Proceedings of the 2001 IEEE International
Conference on Control Applications
September 5–7, 2001 • México City, México

A study on the surface defects of a compact disk

E. Vidal, P. Andersen, J. Stoustrup, T. S. Pedersen

Dept. of Control, Aalborg University
DK 9220 Aalborg Ø

{enrique,pa,jakob,tom}@control.auc.dk

Abstract—
Optical Disk Drives are widely used today. However, even though the technology has been available to the consumer during 20 years, there are still performance issues to be improved. This study reveals a way of dealing with the photo diode signals in the optical pick-up to improve the performance of the Optical Disk Drives.

I. Introduction

Optical Disk Drives (ODD) are widely used today. Whether they are used to hold music, data or computer software, they have become the standard medium for distributing large quantities of information in a reliable package. However, even though the technology has been available to the consumer during 20 years, there are still performance issues to be improved, e.g.[1],[2]. People at their homes may have experienced that the CD player keeps playing a short part of a track repeatedly or that it jumps randomly to another track. In worst case it may even stop playing the CD to a great surprise and irritation of the listener. In order to make CD-players more robust against surface defects, the positioning of the focus point is traditionally relatively slow and it will react slowly against e.g. scratches and in many cases the scratch will have passed before the false information causes the focus point to move appreciably. Slow control will increase the chances for real disturbances such as mechanical vibrations or imperfections on the track to remove the focus point so far from the track that data is lost. The bandwidth of the positioning controllers is consequently a trade off between quick reaction against mechanical vibrations and good immunity against scratches.

In [3] a surface evaluation of compact disks is performed where information is gained by considering the demodulated envelope of the optical sensor's head amplifier signal. Mechanical vibrations were though not studied and it is unknown whether the measurements of surface defects can be misunderstood as mechanical vibrations or vice versa.

This study reveals a way of dealing with the photo diode signals in the optical pick-up, which are used in the positioning controller loops, so surface defect and mechanical vibrations can be distinguished from each other, giving the possibility to design positioning controllers where the mentioned trade off is minimized.

II. Photo diode characteristics

The optical pick-up is a 2-axis device, enabling a movement of the lens in two axes: vertically for focus correction and horizontally for track following. Two coils which are orthogonal to each other are suspended between permanent magnets. A current through a coil creates a magnetic field which repeals with the magnetic field from the permanent magnet. Therefore the coil and consequently the lens will move in the corresponding direction. The absolute distance between the focus point and the signal layer cannot be measured directly. Instead a laser beam is focused on the signal layer and the intensity of the reflected laser is measured by the generated current of two photo-diodes D_1 and D_2. The difference $D_1 - D_2$, is directly proportional to the distance between the focus point and the signal layer in the linear area, see figure 1.

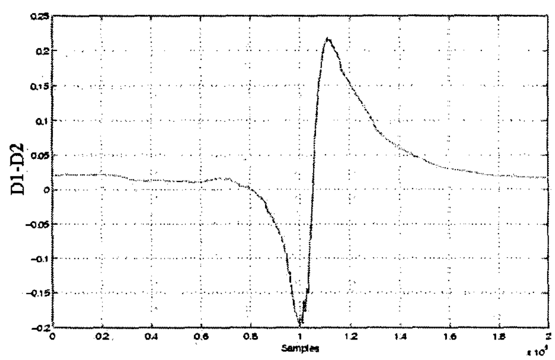

Fig. 1. Measurement of the characteristic of the focus diodes ($D_1 - D_2$).

Figure 1 shows the response of the photo diodes when the focus actuator is excitated with a ramp signal. The lenses of the optical pick-up are arranged in such a way that diode D_2 receives more light when the focus point is too far away from the signal layer, whereas D_1 receives more light when the focus point is too close to the signal layer. The difference between these two signals is used as feedback to the focus controller. The disadvantage of considering only the difference, $D_1 - D_2$, between the two photo diode signals is the impossibility of being able to distinguish between the different disturbances like e.g. mechanical vibrations and scratches.

