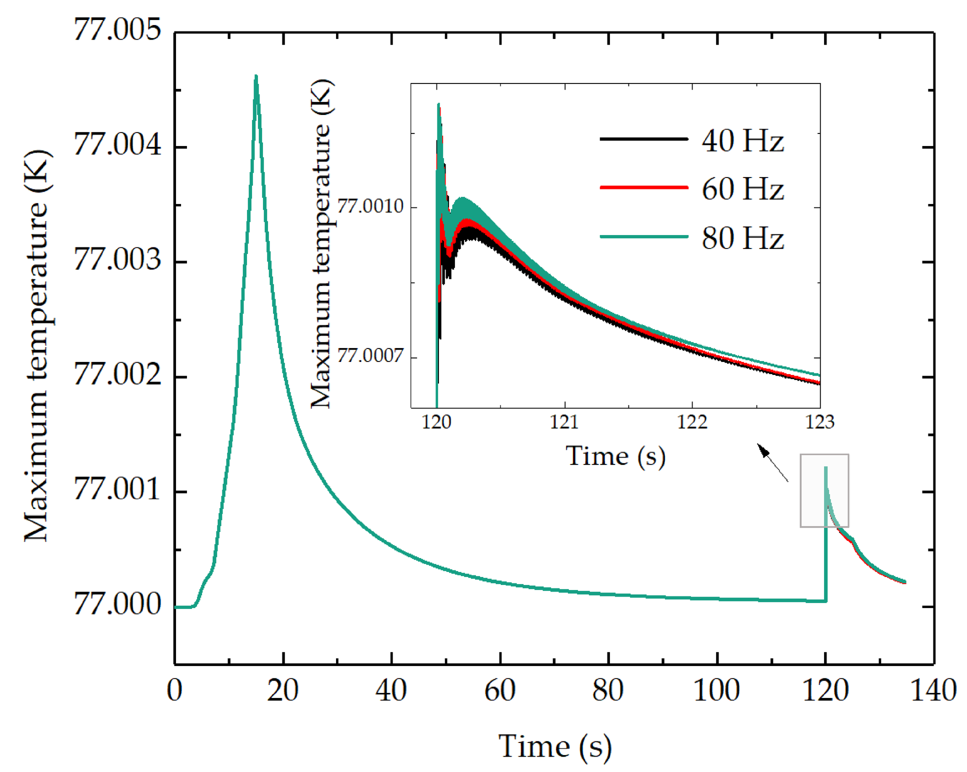
Frequency *f*	FFCM	FFM	PLM
5 Hz	3 h 38 s	3 h 8 min 52 s	2 h 59 min 27 s
40 Hz	5 h 30 min 56 s	6 h 47 min 12 s	5 h 23 min 32 s

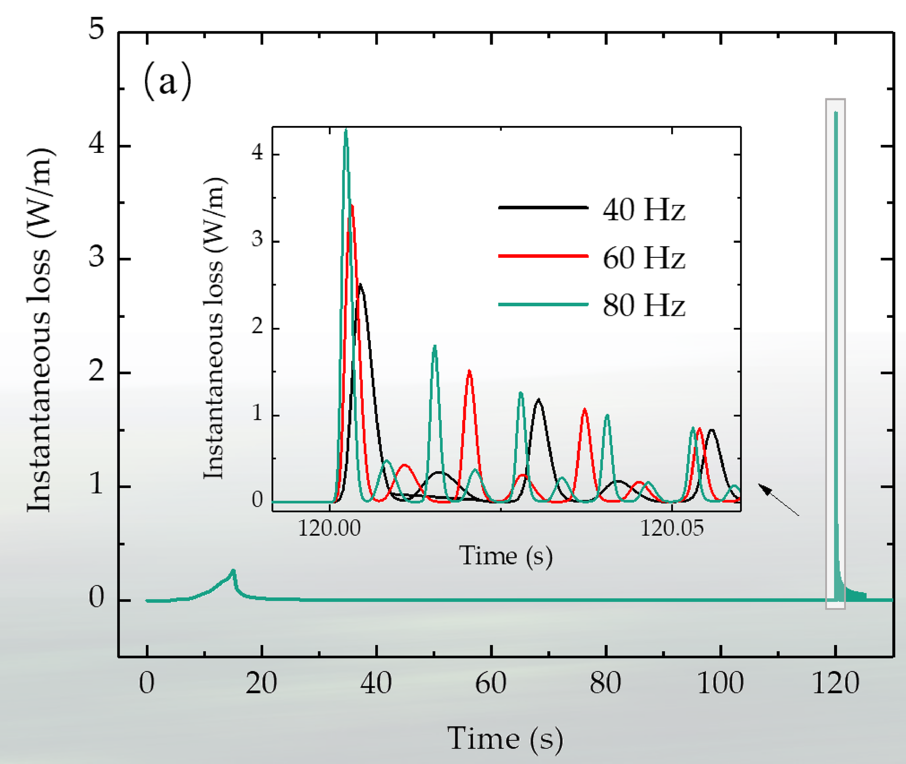
Results: with PLM, Halbach-typed guideway

