INVESTIGATION OF DIFFERENT COMBINATIONS OF STEADY AND ALTERNATING MAGNETIC FIELDS TO CONTROL THE HYDRODYNAMICS AND HEAT/MASS TRANSFER IN SINGLE CRYSTAL GROWTH

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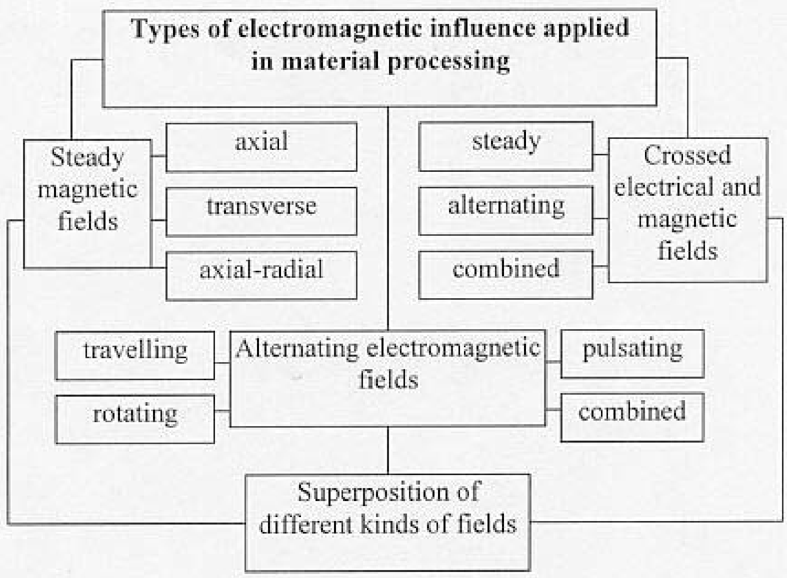
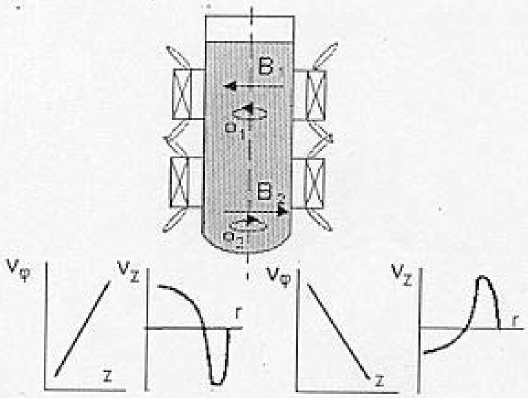
Classification of Versions of Combined Electromagnetic Influence Applied in Material Processing



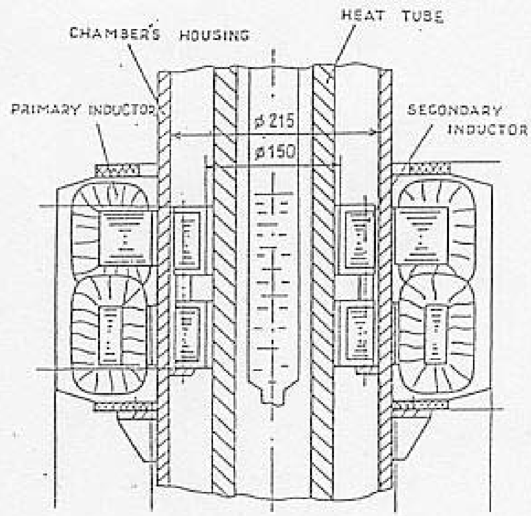
The questions to investigate:

- **Is it possible to combine in one technological aggregate (process) different positive from the practical viewpoint phenomena outcoming from different types of electromagnetic influence?**
- **Is it possible to compensate "deleterious" phenomena from one type of electromagnetic influence by "favourable" phenomena from the other?**
- **Is it possible to extend the range of the parameters for controlling the convective phenomena in the melt by combining different types of electromagnetic influence?**
- **Is it possible to join different types of electromagnetic fields in one construction of the inductor.**

