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Application of the Ultrasound Velocity Measuring Technique to Stirred Vessel Flows with Multi Element Stirrers

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ABSTRACT

1. Introduction

In many fields of the chemical industry, stirred vessel flows are of great importance. Flows of this kind are also of interest to people working in the field of sewage water treatment. Whereas the nature of stirred vessel flows is known and methods have been developed to upscale laboratory experiments, details of the flow are unknown but become of increased importance for detailed layouts of stirred reactors. Measuring techniques, such as laser Doppler anemometry (LDA) usually provide very accurate information but require optical access to the measuring point. This means the use of the LDA-technique in full scale reactors is normally complicated and requires extensive experience of the scientist. Furthermore, these measurements are usually time consuming and yield more detailed information than is needed in praxis. Because of this, an ultrasonic measuring technique (UVP-monitor) has been applied for flow field studies by the authors, providing velocity profile information along the penetration length of an ultrasound wave. Appropriate signal processing yields local velocity information of mean flow properties. This information provides an insight into the flow field of stirred reactor flows with multi element stirrers, studied in the present fluid mechanic research work.

2. Background

In waste water treatment plants biodegradation of pollutants takes place in stirred and aerated tanks. Flakes of sludge which consists out of different colonies of bacteria are responsible for the biological decomposition. These flows must be distributed homogeneously in the basins to use the whole volume. Furthermore deposits could disturb the process essentially. Therefore a minimum bottom velocity is required for waste water treatment plants by

German authorities. To guarantee the desired flow field for different tank geometries laboratory scale experiments are made. In the present work a hyperboloid stirrer which was developed at LSTM-Erlangen is employed. This agitator is distinguished by its special shape, which ensures an attached flow directly above the stirrer surface. Separations and related flow losses are thus minimised. The transport ribs on the stirrer surface cause the waste water to flow off in a radial direction and therefore enhance the circulation of the tank contents. Owing to its energy input near the bottom and the related high bottom velocities, the hyperboloid stirrer possesses good suspension qualities combined with low energy consumption. Increased movement of the water surface, and additional entry of oxygen during denitrification are avoided.

