An Experimental Study on Solitary Waves of a Rotating Disk

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This paper has been studied on the solitary wave phenomena on the flexible rotating disk by experiment of measuring the separation of solitons. The phenomena have been discovered recently by Crandall and Boulahbal in 1995. They have shown some pictures of solitary waves on a flexible rotating disk by using a high speed camera and fotonic sensor. But there is no theory to explain and predict such solitary waves on a flexible rotating disk with a thin film of fluid. In order to establish this theory and to explain these phenomena, more experiments are needed to describe such waves. This paper attempts to provide such necessary experiments by studying the relations of air inflow gaps, radius of rotating disk and its rotating speed. The separation of solitons has been measured by a fiber optic displacement sensor at each speed. Some conclusions have been obtained from this experiment to describe this new phenomena of solitary waves on a rotating disk. It may be a very qualitative description rather than a quantitative prediction using a mathematical model. However we have measured the separation and taken photographs with a high speed camera; therefore this conclusion could be useful in understanding the phenomena and may contribute to future work.

Key Words: Solitary Waves, Rotating Disk

1. Introduction

A lot of research has been done on the stability and instability of a rotating disk. Those works can be categorized into three classifications. The first class can be categorized by bending rigidity, stiffening effect of rotation, and instability of the rotating disk due to imperfections (Lamb and Southwell (1921), Southwell (1922), Tobias and Arnold (1957)). The second class can be categorized by the effects of the air film, load system, and interactions between the disk and load system (Pelech and Shapiro (1964), Adams (1980), Licari and King (1981), Benson and Bogy (1978), Carpino and Domoto (1988), Hosaka and Nishida (1987), Ono and Maeno (1986), Chen and Bogy (1993), Shen and Mote Jr (1991)). The third class can be categorized by the self excited instability on the vibration of a rotating disk (Hosaka and Crandall (1992), Boulahbal (1995)).

This experimental report is related to the work of Pelech and Shapiro in 1964. They have performed an experiment to describe a flexible disk rotating on a gas film next to a wall. Their pioneering work explored the general rules of behavior which might be inherent in the coupling between the mechanics of a rotating disk and the fluid dynamics of a gas flowing through a gap. They measured the disk's steady state deflection for various conditions of air flow rate and disk radius, but they did not discover the solitary waves on the flexible disk in that experiment.

Solitary wave phenomena on the flexible rotating disk have been discovered recently by Crandall and Boulahbal in 1995. It was not a quantitative measurement of solitons but a taking of pictures of solitary waves and measuring their
frequencies via high speed camera and fotonic sensor. Solitary wave is a highly wrinkled wave on a rotating disk changed from harmonic waves. Figure 1 shows these solitary waves which are moving along the flexible disk with less spin rate than the disk.

We do not have any theory to explain and predict such solitary waves on a flexible rotating disk with a thin film of fluid. In order to establish this theory and to explain these phenomena, more experiments are needed to describe such waves. This paper attempts to provide such necessary experiments. These new observations can not give us quantitative predictions, but instead provide qualitative explanations on how these solitary waves can occur and quantitative displacement measurements for new theory in future. This is the beginning of those works.

2. Objective

This experiment has been done with two objectives. One is to describe the phenomena of solitons more quantitatively by measuring the separation of the flexible disk from a rigid plate. The other is to provide the experimental data of displacement for proof of a new theoretical model on the phenomena of solitary waves, which occur