MHD Coating Requirements

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Introduction

- For a self-cooled liquid metal blanket for MFE systems, an insulating coating is necessary to control the MHD pressure drop.
- This insulating coating can be in the form of self-healing coating, a permanent coating or an insulated insert.
- It is important to define how perfect this coating need to be.

MHD Pressure Drop in Fully Developed Flow

Conducting wall

$DP/DX = VB^2 t_w k_w / a$

In which

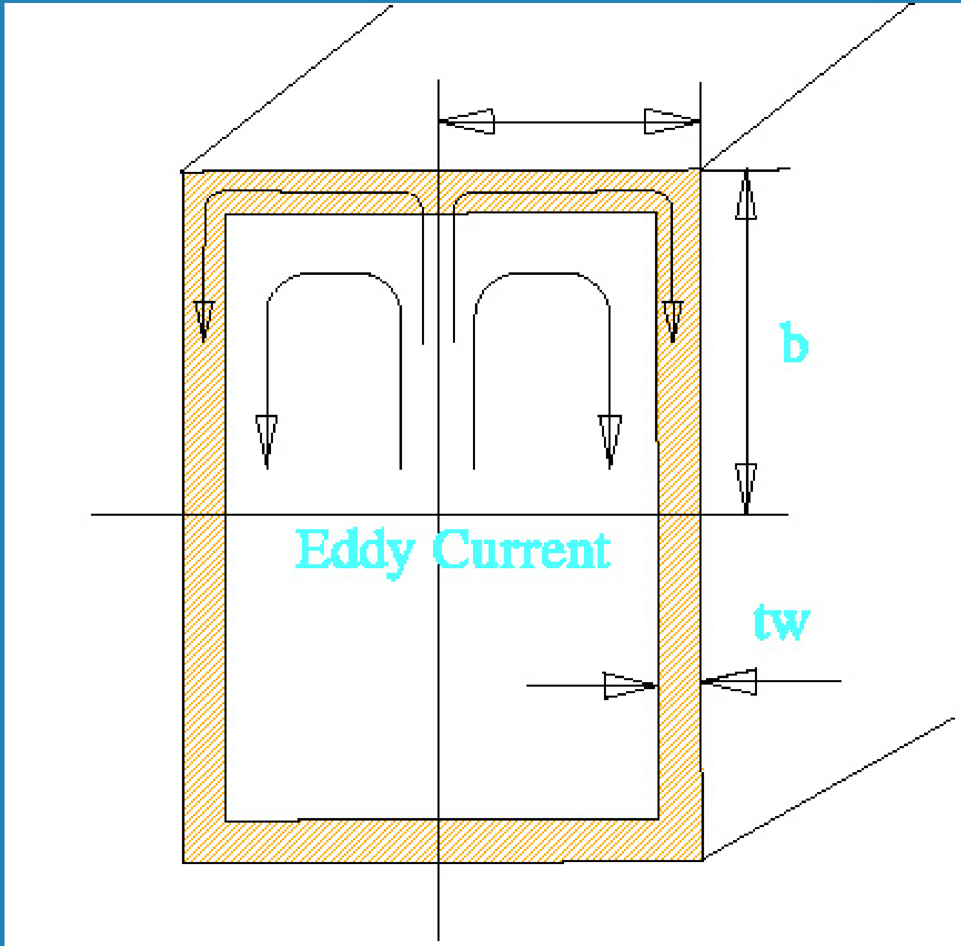
V: average velocity

B: the transverse magnetic field

t_w: wall thickness

k_w: wall electrical conductivity

MHD Pressure Drop in Fully Developed Flow(Continue)



Geometry for Conducting Wall

Insulating Wall Duct

$Dp/dx = kVB^2/M$

K: Fluid electrical conductivity

$M = Ba(k/u)^{0.5}$

U is the viscocity of the fluid.

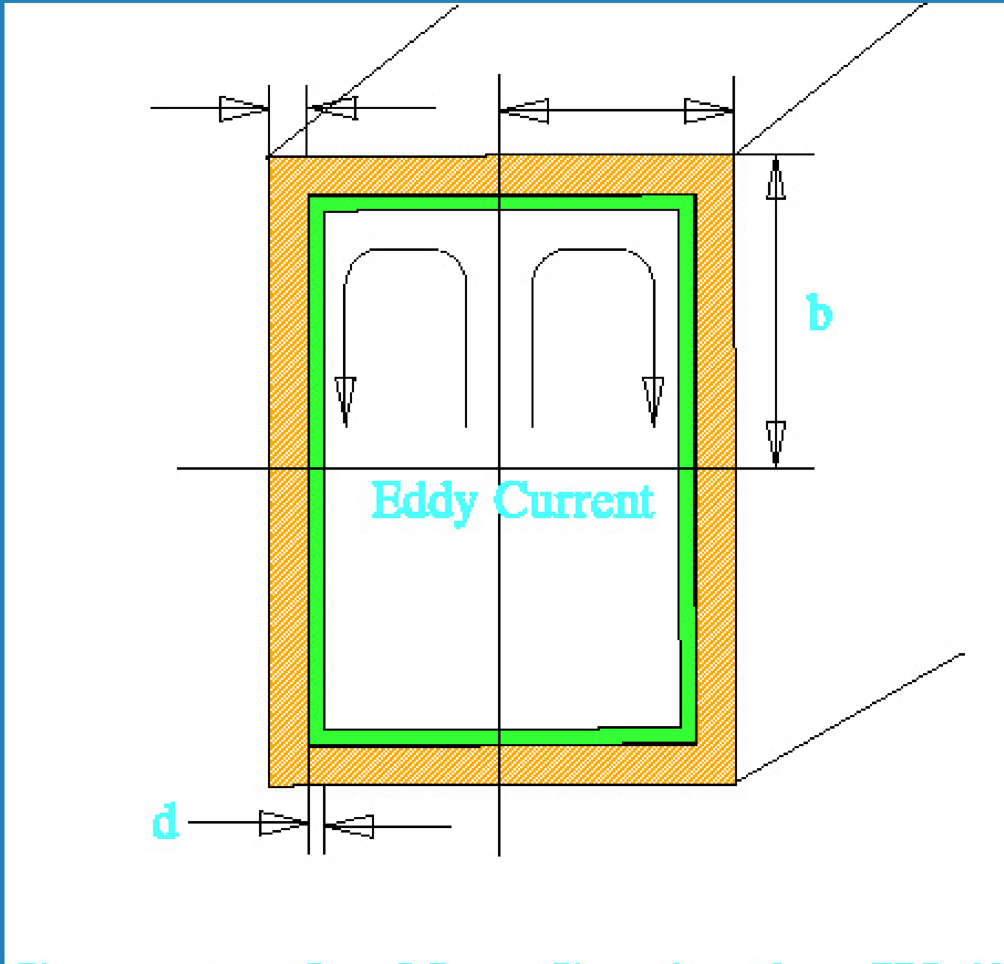
If $a = 5$ cm, $t_w = 5$ mm, $B = 11T$, $V = 1m/s$,