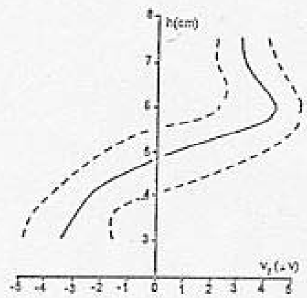
COMBINATION OF TWO COUNTER-ROTATING MAGNETIC FIELDS PLACED ONE ABOVE ANOTHER



Scheme of velocity patterns due to superposition of two RMFs

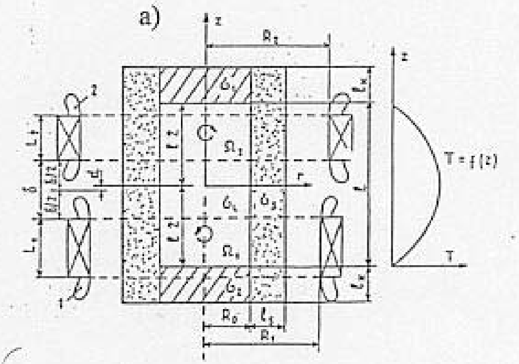


Scheme of a double inductor for high-temperature melts



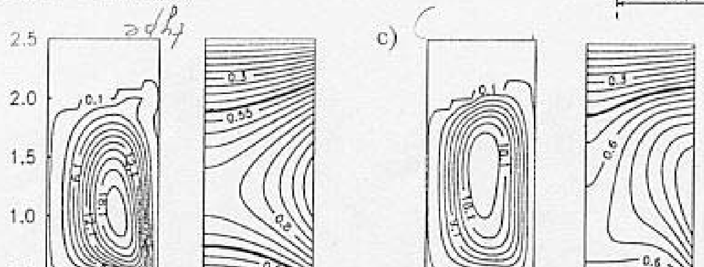
Distribution of azimuthal velocity (solid line) and range of velocity pulsations (dashed lines) generated by a double inductor. 1μV = 0.7 mm/s.

a)



b)

$Gr = 10^5$
$Te = 10^6$
$\frac{Te_2}{Te_1} = 1$



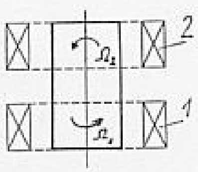
$Gr = 10^5$
$Te = 10^6$
$\frac{Te_2}{Te_1} = 0.8$

Scheme (a) and numerical results of the influence of a double inductor on the shape of crystallization front

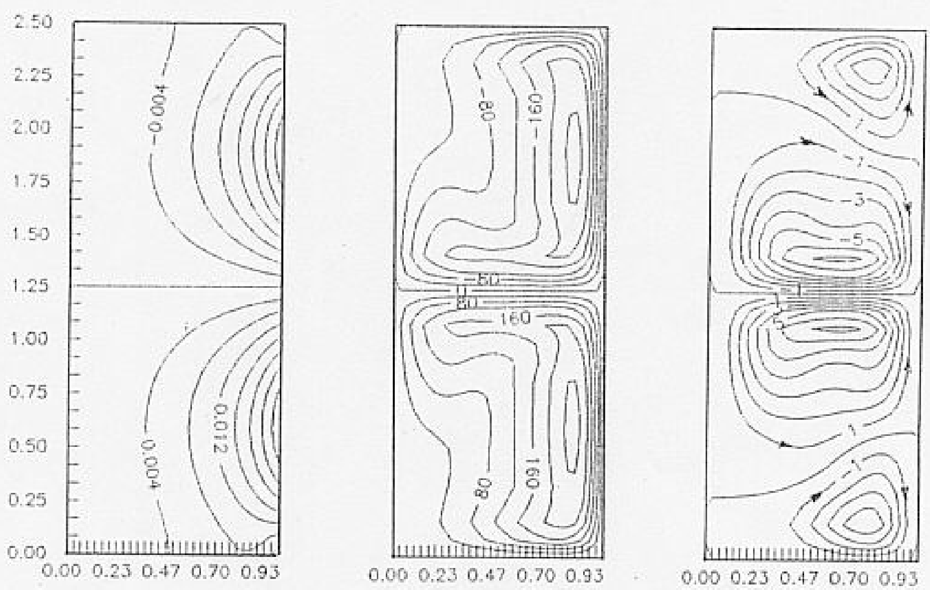
Distribution of electromagnetic forces, azimuthal and meridianal velocities for the case of two inductors generating magnetic fields rotating in opposite directions

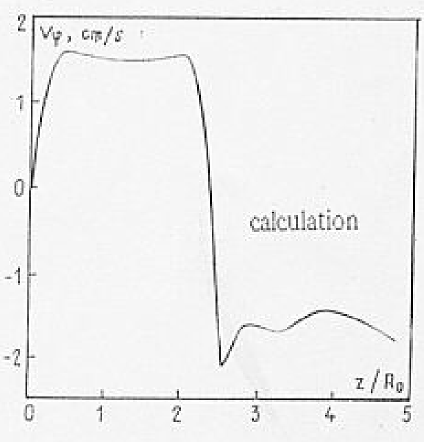
I. Electromagnetic force symmetrical distribution in the inductors