3. Test rig

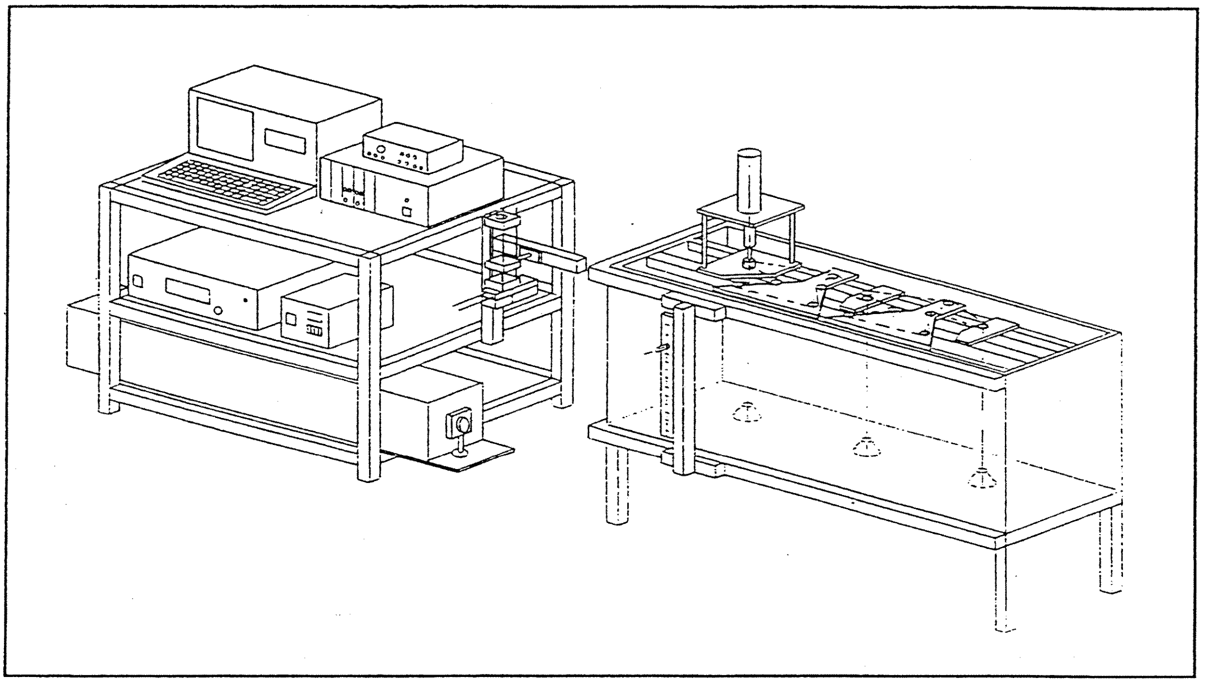


Fig. 1: Schematic drawing of the test rig

A test section was set up, as shown in figure 1 and 2 of the present abstract. The test rig was constructed to achieve geometrical similarity with the most rectangular basins which are used in practice. The volume of the tank can be reduced by a variable wall and so it is also possible to reach the shape of a square tank. Light sheet techniques were employed in order to characterize the flow field generated by one, two and three hyperboloid stirrers mounted in a test section. A UVP-monitor was used to map out the flow field. Prior to the main investigations, tests were made to select the most suitable scattering particles for measuring through a wall made of plexiglas.

The background of these experiments was to determine an installation specification for this kind of stirrer with an optimal relation of operational and investment costs. To reach this aim stir up tests were carried out with artificial sludge, whereby the velocity of the fluid was

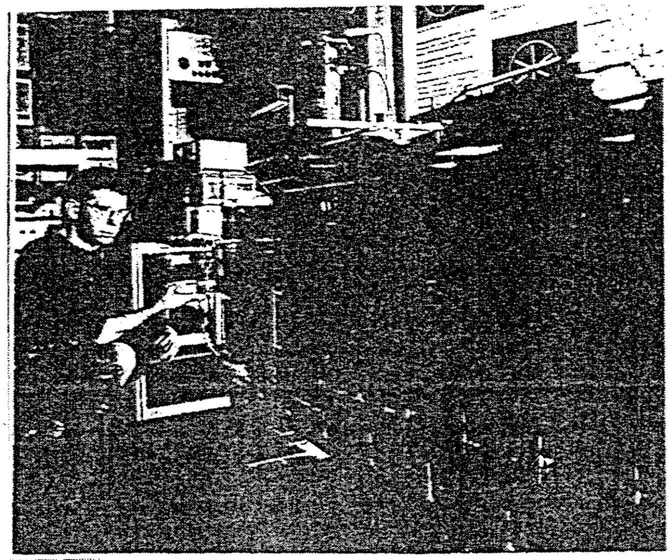


Fig. 2: Photo of the tank

measured at a representative point as a function of the rotational speed of the stirrer, the filling level and the relation of length to width of the tank. The measuring position was found on the basis of flow mapping. We determined that there is a region at the edge of the basin, where the axial component of the velocity is more than 99% of the resultant velocity. So we can characterize the effectiveness of the hyperboloid stirrer (the minimum rotational speed to ensure suspension of the artificial sludge) with just one measurement of one velocity component in the vessel. These results can be transferred to industrial plants.

The UVP-monitor was employed in order to map out the entire flow field inside of the water container. Local velocity information in horizontal planes is shown, for example, in figures 3 and 4. Information has also been acquired on turbulence properties and the local energy dissipation of the stirrer inside of the water container (see figures 5 and 6).

