Quarterly report on "A Rheometer for measuring the material moduli for granular solids."

P. I.: Prof. K. R. Rajagopal

Student and the degree for which they are registered: G. Gupta, Ph. D.

Institution: University of Pittsburgh, Pittsburgh, PA 15261

Grant No.: DE-FG22-90PC90306


DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

MASTER
In this report, we will outline an experimental method for characterizing the material properties of granular solids, like coal particles, and other powders and slurries. The instrument to be used for this purpose consists of two disks rotating with the same angular speed about distinct axes (cf. Fig 1). By measuring the forces and the torque acting on the top and bottom disks and correlating them with the theoretical expressions for the tractions and moment in question. The above described technique draws upon a method devised for measuring the properties of viscoelastic solids and fluids.

**The Orthogonal Rheometer:**

We have earlier described the basic principle on which the rheometer works. Here we would like to describe the basic design approach for the proposed and the progress we have made so far. Figure (1) shows the basic design of the rheometer. Motor A rotates the lower disk. There is a torque sensor connected to the motor A through a flexible coupling and another flexible coupling connects the torque sensor with the lower disk A. There is a bearing in between the torque sensor and the lower disk A. This is required in order to eliminate any bending moment due to the shear force generated at the surface of the lower disk A, so that the torque sensor only measures the pure torque. The upper portion of the instrument consists of the upper disk B rotated by the motor B at the same speed as the lower disk. Both the motor A and B are of the same specifications. There are load cells connected to the upper shaft. Load cell A and B are required to measure the forces generated in the two planes XZ and YZ, while the load
cell C measures the normal force generated due to the shearing. These load cells also act as bearings. Thus we can measure all components of the forces and the torque and then correlating with the theoretical expressions, we can measure the material moduli, as explained earlier.

The main component consists of two disks which are rotating at the same speed but at a different axes. In order to make the instrument versatile we are designing the instrument such that we can control the distance between the axes of rotation. We are providing a scope for the horizontal movement of the platform on which the lower part of the system supporting the lower disk is going to be mounted. This platform is going to have the vertical movement capability also. This is required for two main purposes:

1.) Handling of the material which is going to be tested.

2.) To make sure that the upper disk is properly in contact with the material which is placed in the lower disk. This is essential to avoid any kind of slippage between the upper disk surface and the material to be tested.

This platform is going to be custom made for precision and proper accuracies in movements and positioning. This platform will also be able to handle the load of the system which is going to be mounted on the platform. Hence we have decided to buy it from an agency, "DAEDAL" (Positioning Tables and Controls) which makes this kind of instrument, 'Linear positioning system' professionally. We have described to them our ideas and our need of such a system. They are in the process of evaluating our ideas and pretty soon they are going to quote a price on it.

Second important component of the instrument is the motor. We have looked into
our need of the speed, torque and power requirements. Our main concern here is to buy a motor which can rotate at a very low speed (the need of low speed has been described earlier) and at the same time is able to provide a high torque. This is not the only essential characteristics we are looking for, but the fact that our analysis is based on steady state, we are looking for a motor which could possibly give us constant torque for the speed range we are considering. One such option is a servo motor, which provide a constant torque for a fairly large range of speed. Servomotors have lightweight, low inertia armatures that respond quickly to excitation-voltage changes. In addition, very low armature inductance in these motors results in a low electrical time constant that further sharpens motor response to command signals. This is one of the important characteristics of the servomotors and we are further exploring the possibility of using servomotors for our instrument purpose. This motor will be equipped with the speed and the torque control devices. We are also looking for the possibility of using a permanent magnet (PM) motor.

The third important component of the instrument is the measurement of forces and the torque. Since both the disks (shaft) are rotating, strain gages cannot be mounted directly on the shaft to measure any of the above quantities. We are going to be using in line rotating shaft torque sensors. There are two different types of such devices available in the market.

1) Slip rings type

2) Rotary transformer type

In the slip rings type, the strain gage bridge is connected to four silver slip rings
mounted on the rotating shaft. Silver graphite brushes rub on these slip rings and provide an electrical path for an incoming bridge excitation and the outgoing signal. Whereas in rotating transformer types, only either the primary or secondary winding is rotating. One transformer is used to transmit the AC excitation voltage to the strain gage bridge, and a second transformer to transfer the signal output to the nonrotating part of the transducer. Thus two transformers replace four slip rings and no direct contact is required between the rotating and stationary elements of the transducer. The signals obtained from these sensors are then fed into the strain gage indicator or some sort of data acquisition system, where we can convert these electrical signals into the required quantity.

To measure the axial components of forces, we are going to be using load cells. Selection of a load cell which will fit our requirements depends on many considerations. The most critical mechanical component in any load cell, as with any strain gage transducer, is the "spring element". In general terms, the spring element serves as the reaction to the applied load and focuses that load into a uniform, calculated strain path for precise measurement by the bonded strain gage. Critical to this function is that the strain level in the gaged area of the spring element responds in a linear and repeatable manner to the applied load. The perfect load cell would repeatedly produce a proportional relationship between the strain and the induced load. Achievement of this goal is made difficult by the presence of numerous application, economical, and performance requirements which must be simultaneously satisfied. Compounding this difficulty, is the great number of second and third order effects, such as natural frequency and thermal sensitivity that become highly significant in the attainment of a precision force measuring device. Hence, the load cell selection is one of most important aspect for our design purpose. We have looked into different companies which makes load cells. Lebow Inc. is one such concern and right now we are in the process of selecting the proper load cell for our design purpose.
Once we have selected the torque sensors and the load cells, we will then select the strain indicators and the data acquisition system. The three major components, which we have described earlier, are necessary to design the structure of the instrument. Figure 1. shows the various parts in the proper place.
ORTHOGONAL RHEOMETER

Figure 1.

[Diagram showing components such as Load Cell A, B, C, Motor A, B, Belt & Pulley, Upper Disk B, Lower Disk A, Bearing, Flexible Coupling B, Torque Sensor, Flexible Coupling A, and Platform.]