Electromagnetic Attractive Bulging of Small Pipe Fittings: Fundamentals and Simulations

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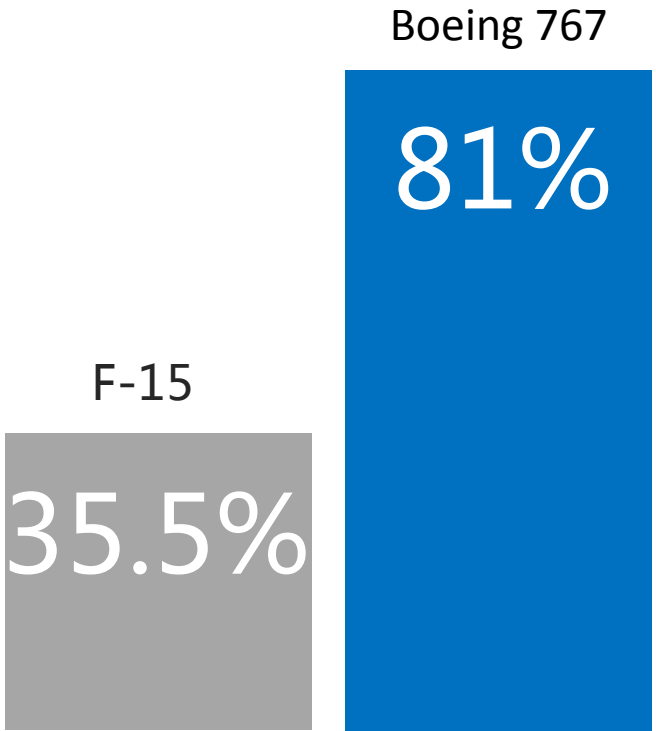
Light-weighting

5kg loss of aircraft body weight can increase the payload by 50kg.

10% loss of car weight reduce the fuel consumption by 6%-8%.

Research background

Aluminum alloy is an ideal lightweight material because of excellent material performance and low density.



Electromagnetic forming(EMF)

Electromagnetic forming is an optimum forming method for aluminum alloy.

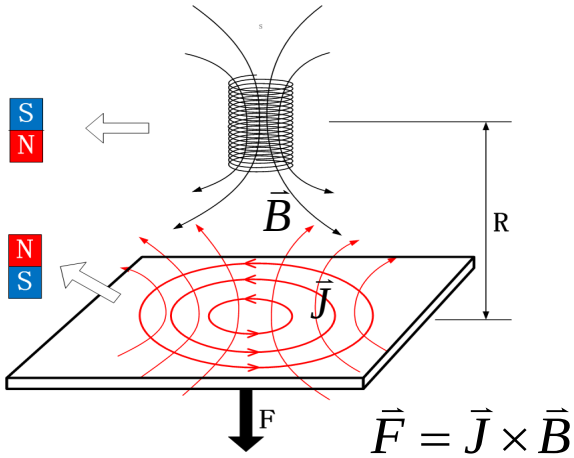
Comparison of forming methods	
Traditional forming	**EMF**
◆Mechanical force ◆Hydraulic pressure ◆Quasi static	◆Electromagnetic force ◆Non-contact ◆High rate

Advantages of EMF

- ☑ **Improve the forming limit of materials 5-10 times**
- ☑ **Improve surface integrity and fatigue life**
- ☑ **Strong flexibility and Simple tool**

