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DETERMINATION OF DYNAMIC POWDER MODELING PARAMETERS VIA OPTICAL METHODS

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Abstract

Dynamic parameters, such as restitution and friction coefficients are important for powder flow simulations of laser based deposition processes. These parameters are difficult to find, especially for industrial metal powders. This paper introduces an optical method for measuring restitution and friction coefficients. The free falling powder flow was illuminated by a laser sheet. In order to obtain particle velocity, streaks proportional to particle velocities was generated by laser pulse obtained by a chopper. Recorded imaged were analyzed to determine particle velocities both before and after various impact conditions as well as impact parameters.

Motivation

A consistent powder delivery system is necessary to achieve consistent deposition quality in the laser aided deposition process. More specifically, the ability of the nozzle to focus the powder stream into the melt pool directly relates the system's quality, build rate, and efficiency. Experiments and simulations are used to optimize the geometry of the nozzle [1] . To accurately simulate the kinematics of a population of powder, such as the H13 tool steel powder shown Figure 1, a model for particle-wall collisions must be created. ABS plastic was chosen as one of the materials in this study because how a FDM prototype nozzle behaves with respect to the final design is an item of interest for later study. Once the model is verified against and ABS plastic nozzle, the prototype behavior can be used to infer the behavior of the final nozzel.

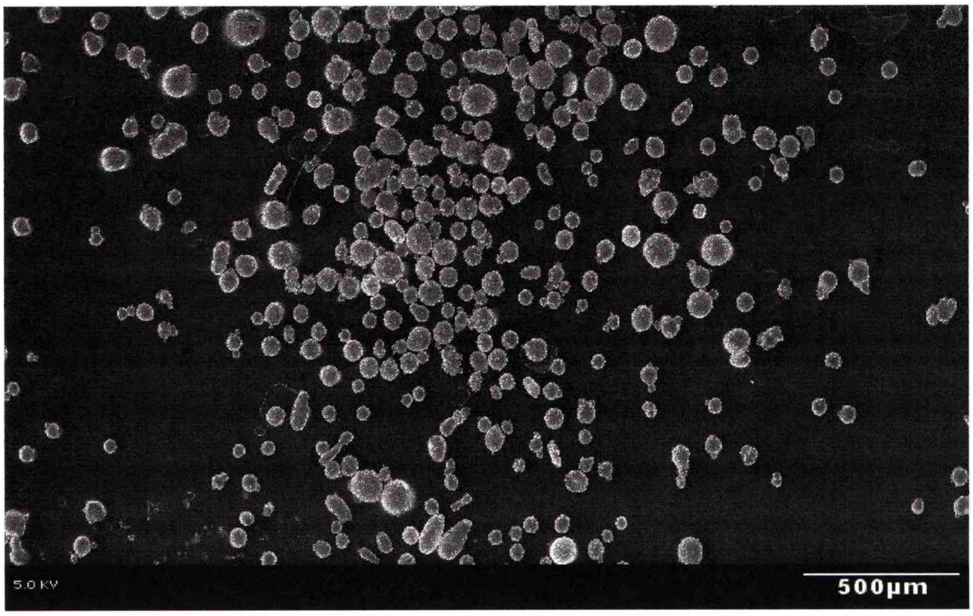


Figure 1 – H13 Tool Steel Powder Population.

There are several ways to deal with the particle impact. Models that idealize the particles as spheres produce unrealistically smooth looking flows. Purely deterministic models are too computationally expensive to be used. A statistical model proposed by Sommerfeld combines computational efficiency with acceptable accuracy [2]. However, choosing the parameters to use in the simulation can be difficult. Parameters such as restitution and friction coefficients need to be tailored for the specific situation. Thus, having a simple method of measuring these parameters would be benficial.

Experimental Methodology

In order to measure the restitution and friction coefficients, a detailed experimental analysis of the particle-wall collision process is performed using particle tracking velocimetry. To reduce the non-spherical particle shape effects on rebounding behavior, H13 tool steel particles are used (-100+325 mesh, gas atomized) of which approximately 50% are spherical in shape. Moreover, the ABS plastic plate is polished until the effects of the wall roughness on particle bouncing can be neglected.