$L = 1$ m

For conducting wall DP= 12 MPa

For insulated wall DP= 0.01 Mpa

Insulating Wall Duct (Continue)



Geometry for Non-Conducting Wall

Coating Requirements

- • Thermodynamically stable at elevated temperature.
- • Chemically compatible with liquid metal and structural material at elevated temperature.
- • Sufficient high electrical resistance during normal operation.
- • Either self-healing or maintain low cracking fraction during the operation.

Question

What is the acceptable cracking fraction in the coating?

Answer

The electrical resistance across the crack is much larger than the electrical resistance on the side wall.

Current Path on the side wall

The resistance on the side wall is

$$R_w b/t_w$$

The resistance on the crack is

$$Rd/ax$$

Current Path on the side wall (Continue)

In which R_w is the electrical resistivity of the wall material

b is the dimension of the channel perpendicular to the field.

t_w is the wall thickness

R is the electrical resistivity of the coolant

d is the coating thickness

a is the half width of the channel parallel to B

x is the fraction of the crack.

Current Path on the side wall (Continue)

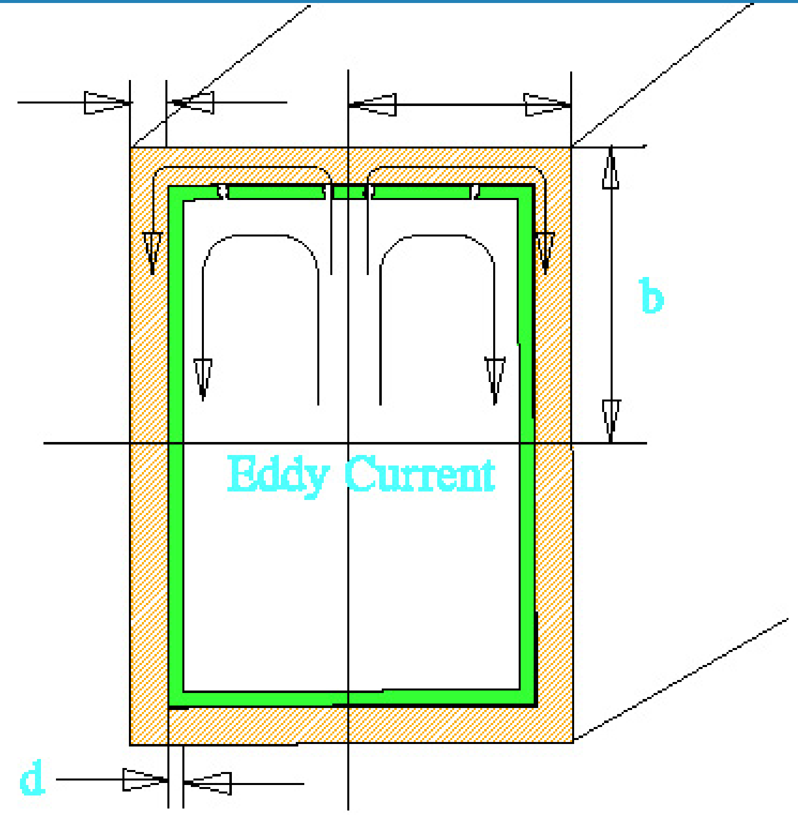
For the channel to act as insulated channel, the resistance has to be dominated by the crack, or

$$Rd/ax >> R_w b/t_w$$

R is $0.25X10^{-6}$, d is 10 micro, t_w is 1mm, a is 5cm, R_w is 10^{-6}, and b is 10 cm. Therefore,

$$X \text{ is } << 5X10^{-7}$$

Current Path on the side wall (Continue)



Geometry for Non-Conducting Wall With Crack

Conclusion

- For the wall to act like a perfectly insulated wall, the fraction of the crack on the wall has to be less or about 10^{-10}.
- If the cracking fraction is higher than 10^{-7}, the wall will act like a perfect conducting wall.
- Question: Can we develop and maintain an insulated wall with a cracking fraction below 10^{-10}?

- Possible Solutions
- * Develop a self-healing coating.
- * Develop a laminated wall system.
- * Investigate the contact resistance between the liquid and the wall.
- * Investigate designs which can accept higher crack fraction.