Research background

Lenz's law



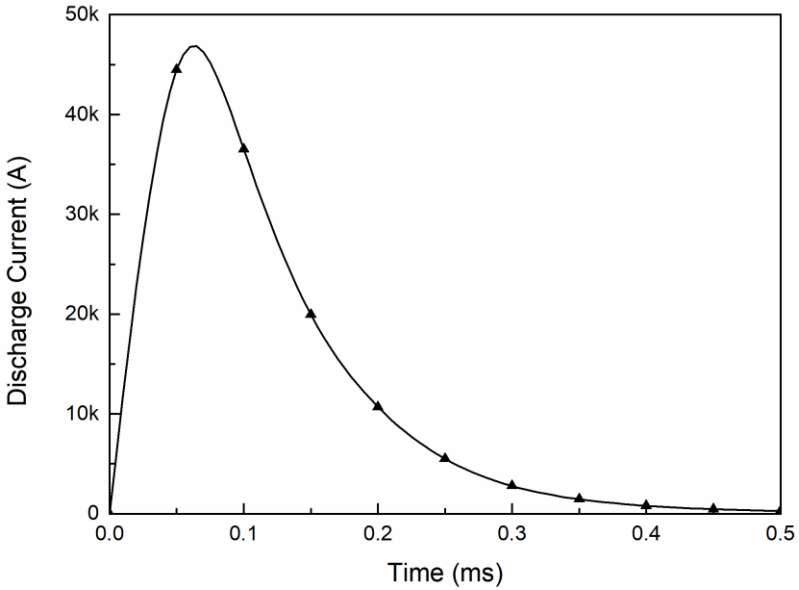


Fig. 1 Discharge current of EMF process.

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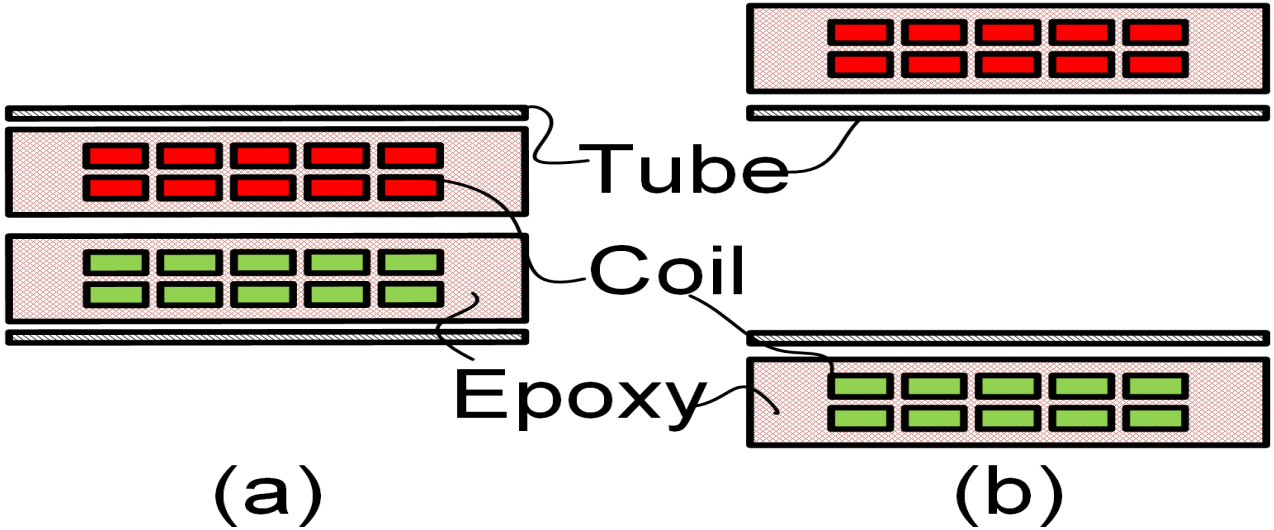
Research objective