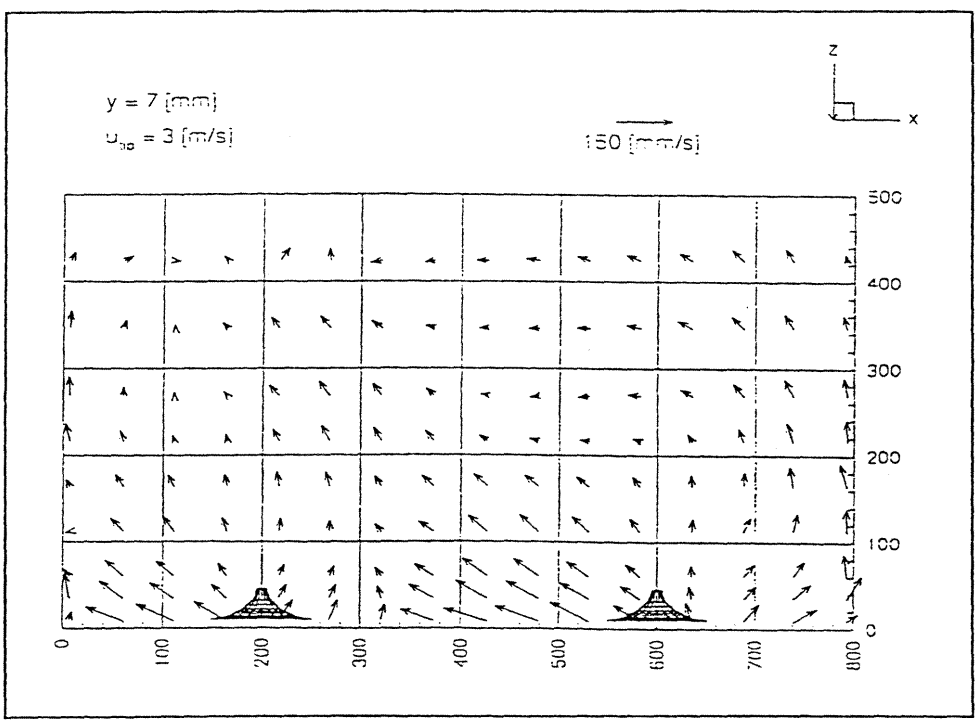


Fig. 3: Horizontal flow mapping of one plane

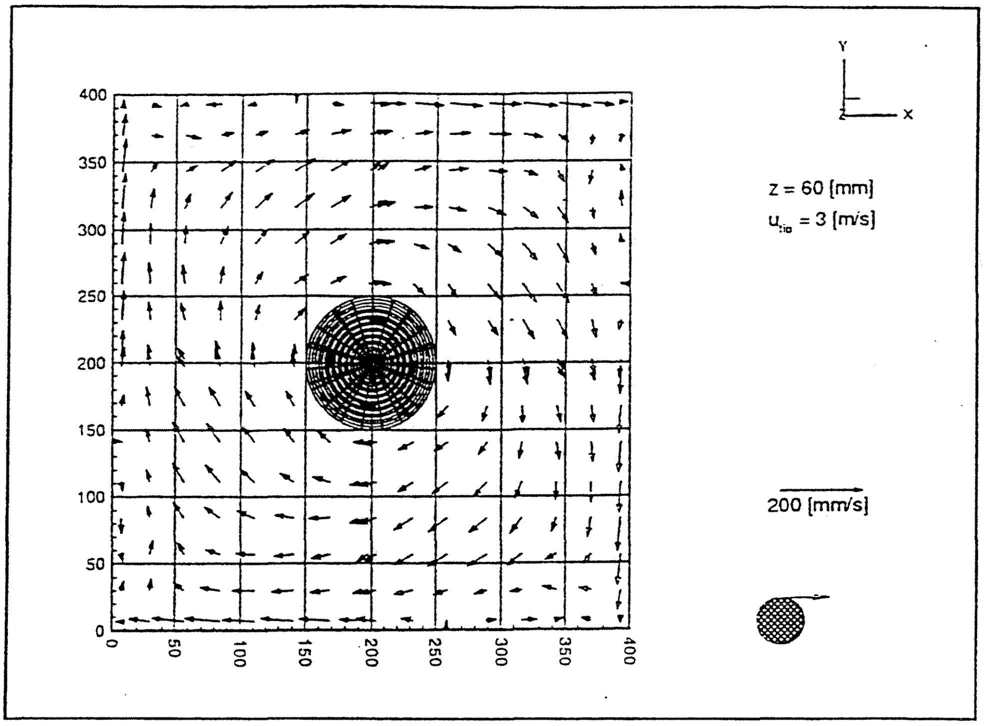


Fig. 4: Vertical flow mapping of one plane

The turbulent flowfield is composed of vortices with a different power density. These fluctuations of the local mean velocity contribute to an effective mixing in a stirred tank. The