STUDY OF TURBULENCE THE IN PRESENCE OF STRONG ELECTROMAGNETIC NOISE IN THE MHD STIRRER WITH TRAVELLING AND ROTATING MAGNETIC FIELD

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Abstract : We discuss the problem of spectral analysis of signals from electromagnetic probes operating in turbulent MHD flow, provided by strong magnetic field. Using a wavelet based technique for cross-correlation signal analysis and filtrating we show that at frequencies lower than the frequency of applied magnetic field the spectral properties of the velocity field can be clearly seen in spite of the fact that the measured fields are much weaker than the driving rotating (or travelling) magnetic field.

1. Introduction

External alternating electromagnetic fields (for example rotating or/and travelling magnetic fields) are widely used in various areas of science and technology for liquid metal flow generation. Arising flows are characterized by sufficiently strong turbulence. Turbulence affects the processes of heat and mass transfer in liquid metals, and its study is an important applied (and scientific) problem.
However, direct measurement of turbulent fluctuations in the considered flows is problematic. This is due to the fact that the measurement of the turbulent flow characteristics are made by sensors which are located in the metal forced by the external alternating electromagnetic field. In this case, weak currents and their fluctuations measured by sensors contain information not only about the turbulent flow characteristics, but also about fluctuations of the external electromagnetic fields. Hence, there is a problem of separation of the useful signal in such experiments from interference caused by external fields.
We study the possibility to separate the pulsations caused by the liquid metal flow from the direct and indirect influence of the applied magnetic field. In our studies, we used one of the most common methods for measuring velocity in MHD flows based on the conductive probes. For processing the obtained data, we have developed a method based on the wavelet analysis.

2. Presentation of the problem

We study the liquid metal flow generated in a cylindrical vessel by the electromagnetic stirrer (fig. 1). The stirrer is a set of a ferromagnetic core (magnetic circuit) and copper coils which generate variable magnetic field inside the cylinder volume. A cooling system of tubes, in which water is circulating, prevents the coils overheating. The stirrer includes two independent coil systems which allow to generate the rotating flow (by rotating magnetic field, RMF) and the poloidal flow (by travelling magnetic field, TMF) [1, 2].
The velocity measurement were carried out using 2 conductive probes, mounted on the side wall of the vessel on the distance of 10 mm from the wall (fig.1). We use 2-axis local probes designed to provide a good dynamical resolution of rotating and poloidal motions. A small permanent magnet imposes locally a strong magnetic field and nearby electrodes are used to measure the induced difference of electric potentials, linked to the local velocity of the fluid. Each conductive probe consists of two pairs of electrodes 1 placed around the magnet 2 (the

sizes of the magnets are 10 x 2 x 2 mm), magnetic field induction on the magnet is ~20mT on the distance of 3 mm. Diameter of the sensor housing 3 is 6 mm. The probe measures the axial and azimuthal velocity components. The instrumentation preamplifier 4 is INA128 (Texas Instruments, bandwidth 20 KGz, common-mode rejection ratio above 120dB with gain 30dB). The data acquisition system comprises an 24-bit analog-to-digital converter (ADC) NI 9227 with a sampling rate of 5 kHz. Also, we are recording the signal from the current loop, located on one of the phases of the power supply and the signal from the Hall sensor PM placed outside the vessel inside the stirrer (fig.1).

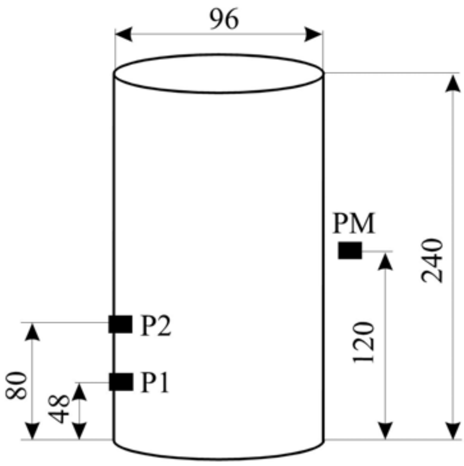

Figure 1: Scheme of sensors position.

Analyzing signals, we have recognized a strong dominance of harmonic (and nonharmonic) oscillations caused by the applied magnetic fields. This dominance makes questionable even the possibility to recover some reliable information concerning the properties of small-scale (turbulent) velocity oscillations. The signal show that the vertical (as well as the azimuthal) component of the velocity oscillates (and change directions) together with the magnetic field. The measured signals are well correlated and we cannot determine what do sensors measure: fluctuations of the velocity, magnetic fields or both.
To separate the useful signal against external noises, we developed a scale-by-scale correlations analysis filtering method, created on the base of wavelet analysis. The method allows us to define the range of frequencies for which the signal oscillations are strongly provided by the turbulence and not by the electromagnetic noise.
In the frame of the problem under discussion of special interest is the wavelet cross-correlation, which allows us to look for the scale-by-scale (or frequency-by frequency) cross-correlation of two signals [3]. The choice of the analyzing wavelet is very important. In the case of signals which contain a number of isolated events (pulses) of different duration (scale) and one would like to analyze the correlation of this events in both signals scale-by-scale, the wavelet with a good space resolution is required.

3. Results

The modulus of the wavelet cross-correlation function between vertical component of velocity from probe P2 and the magnetic field, measured by the Hall probe at position PM (see fig.1), is shown in fig.2 for the case of applied RMF with different value of frequency. The strong correlated interval shifts to higher frequencies. It is related with the fact that the influence of the magnetic field occurs on the carrier frequency and multiples thereof. Hence, at frequencies below the carrier one the cross-correlation becomes small. Then, the measured spectrum should be determined in this frequency range by the flow fluctuations and not by the RMF. Thus, below the carrier frequency of RMF the potential probe is weakly affected by the strong external magnetic field and can be used for analysis of turbulence in the flow.