By plotting D_1 versus D_2, see fig. 2, more information can be retrieved. As the information of the defects on the disk surface is present in both focus and radial signals, only the focus signals are treated in this study. The black spot at voltage $D1 = D2 = 2.5V$ in the linear area represents the reference position of the focus point. Mechanical vibrations move the optical pick-up from the actual position and result in a real error, oscillating at the reference position. As long as the vibrations are moderate, the oscillations of the signals will remain in the linear area (grey

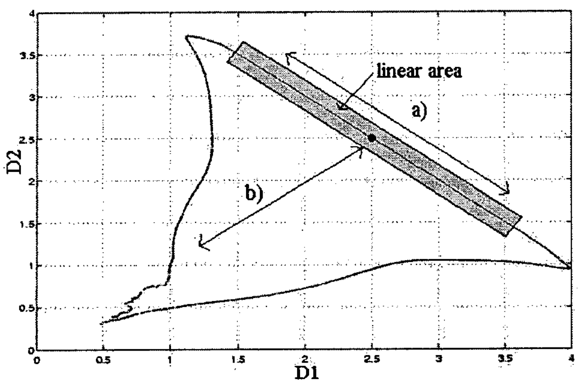

Fig. 2. Measurement of the characteristic of the focus diodes (D_1 versus D_2).

rectangle) shown as case a). On the other hand, defects on the disk surface, as it is demonstrated in the experiments, change the reflection properties of the disk resulting in a false error, shown as case b).

III. Laboratory setup

The laboratory setup is composed by a 300 MHz Pentium II with an I/O card which has 12-bit A/D and D/A converters. The I/O card is connected via a hardware interface to a Compact Disk player. Direct Access Memory is used and the sampling frequency for every channel is 35[kHz]. The setup gives the possibility to implement simple controllers in the PC and to log the response from the photo diodes of the optical pick-up in the CD player.

IV. Experiments

The following experiments are presented to study the behavior of the photo diode signals with a CD having different surface defects. The same experiments are also performed when then CD player is subjected to mechanical vibrations in order to examine if the surface defects are still detectable.

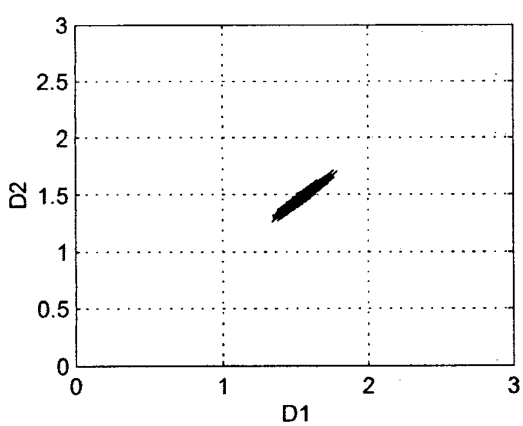

Fig. 3. CD without visible surface defects.

As the experiments are performed in closed loop the amount of the reflected light is smaller because the radial loop brings the focus point on the track where the reflection is lower, that is, the zero point is located approximately at $D1 = D2 = 1.5V$. Figure 3 shows the signal levels of $D1$ and $D2$. Since the controller is not perfect, the plotted signal moves slightly along the linear area. Due to the disturbances in the radial loop the plotted signal moves also perpendicularly to the linear area. The ideal case would be just a spot at the reference position but a perfect controller and noise free measurements are unrealistic.

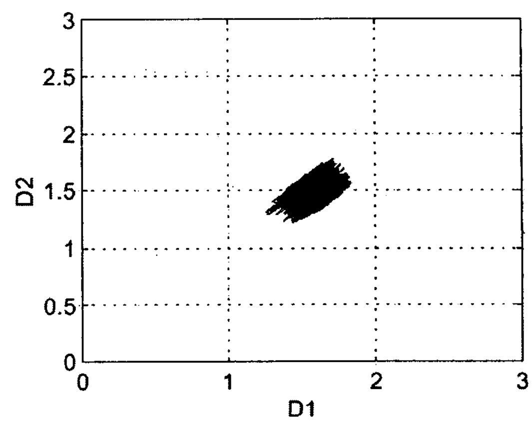

Fig. 4. CD without visible surface defects subjected to mechanical vibrations.