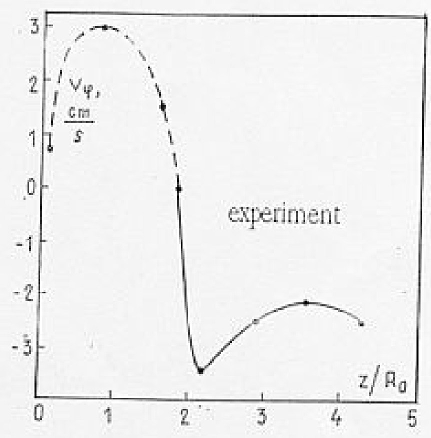
computational model



Distribution of electromagnetic force | Distribution of azimuthal velocity | Streamlines of meridional flow

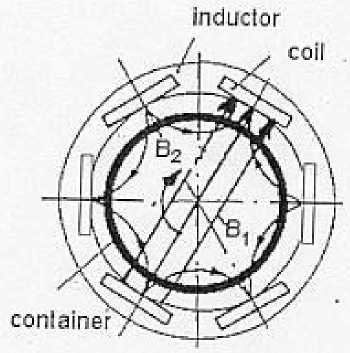




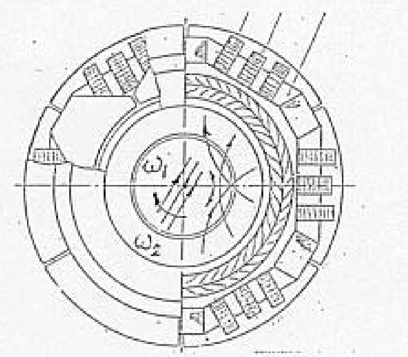


Comparison of calculation and experimental results.

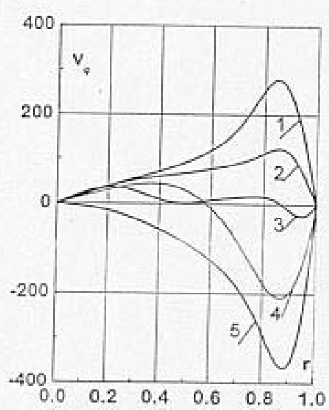
COMBINATION OF TWO RMF WITH A DIFFERENT DEPTH OF PENETRATION INTO THE MELT

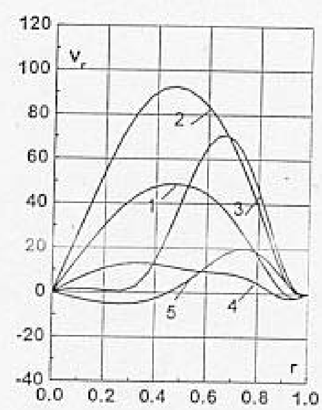


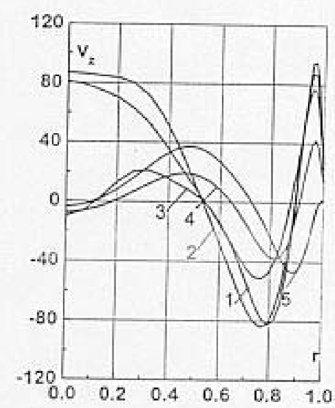
Scheme of superposition of two types of RMF



Scheme showing how to implement two types of RMF in one inductor







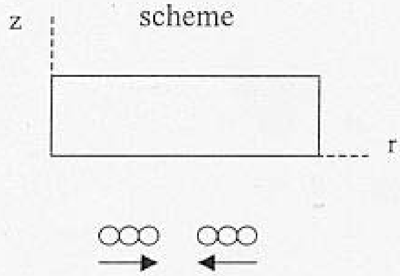
Distribution of V_φ, V_r and V_z velocity components at different operating regimes of a combined inductor.