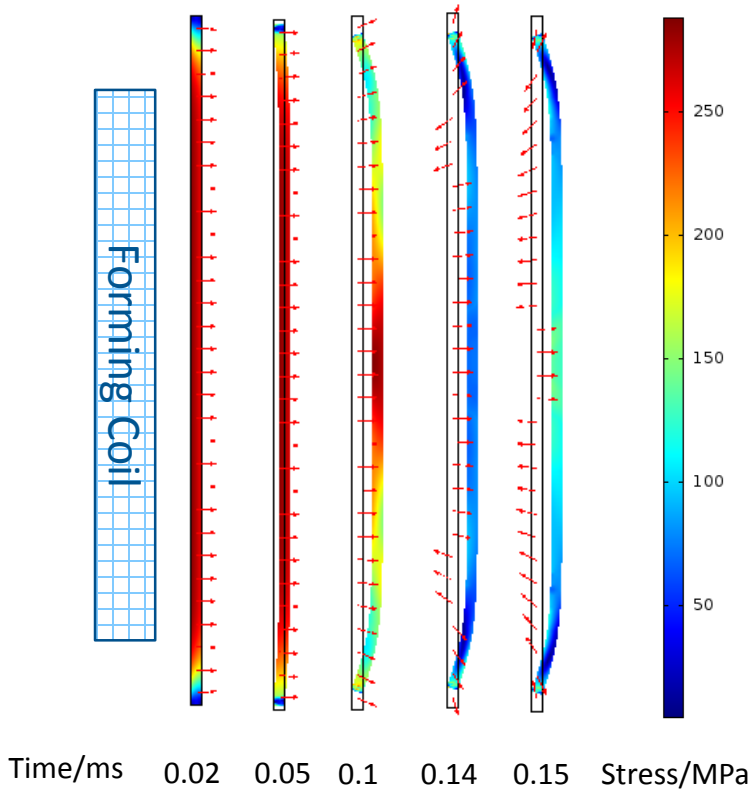
(a) Conventional tube bulging.

(b) Attractive bulging.



Repulsive → Attractive

Research objective



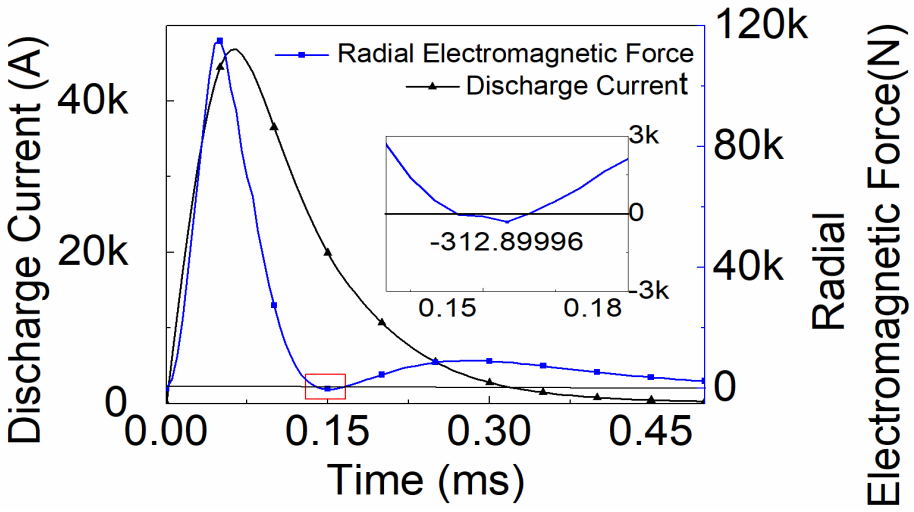


Fig. 2 Electromagnetic force of the traditional EMF.