Figure 4 shows D_1 and D_2 where the CD player is perturbed with mechanical vibrations. As mechanical vibrations are real disturbances they result in an increased error, that is, a larger distance between the focus point and the signal layer.

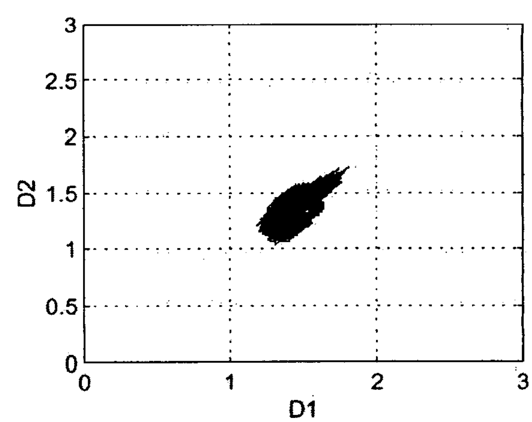

Fig. 5. CD with a finger mark.

Figure 5 shows the effects of a CD with a finger mark on the surface. It can be observed that the diode signals move only slightly away from the linear area as the finger mark in question is not a serious surface defect.

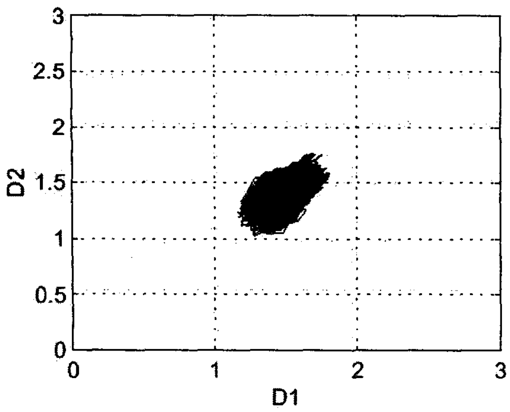

Fig. 6. CD with a finger mark subjected to mechanical vibrations.

Figure 6 shows also a CD with a finger mark on the surface. It can be observed that the diode signals move only slightly away from the linear area and that the mechanical vibrations increase the focus error.

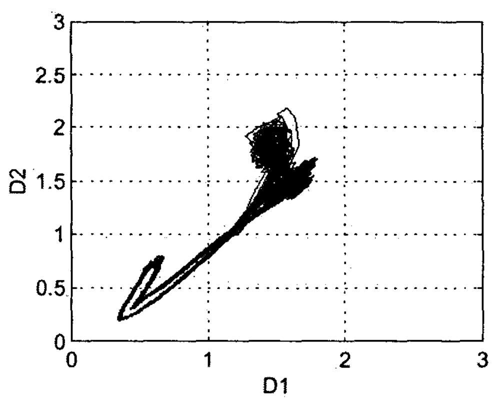

Fig. 7. CD with a scratch.

Figure 7 shows a CD with a scratch of approx. 0.5[mm] width on the surface. Due to the fact that the scratch changes the reflection properties of the disk surface abruptly, little of the reflected light is received by the photo diodes, causing a drastic fall of both signals moving towards origo. At position $D_1 = 1.5$, $D_2 = 1.75$ a different behavior is present, which is the result of the controller reaction trying to suppress the effects of the scratch.

Similar observations can be made in figure 8 where the CD player is subjected to mechanical vibrations. The focus error is increased and the scratch results in random jumps from/to the linear area.

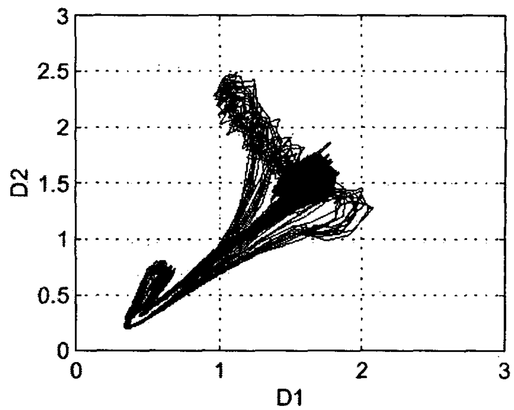

Fig. 8. CD with a scratch subjected to mechanical vibrations.