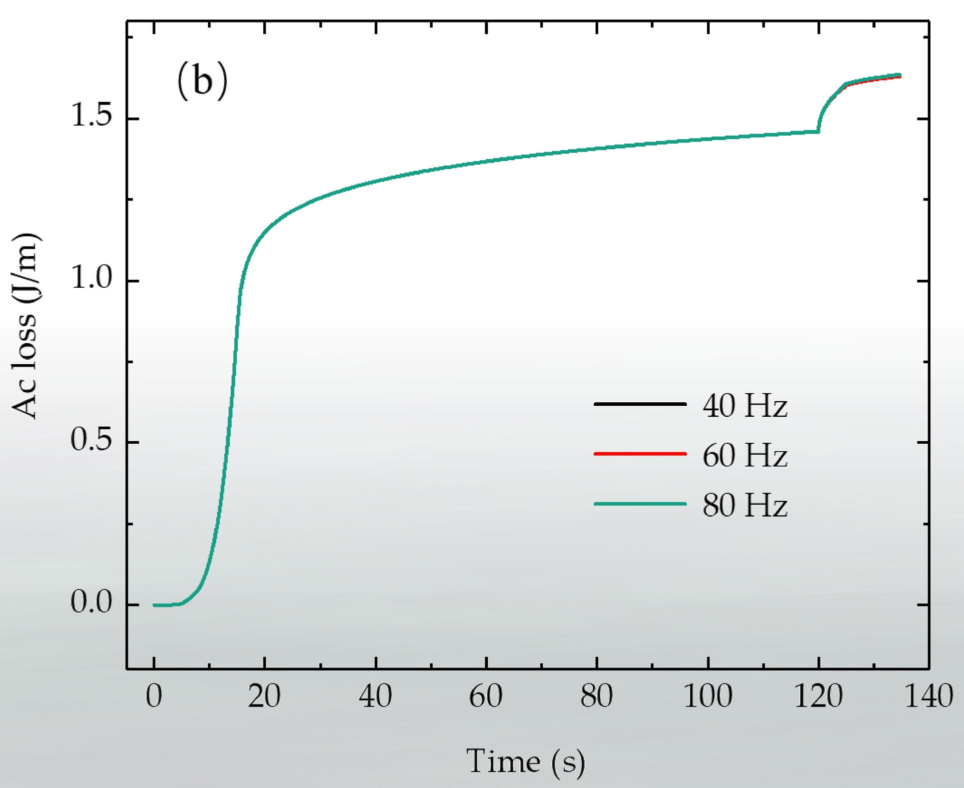


☐ **Dynamic levitation force and thermal effect:**



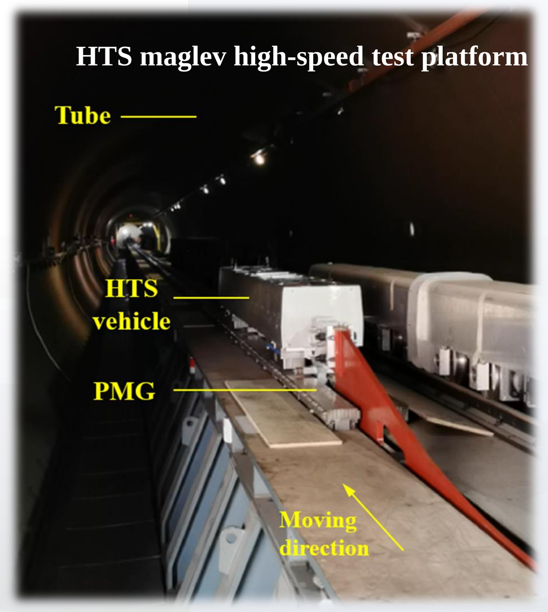






Conclusion

- **The results of the PLM and the FFCM are consistent and reasonable.**
- **The PLM has higher efficiency in computation and simple form, it is the recommended model, while the FFM is not recommended.**
- **The temperature rise inside the HTS bulks under high speed operation (high frequency) is very small, less than 1 K.**
- **The frequency changing has little influence on the AC loss of the HTS bulks, which shows the high-speed and ultra-high-speed operation potential of the HTS maglev.**



Besides, we are promoting the high-speed ejection test of the HTS maglev 1:10 prototype vehicle, which can reach 334.8 km/h at present. The diameter of the tube with vacuum pumping system is 4.2 m, and the length of it is 142.6 m. The lateral offset of the vehicle model: < ±1.5 mm (183 km/h, with acceleration of 3g).