vortices decay step by step in smaller units and ultimately dissipate. To stir a mixture gently a homogeneous distribution of the dissipated energy is strived for in the whole tank.

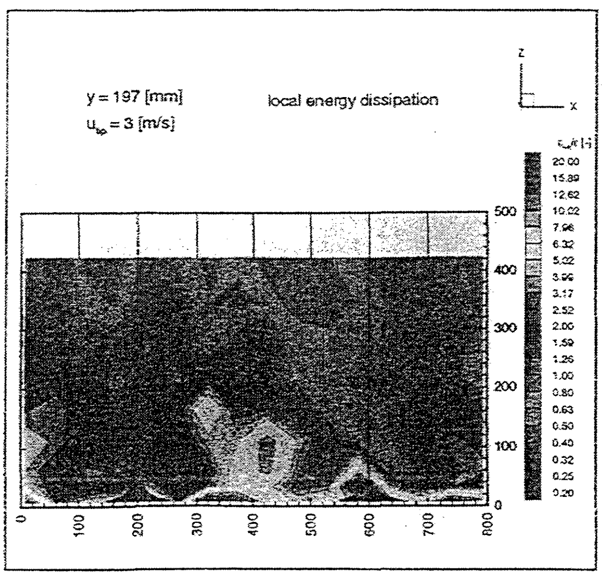


Fig. 5: Turbulence intensity of a horizontal plane

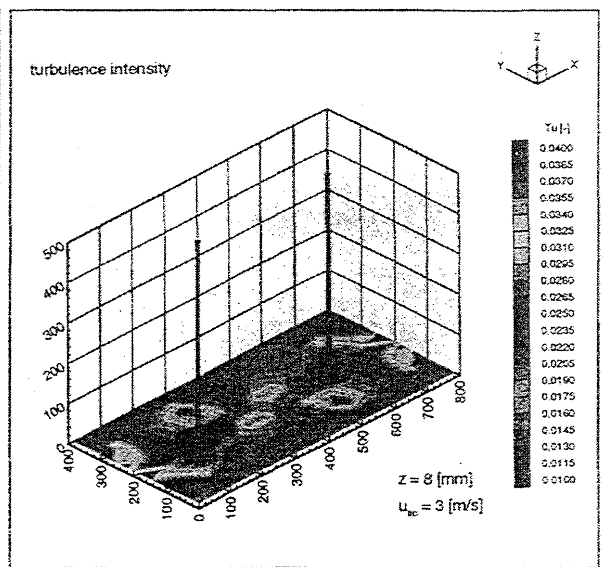
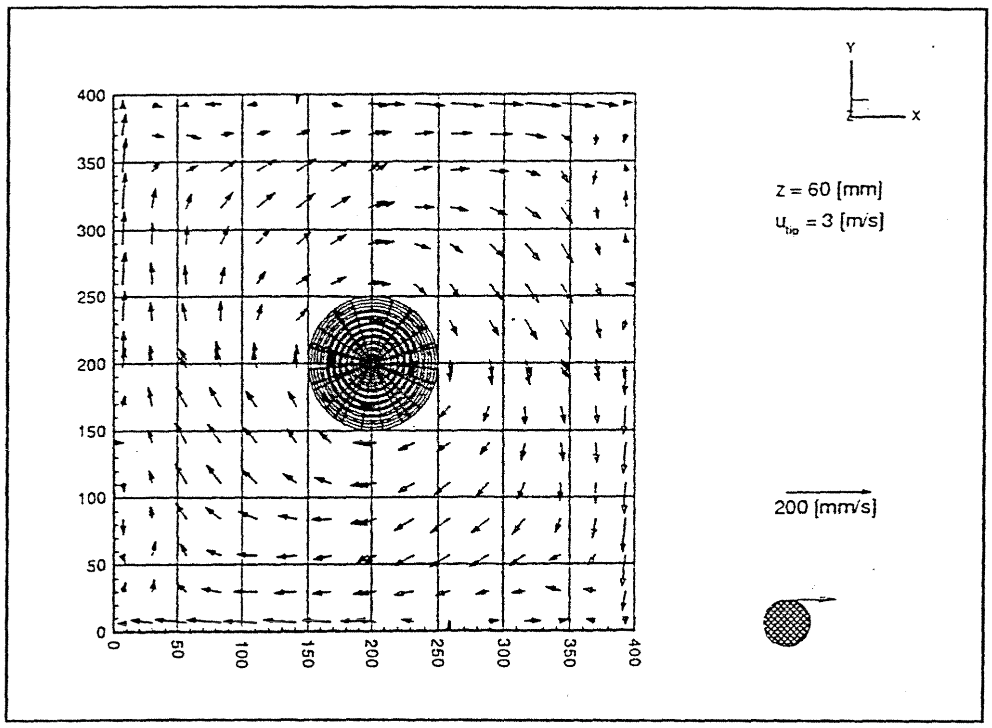


