Oscillations of an arc burning in mercury vapours and exposed to an external axial magnetic field were recorded. The fast Fourier transform, phase portrait construction and attractor dimension calculations show that the experimental results present a nonlinear dynamic system with a rich scenario of various metastable states and transitions between them. The system develops spontaneously with time mainly through a formation of new subharmonic frequencies. Among the different transition types especially the chaotic transitions may result in relatively long intervals of chaotic behaviour which are interesting from the point of view of the nonlinear system studies.

1 Introduction

An arc burning in mercury vapours and exposed to an external magnetic field was found to be a good example of the nonlinear dynamic system, showing some features which are for such systems typical (see Něnička and Hlína [1], Hlína and Něnička [2], Hlína and Něnička [3]). The Lorentz force generated by the magnetic field is responsible for the change of the straight arc column into a spiral-shaped one and it also presents a source of energy for the arc oscillations which arise under some conditions, determined mainly by the magnetic field intensity and pressure in the tube. An arc rotating in an intrinsic or external axial magnetic fields was a subject of some theoretical and experimental investigations dealing with the dependence of the arc rotation frequency on the arc length and magnetic field intensity (Gaede [4]) or with conditions leading to the onset of the arc rotation (Hülsmann and Mentel [5,6]). In these papers, however, the authors have not studied the development of complicated oscillation types with nonlinear transitions, characterizing the arc motion in the mercury vapour discharge tube, from the point of view introduced by the theory of nonlinear dynamic systems.

The development of the dynamic system represented in our case by the time series carrying the information about the arc voltage and motion can be analysed by a wide range of methods which have been developed and tested for various theoretical and experimental nonlinear dynamic systems. Most of these methods have been published during the last 15 years. One of the attractive features of these systems is their relative simplicity (e.g., the autonomous Lorenz system can be generated by the system of 3 nonlinear differential equations). The nonlinear dynamic systems, though they are deterministic, can show both the regular (periodic) and chaotic behaviour. The transitions between both behaviour types (which can be identified with the transitions between the laminar and turbulent flow in relevant cases)
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present an important subject for the studies of nonlinear systems. The experimental results based on the records of the arc oscillations in the external magnetic field include different types of such transitions and may be therefore used as a good material for the studies of nonlinear system properties; on the other hand, the results and conclusions following from the theory describing the properties of these systems in general can be adopted to derive some interesting characteristics of our experimental system.

The behaviour of the experimental system presented here also shows one important feature of nonlinear systems: the system evolution is extremely sensitive to initial conditions. Our system develops in quite different ways though the basic quantities determining the principal experimental conditions (the arc current, magnetic field intensity etc.) are, as far as possible, set to the same values at the beginning of the experiment.

The aim of this paper is to summarize the principal manifestations of nonlinear behaviour of the experimental system and to show the way in which some approaches familiar in the theory of nonlinear dynamic systems can be applied to our case.

2 Experimental arrangement

The experimental apparatus (Fig. 1) consisted of a vertically situated mercury vapour discharge tube (medium pressure type TESLA RVL 250 with an electrode separation of 55 mm and an inner diameter of 17 mm) which was fed through a

![Diagram of experimental arrangement]

Fig. 1. Experimental arrangement.