Research objective

① $\vec{F}_r = \vec{J}_e \times \vec{B}_z$

② $\varepsilon = \frac{d\psi}{dt}$ $\psi = L \cdot i$

③ $\vec{J}_e = i_e / S$

④ $\varepsilon \propto \frac{di}{dt}$

⑤ $i_e \propto \varepsilon$

⑥ $\vec{F}_r = \alpha \frac{di}{dt} \times \vec{B}_z$

$\frac{di}{dt} > 0 \Longrightarrow F_r > 0$

$\frac{di}{dt} < 0 \Longrightarrow F_r < 0$

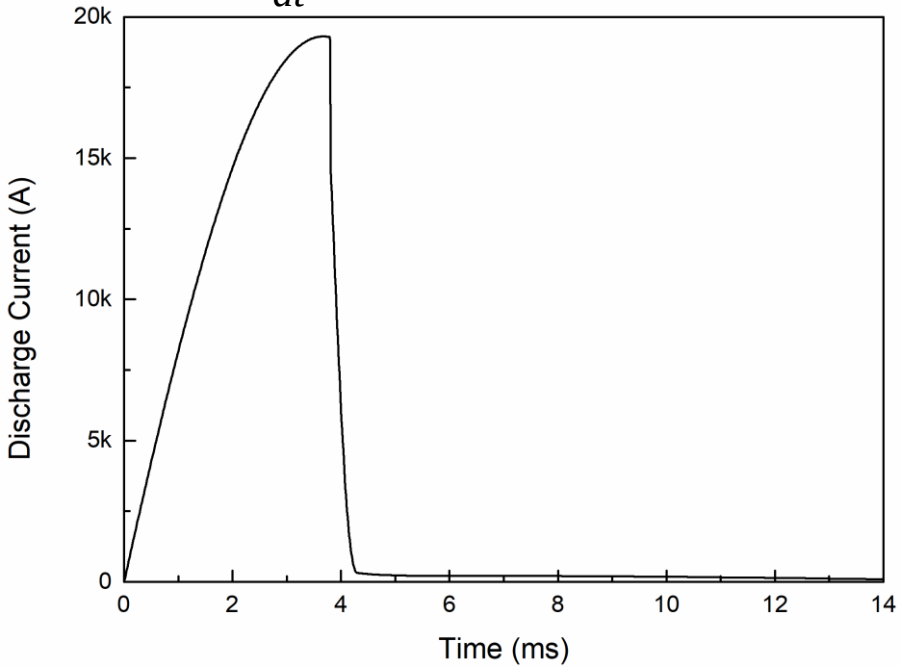


Fig. 1 The ideal waveform of discharge current.

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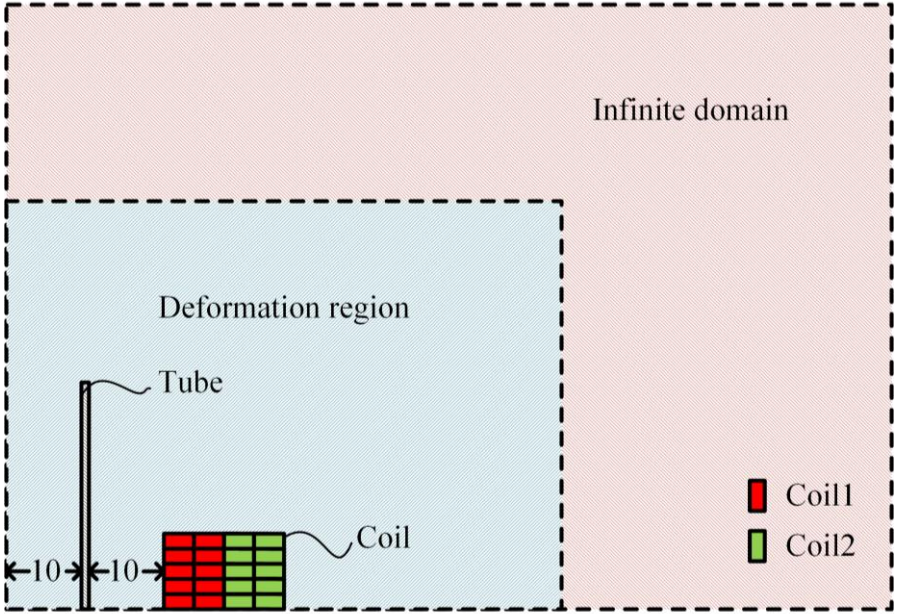

Fig. 1 The geometry of the finite element model.