For providing reliable data for the collision of particles with inclined substrate, an experimental configuration (Figure 2) is set up. The aperture is at 15cm above the substrate which is hinged with adjustable angle. The testing material (ABS and Steel) can be attached on the substrate surface. The particles are released and impact with the testing plate with specified impact angle. The simple experimental setup has the advantage that the rotational velocity of the particles before collision can be assumed to be zero.

For the visualization of the particle trajectories the particle tracking velocimetry in the streak line mode is applied. A pulsed laser light sheet is produced by a Spectra-physics Argon-Ion laser, a chopper and a cylindrical lens. The chopper is used to pulse the laser at a pre-defined frequency (1.2kHz). The experimental setup can be seen in Figurea 3a and 3b.

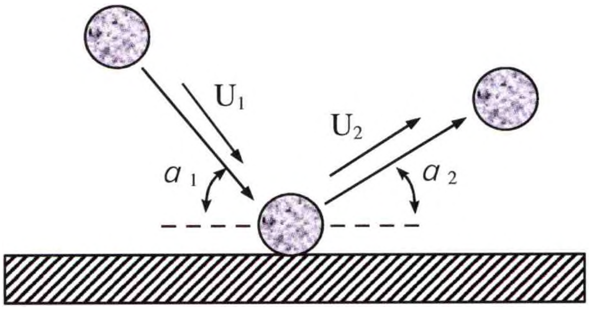


Figure 2 - Definition of velocities and angles before impact and after collision.