$p_1 = 1$; $p_2 = 2$; $\omega_1 = \omega_2 = 8.2$; $Te_2/Te_1 = 2.5; 3; 3.9; 5; 8.$

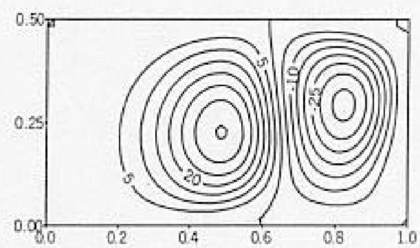
Travelling Electromagnetic Fields

<u>The case for Te = 10^7; Gr = $3\cdot10^6$; ω_* = 100; Sc=100; l/R=0.5</u>

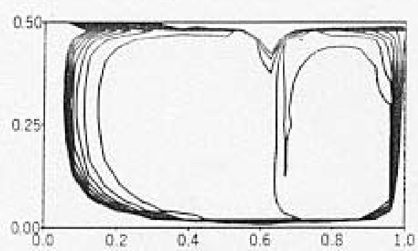
scheme



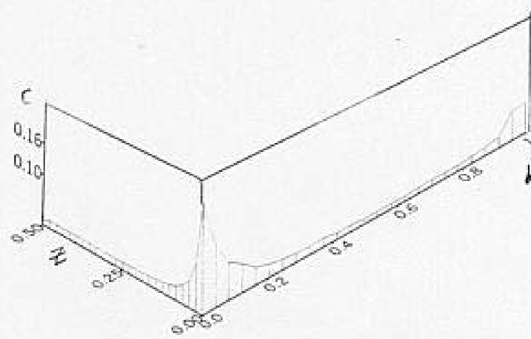
streamlines



isolines of concentration



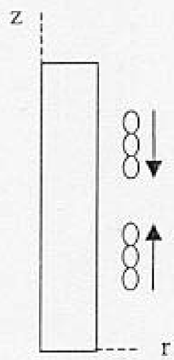
distribution of concentration



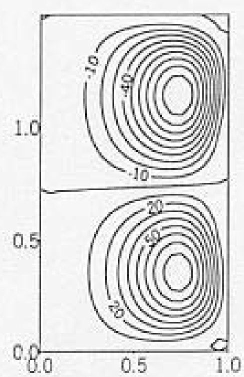
Travelling Electromagnetic Fields

The case for Te = 10^7; Gr = $3\cdot10^6$; ω_* = 100; Sc=100; l/R=1.5

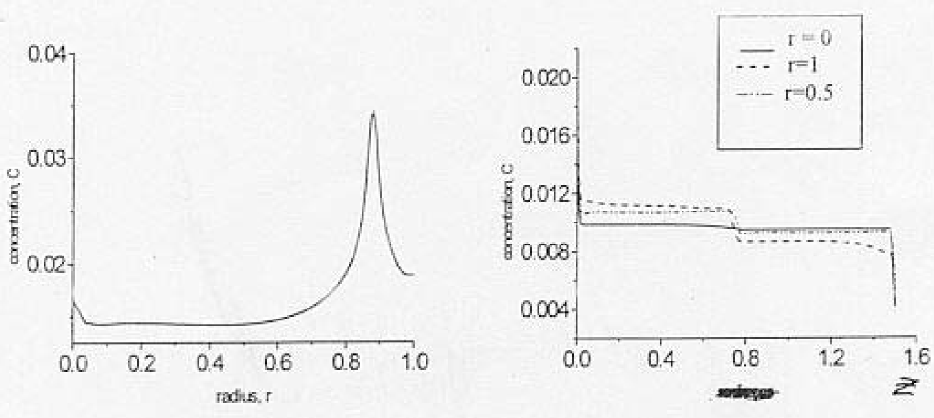
scheme



streamlines

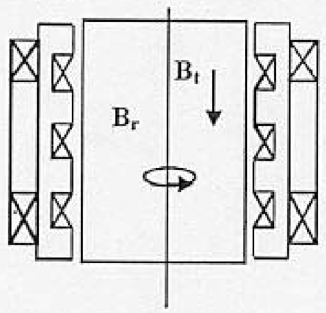


distribution of concentration



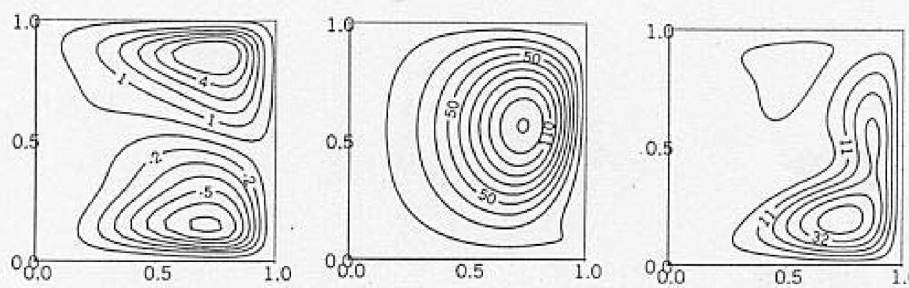
Combinaton of Rotating (RMF) and Travelling (TMF) Magnetic Fields