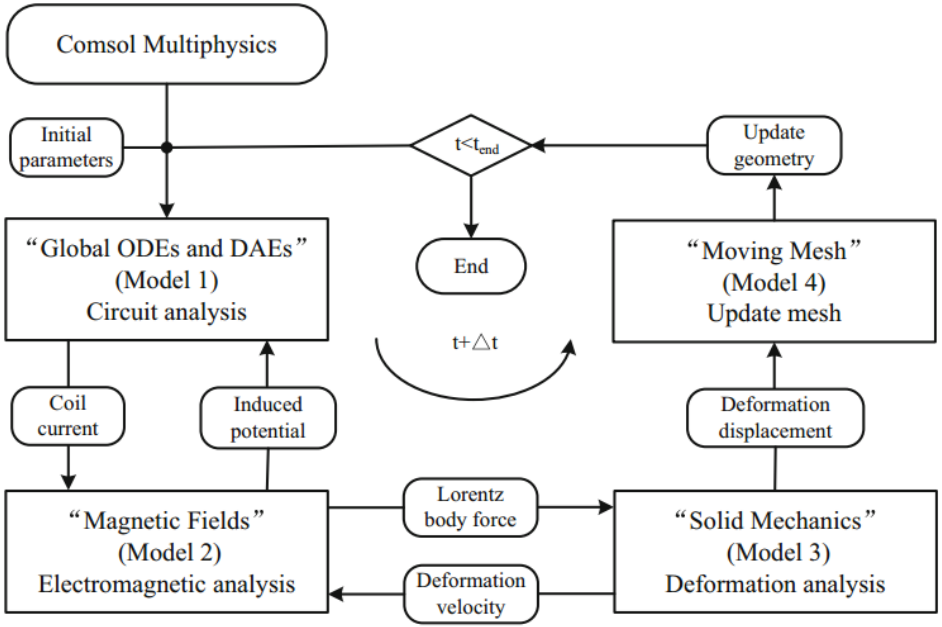

Fig. 2 Flowchart of the implemented algorithm

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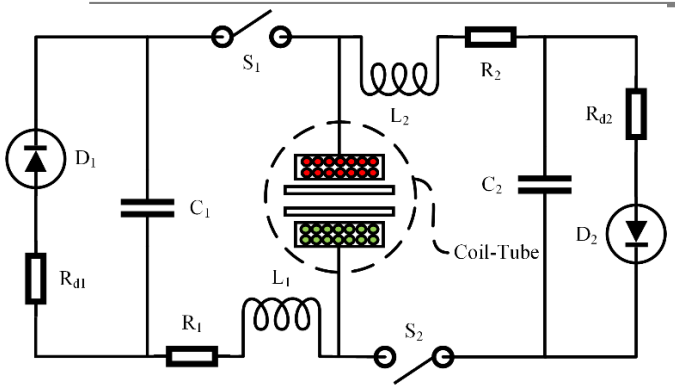

Fig. 1 The circuit schematic diagram of dual-power system.

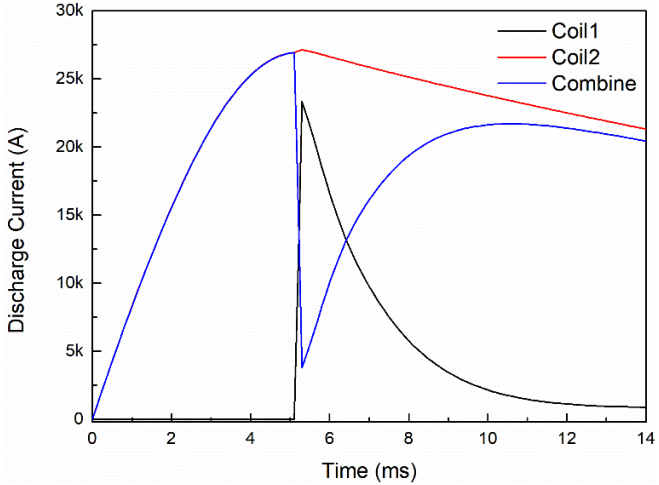

Fig. 2 Double pulse width current and its equivalent current.