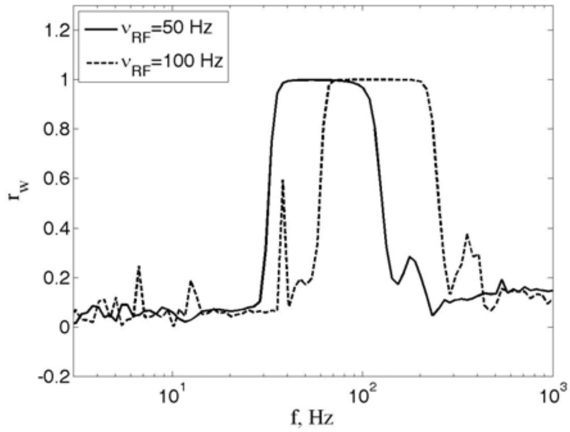

Figure 2: Cross-correlations for different frequency of applied magnetic field.

Rotating magnetic field leads to the formation of helical Taylor–Gertler vortices in the wall region. The size of the vortices depends on the velocity (Hartmann). Since different vortices have different direction of rotation, the traveling magnetic field acts on neighboring vortexes differently. Some vortices must be amplified, while others weaken. Sensors in the experiment located at a distance 10mm from the wall. As shown in [4], just as the sensors are located in vortex area. Therefore, we can assess the impact of both fields on the flow from the measured data. The figure **N** shows the change in the turbulence intensity measured by the probe P2. Clearly seen that the injection energy on the main scale (and therefore the entire spectrum) decreases with increasing amplitude of the traveling field. In addition, from the behavior of the spectra we can see, that structure of a turbulent field is changed too. Thus, we arrive at the possibility to control the intensity of turbulence near the wall, which is very important in many metallurgical applications.

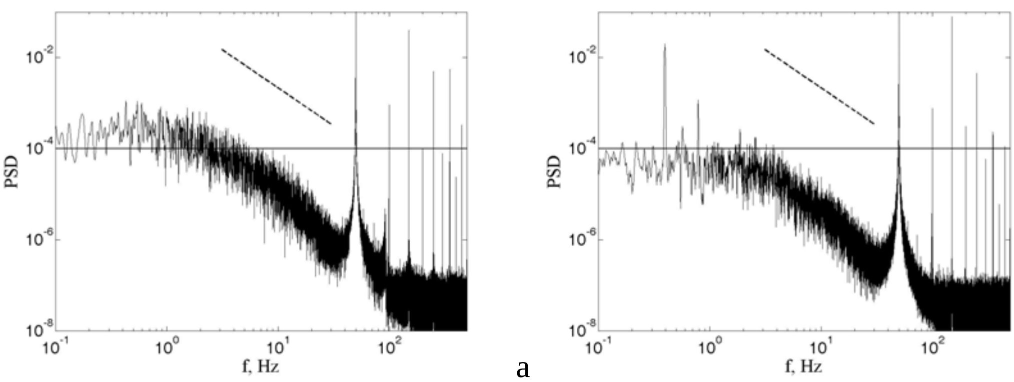

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Figure 3: Spectra of azimuthal component of velocity; (a) - I_{TMF} = 7A, (b) (I_{RMF} = 1.6 A, 50 Hz, probe P2, dotted line is the Kolmogorov's spectra -5/3).

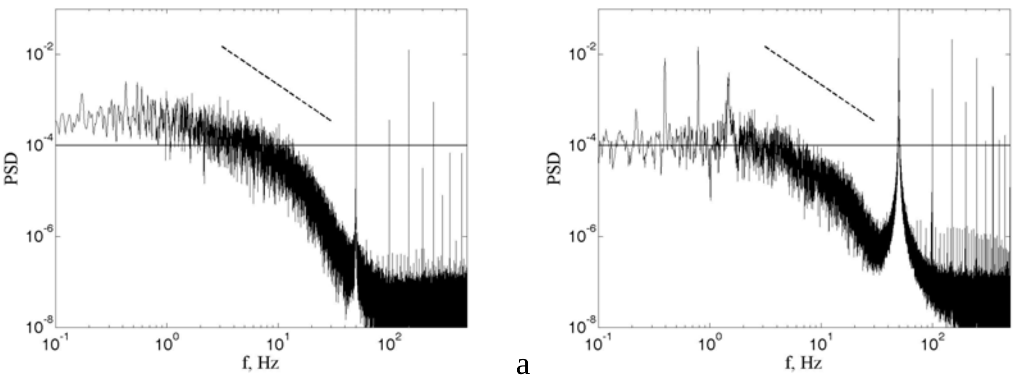

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Figure 4: Spectra of axial component of velocity; (a) - I_{TMF} = 7 A, (b) (I_{RMF} = 1.6 A, 50 Hz, probe P2, dotted line is the Kolmogorov's spectra -5/3).

3. Conclusion

Thus, we propose a method of purification and analysis of turbulent MHD experimental data. The developed method of processing these data, based on the study of scale-by-scale wavelet cross - correlations. We studied the possibility of separation between the signals from MHD turbulent flow pulsations and the direct or/and indirect influence of an external magnetic field. On the basis of wavelet cross-correlation analysis we show that it is possible to allocate a range of frequency in the measured spectra which characterizes the pulsations of the velocity field. Further development of this method will allow us to analyze the turbulence in the flow under the study and obtain its performance in different conditions of exposure to electromagnetic fields.

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4. References

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