1. Schematic for implementing the combination of RMF and TMF

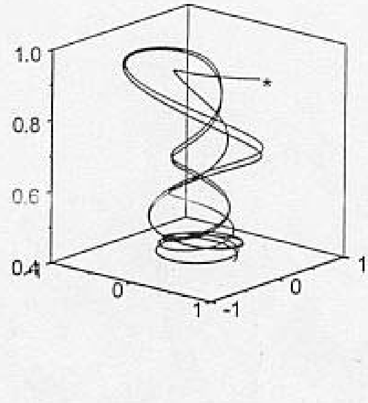


2. Meridional flows in situations when:

RMF ≠ 0, TMF = 0; RMF = 0, TMF ≠ 0; RMF ≠ 0, TMF ≠ 0

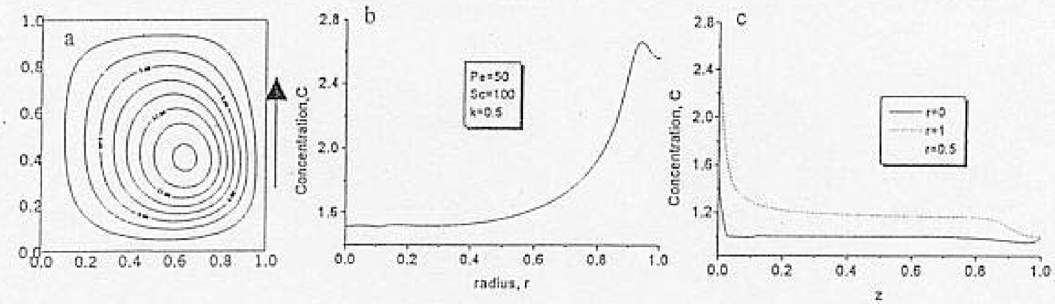


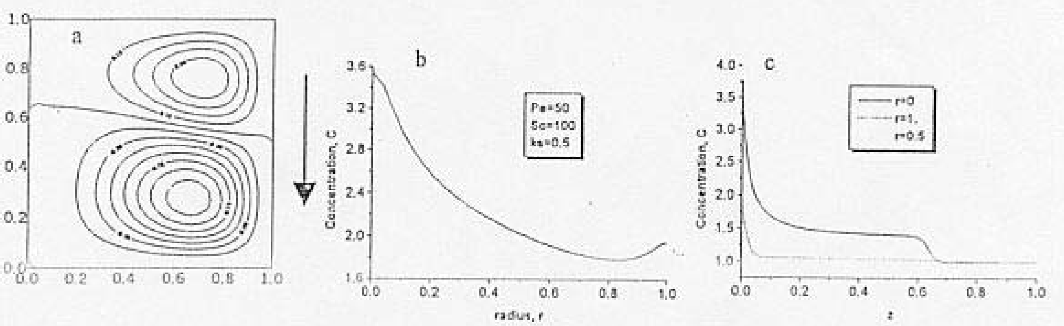
3. Flow paths of liquid particle



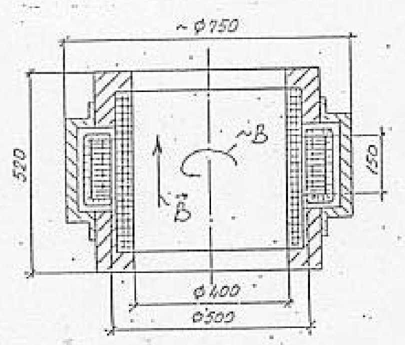
Combination of Travelling (TMF) and Rotating (RMF) magnetic fields

Meridional flows and the dependence of concentration distribution for $B_{RMF} = B_{TMF}$ and $Gr = 8.6 \cdot 10^6$