CIRCUIT PARAMETERS FOR DUAL-POWER SYSTEM

Symbol	Description	Value
Wide plus power system		
C_1	capacitance	6400uF
U_1	maximum discharge voltage	25kV
R_1	line resistance	0.02Ω
L_1	line inductance	1.7mH
R_{d1}	crowbar resistance	0.02Ω
Narrow plus power system		
C_2	capacitance	80uF
U_2	maximum discharge voltage	25kV
R_2	line resistance	8mΩ
L_2	line inductance	40uH
R_{d2}	crowbar resistance	0.02Ω

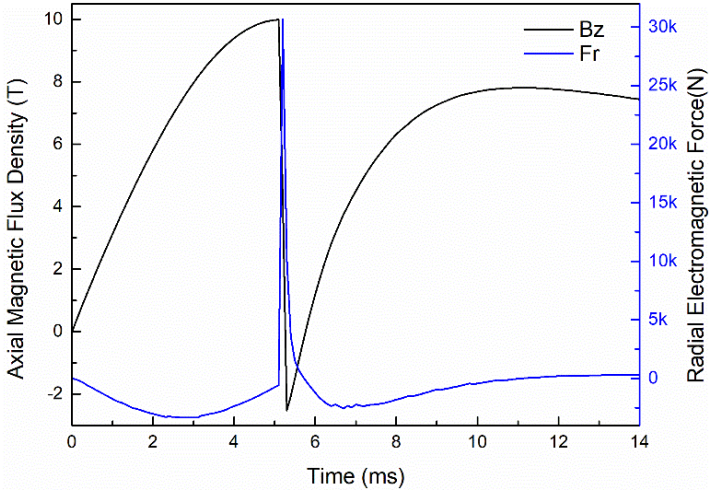

Fig. 3 Axial magnetic flux density and radial electromagnetic force of new tube bulging.

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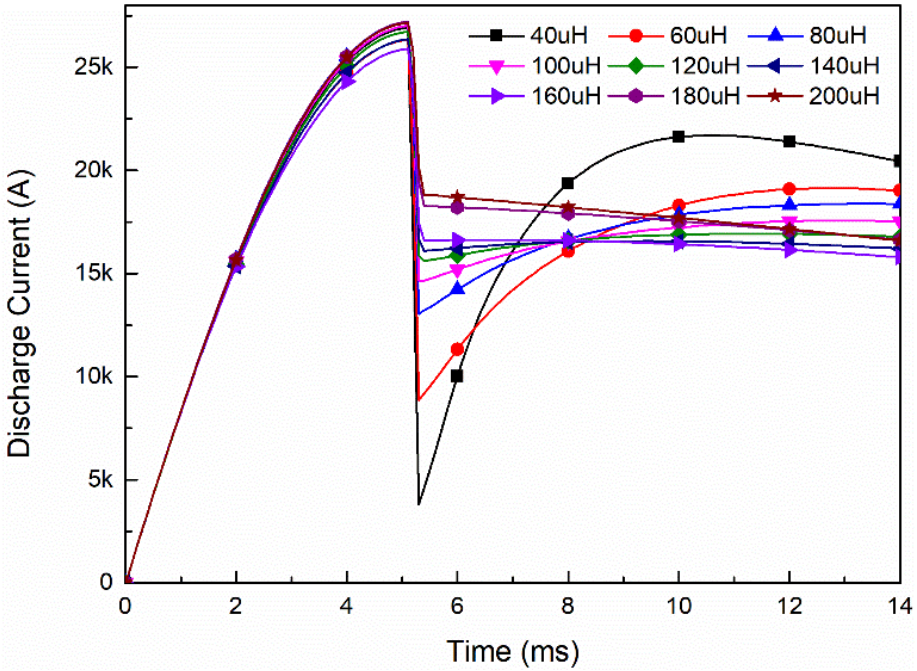

Fig. 1 The waveform of combine current in narrow power system with different inductance values.