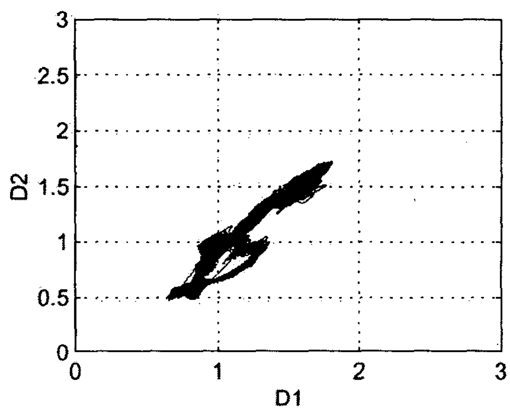

Fig. 9. CD with a black ink marker pen line.

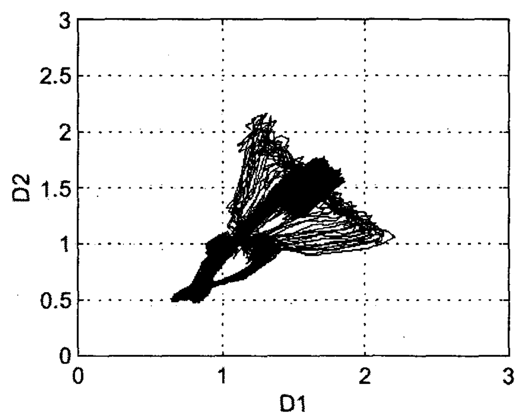

Fig. 10. CD with a black ink marker pen line subjected to mechanical vibrations.

The effects of the line drawn with a black ink marker pen are comparable to the effects of the scratch. In figure 9 the signal levels of the photo diodes experience also a drastic fall.

In figure 10 the focus error is increased when the CD player is subjected to mechanical vibrations and the line from the marker pen results in random jumps from/to the linear area.

V. Discussion

The idea investigated is to extract more information from the photo diodes which sense the reflected laser beam. In order to minimize the mentioned trade off in the design of the positioning controllers one approach could be to construct a subspace of possible combinations of the signals from the photo diodes assuming they are not disturbed by surface defects. Signals not belonging to this subspace could originate from e.g. a scratch giving a possibility for detection. The experiments have shown that signals from photo diodes show characteristic patterns when the focus point passes a surface defect. Systematic analysis of such patterns will make a much more precise detection of e.g. scratches possible. Knowledge about the characteristics of the photo diode signals makes it possible to add a quality factor to the position estimate which is the primary measurement to extract from the signals. This quality factor can be used in an estimation-based controller, where the position and velocity of the focus point are estimated using a model with the control signal as input and the measured position as correction signal. When the quality of the measurement is good the measured signals are weighted high, while the measured signals are weighted low or not at all when the quality is poor.

A. Acknowledgments

We would like to thank K. G. Hansen, R. S. Andersen and K. B. Poulsen for helping us with the practical issues at the laboratory.

References

[1] M. Dettori and C.W. Scherer. Gain scheduling control for a CD player mechanism using LPV techniques. *6th IEEE Mediterranean Conference on Control and Systems, June 9-11, 1998, Alghero, Italy.*

[2] Chak Hong Lee. Robust repetitive control and application to a CD player. *A disertation submitted for the degree of Doctor Philosophy, Trinity Hall Cambrigde, February 1998.*

[3] Franz G. Pavuza, Geza Beszedics, Heinrich Pichler. Surface evaluation of compact disks by electronic means. *Proceedings of the 1999 IEEE Canadian Conference on Electrical and Computer Engineering. Shaw Conference Center, Edmonton, Alberta, Canada May 9-12 1999. pages 1449-1453*