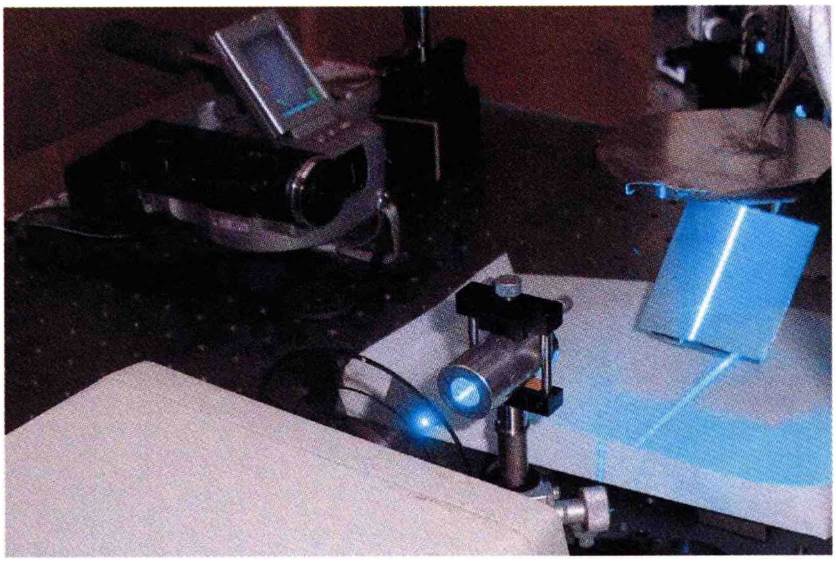


Figure 3a – Experimental Setup

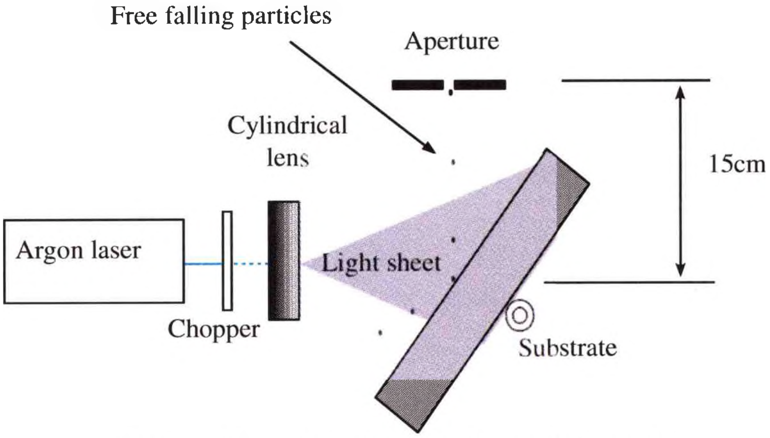
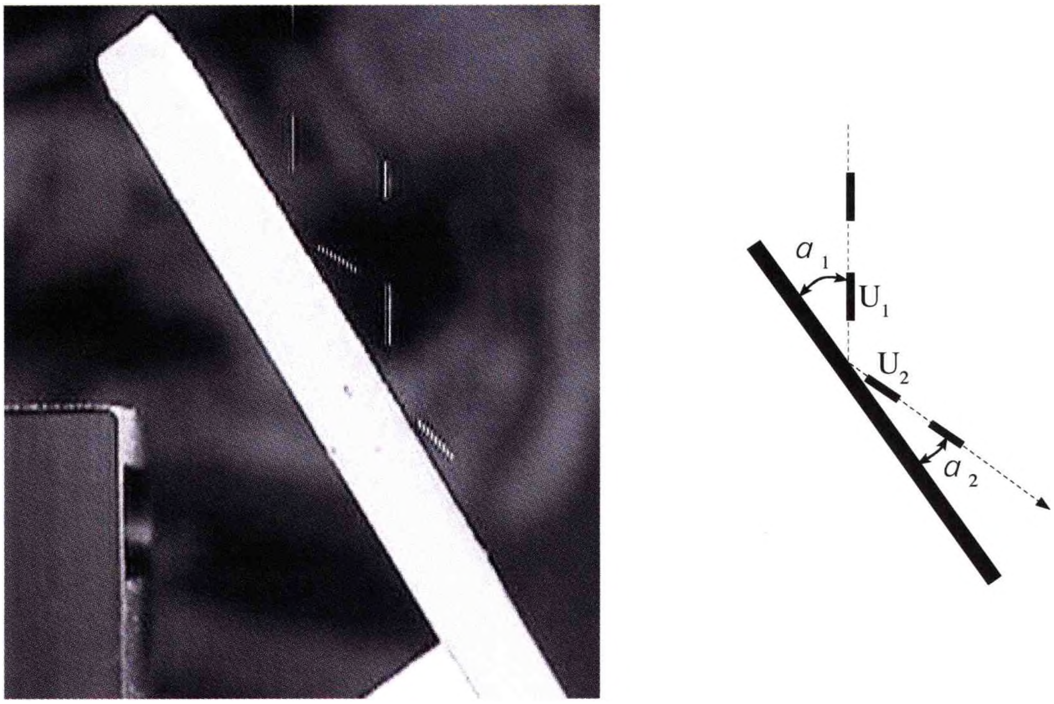


Figure 3b – Experimental Setup Schematic

The particle traces in the near wall region are recorded by a Sony digital video camera, which has a resolution of 704 x 480 Pixels. A series of individual images of the particle traces are recorded as DVD video during the measurement period. Impacts were recorded for three substrate angles for both ABS and steel.

Results

The 30 minutes of captured video was converted to a series of 58,000 PNG still frames using transcode (www.transcoding.org), a open-source utility for converting audio/video codecs and container formats. From these images, a set of clear impact images was culled. A typical chosen image is shown below in Figure 4.



(a) (b)

Figure 4. Typical image of particle trajectories (a) and the determination of velocities and angle of collision (b).

From these images, the pre and post impact angles and velocities were measured. The ratios U_2/U_1 and α_2/α_1 were then compared to a set of simulation results to determine the proper friction and restitution coefficients. Table 1, below summarizes the measured data.

Table 1 - U_2/U_1 and α_2/α_1 ratios

		U_2/U_1		α_2/α_1	
Material	Angle	Mean	StDev	Mean	StDev
Steel	9.7	0.87	0.09	1.09	0.6
Steel	13.3	0.82	0.11	1.04	0.61
Steel	27.8	0.72	0.17	0.71	0.28
ABS	13.4	0.66	0.16	1.4	0.76
ABS	21.1	0.66	0.15	0.91	0.48
ABS	30.0	0.61	0.14	0.82	0.33

Figure 5, below shows the compiled results of a set of numerical simulations that show the relationship between the friction and restitution coefficients used in the simulation and the resultant U_2/U_1 and α_2/α_1 ratios.