TABLE I
MATERIAL PROPERTIES OF TUBE

Material	Parameters	Value
A1060-H28	Density	2.71 g/cm^3
	Electrical conductivity	3.6e7 S/m
	Relative permittivity	1
	Relative permeability	1
	Young's modulus	6.9e10 Pa
	Poisson's ratio	0.34
	Initial yield tensile strength	9.8e7 Pa

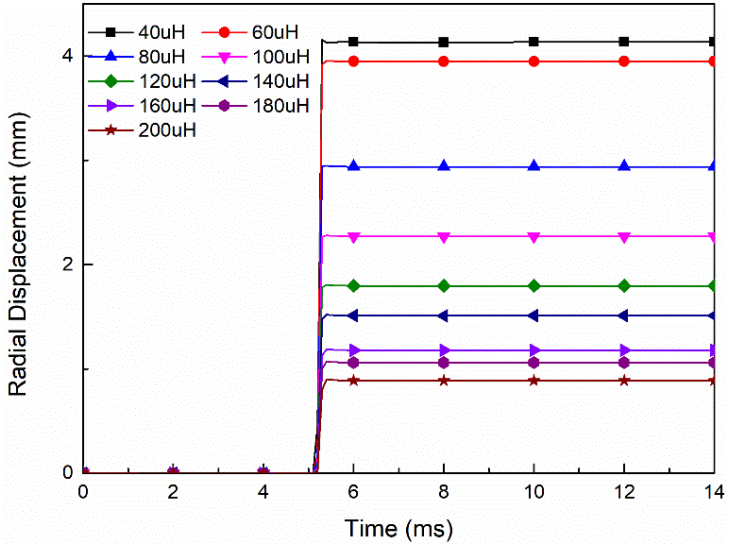

Fig. 2 Radial displacement of tube in narrow power system with different inductance values.

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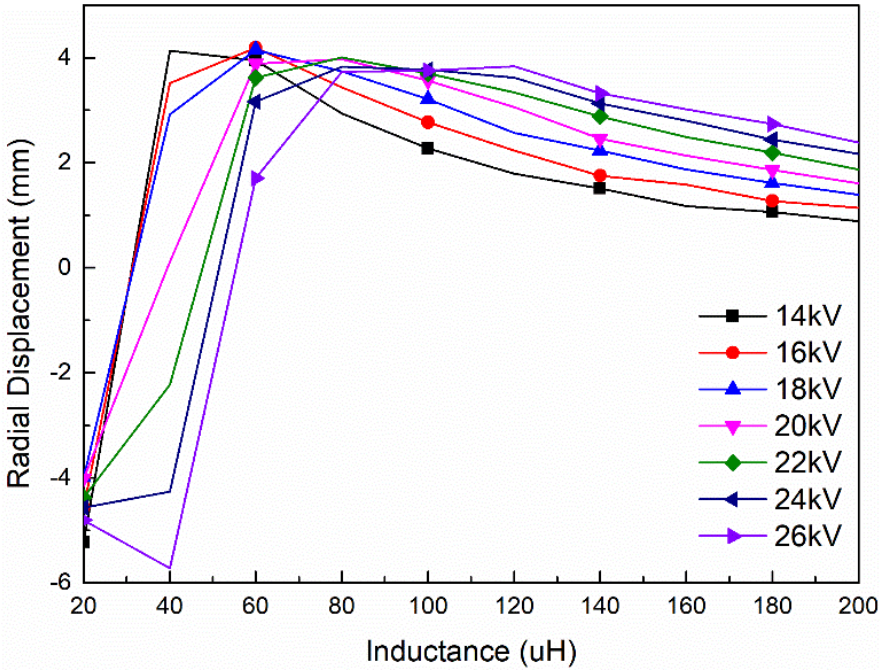

Fig. 1 Radial displacement of tube in narrow power system with different inductance and different discharge voltage.