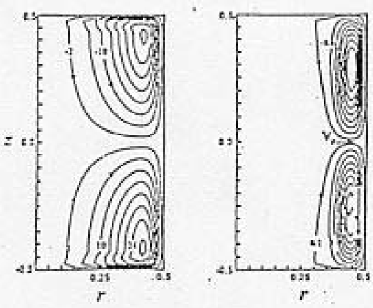




Combination of Rotating (RMF) and Vertical Steady (SMF) Magnetic Fields

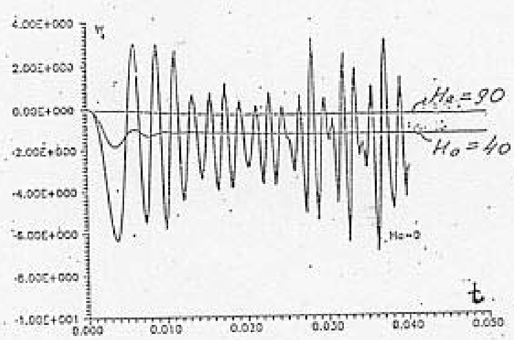


Schematic of the inductor

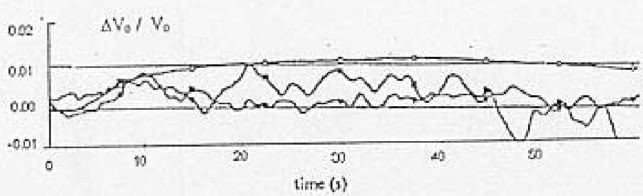


Distribution of meridional flows:

a) for small values of steady magnetic field induction
b) for large values of steady magnetic field induction

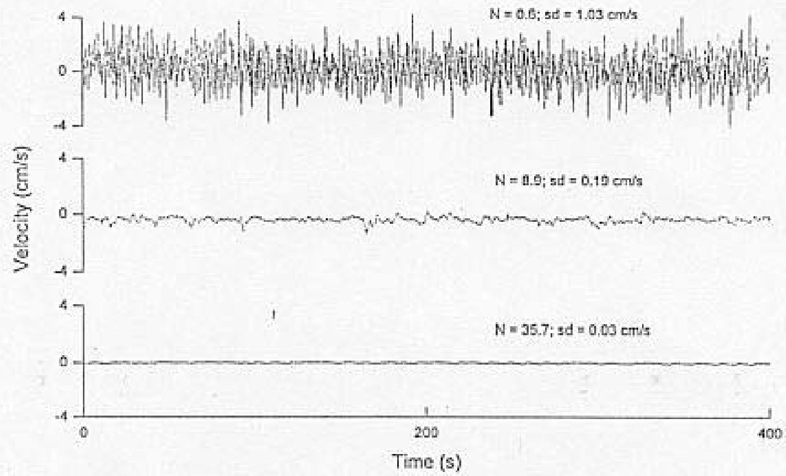


Flow regimes for different values of the steady magnetic field

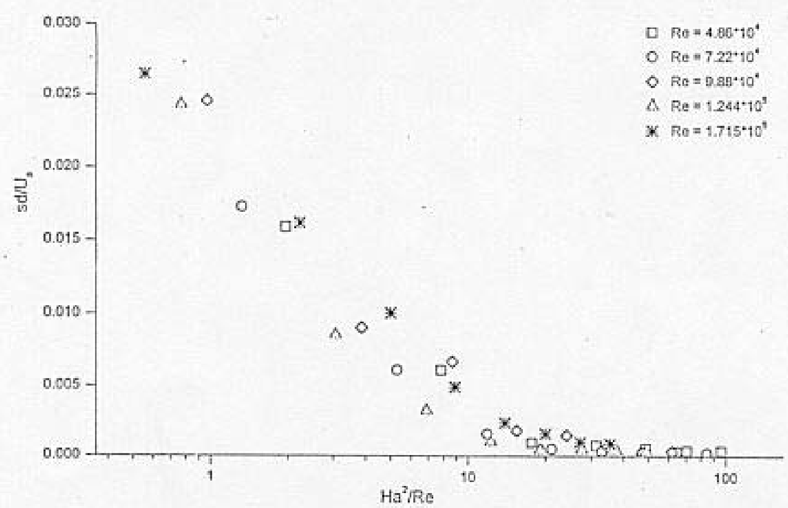


Experimental results of the SMF influence on the flow oscillations generated by RMF at Re = 10^4 and Hartman numbers: - ■ - = 35; - ▼ - = 115; - o - = 290

Combination of HF Pulsating and Steady Magnetic Fields



Vertical DC magnetic field. Pulsating component of velocity at 0.5L, 0.5W, 0.1H and Re = 171000 for three values of the Hartmann number: sd – static deviation of the signal from the mean value



Normalized static deviation of velocity pulsations in the core of the liquid metal vs MHD interaction parameter