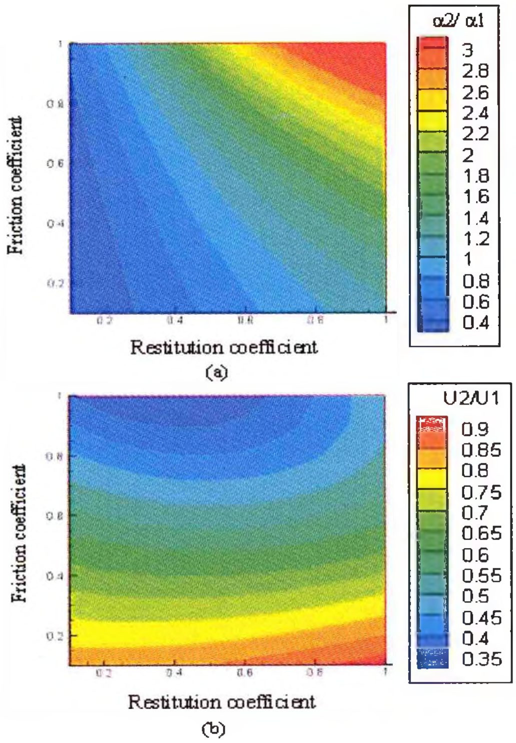


Figure 5 - The contour for the determination of the restitution and friction coefficients.

By correlating the measured results to Figure 5, a dependence of the restitution and friction coefficients on the impact angle can be seen. Figures 6 and 7, below, show the resitution and friction coefficients' dependence on impact angle.

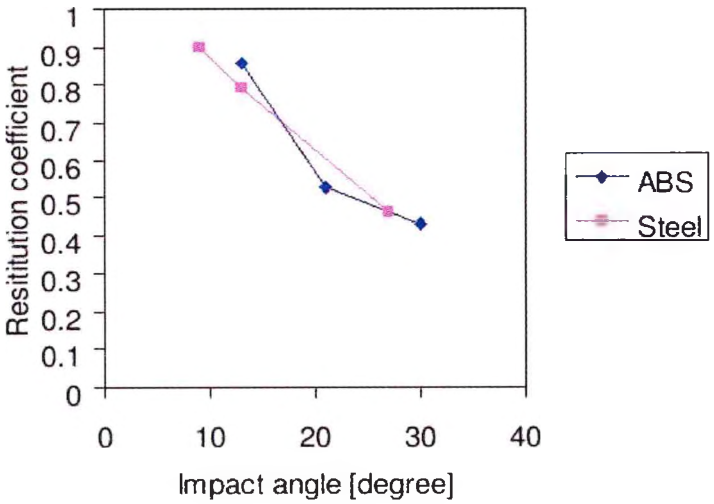


Figure 6 – Restitution Coefficient vs Impact Angle

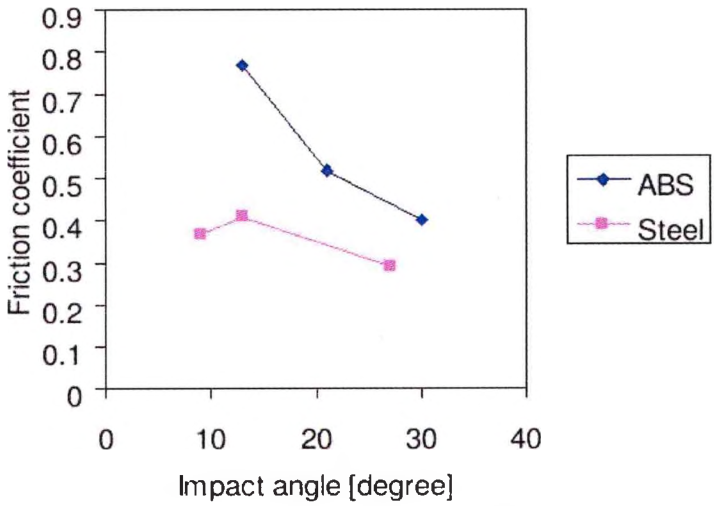


Figure 7 – Friction Coefficient vs Impact Angle

Conclusions

The methods used in this work proved to be a viable method for measuring friction and restitution coefficients for numerical simulations. The results for the coefficients agreed well with the assumptions made by Pan [4] However, development of some tools to automate the image analysis process would make the task less arduous.

Acknolwdegments

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