Fig. 6: Local energy dissipation in a vertical plane



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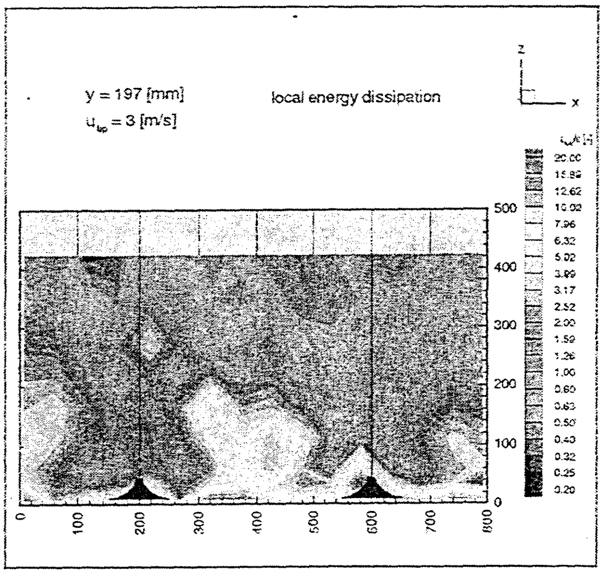

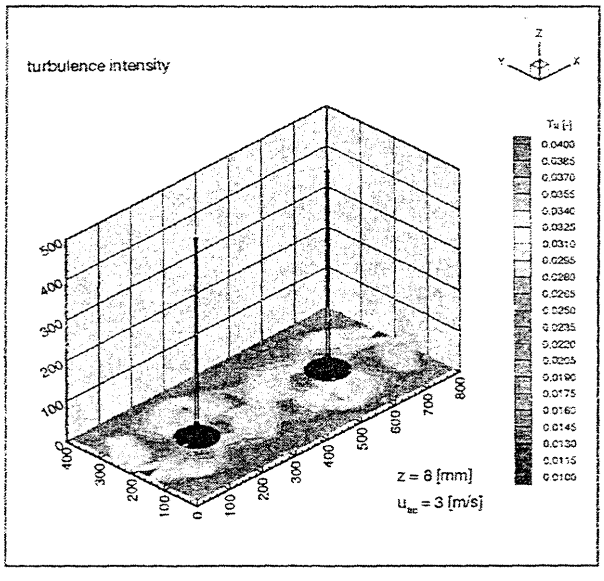

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