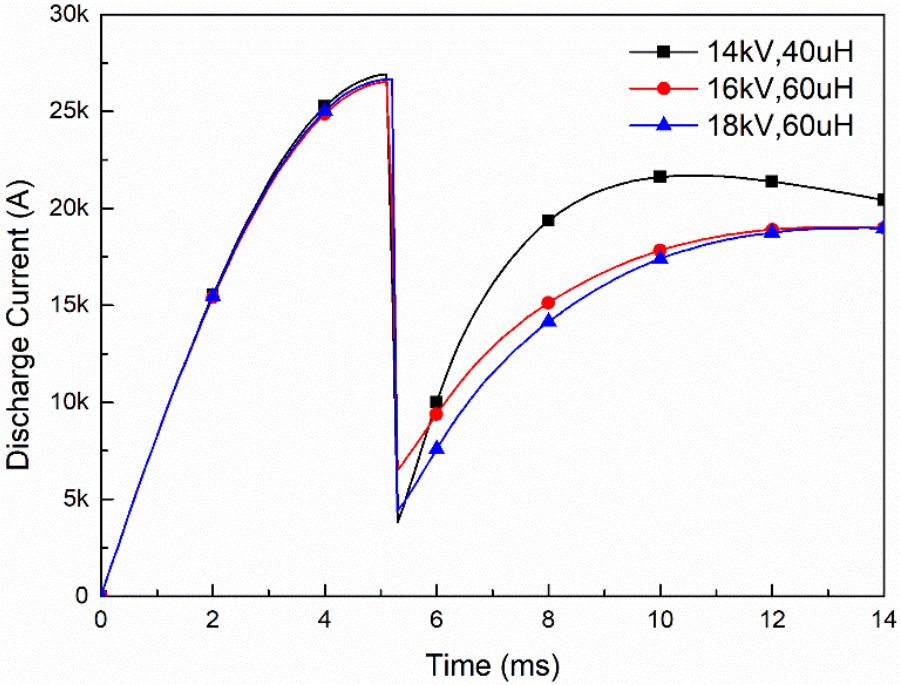

Fig.2 Discharge current of three case.

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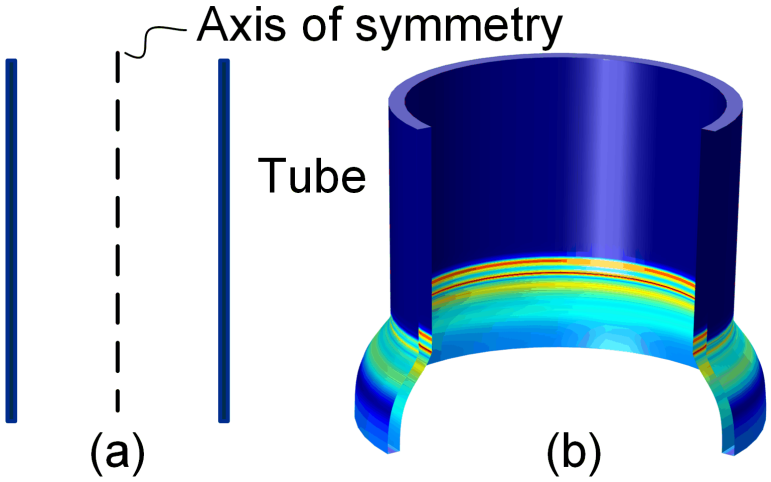

before

after

4.19mm @ 16kV,60μH

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Summary and Prospect

Summary:

- ✓ Attractive bulging is not impossible
- ✓ A maximum expansion of the tube with a diameter of 20 mm was got: 4.19 mm@16kV, 60μH.

Prospect:

- ✓ Experiments
- ✓ Less energy, larger deformation

THANK YOU