Pink and Fire: Computational Fluid Dynamics Simulation Analysis of My Recent Gender Reveal Party Disaster

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Abstract

In my disastrous gender reveal for our unexpected girl Alice, a chain reaction involving confetti, a leaf blower, and eighteen tubes of smokeless pink powder has rendered my backyard craft shed decimated. Despite the unexpected nature of this gender reveal disaster, my insurance company refuses to honor my policy to cover the burning down of my backyard craft shed estimated at a value of $10,000, and $3,000 of craft supplies and gardening equipment. In this paper, we will use a Computational Fluid Dynamics (CFD) engine Gender Reveal Simulation (GRSim) mandated in my insurance policy to lower my deductible to show this fire was a freak accident. We will develop a turbulence, combustion, radiation, and pyrolysis model to show that we were cursed with the perfect storm of pink-colored corn starch and Holi dust canons ignited by a confetti-clogged factory defect leaf blower causing a massive twenty-foot fireball a $1,000 a year licensed software could not have predicted.

Keywords: Gender Reveal Party, Computational Fluid Dynamics, Pink Dust Canons, Confetti Clouds, Crafting Shed, Insurance Scam, Gender Reveal Simulation, Arson Investigation, Firework Free Reveal, It's a Girl!

1. Introduction

My shed is ruined, and the insurance company, Guardian Umbrella, is screwing me over! Gender reveal parties are becoming more of a nuisance when it comes to arson investigations, so I took out a specific policy for my upcoming backyard BBQ and gender reveal. The policy required careful planning and detailing of the reveal, a strict NO FIREWORKS policy, a safety review board, a fire marshal inspection, the use of smokeless powder, and a pricey computational fluid dynamics simulation that I thought I wanted anyway. I've sunk most of my life savings into my current suburban home and did not want to risk it, so I took the policy following all of the precautions simulation and all.

Now the insurance company's stiffing me out of 13K because they think I ran the numbers wrong! Little does this company know that they're dealing with the wrong policyholder who is an expert in simulations [1]! I'm double-checking the numbers, all of the models of our materials, and flow patterns, and it's looking more and more like this was a total freak accident GRSim could not have predicted. Additionally, I would like the $1k back I spent on this useless piece of software. An intern could have written a better simulator!

Figure 1: My Shed on Fire

2. Background

Beginning as a quaint American cake-based ritual in the 2000s, the Gender Reveal party has figuratively and literally exploded into American society. It was everything Americans loved about a party…Going Big. While the Fourth of July was previously the only fire-based holiday, and the fireworks and explosion-based gender reveal party mixed with vloggers in the 2010s, the practice kept getting bigger and bigger until they began causing major forest fires [2], a deadly plane crash [3], an outbreak of blue powder-based popcorn lung [4], and the deadly eruption of Gang Violence in a Chicago Suburb [5]. As the danger made headline news, the practice grew because of one inconvenient fact; Americans love Danger.

Figure 2: Day of the Great Chicago Gender Reveal Disaster

It was only after these deadly incidents that companies such as our own Guardian Umbrella Insurance Company began a Gender Reveal party-specific insurance policy and real-world risk mitigation techniques began to form to prevent such tragedies. As the California couple who caused a 22,000-acre wildfire from their smoke-generating pyrotechnic device faces jail time, many began flocking to the robust insurance policy instead of just getting a lame pink or blue cake.

In order to facilitate proper risk mitigation, the simulation engine Gender Reveal Simulation (GRSim) was developed. Insurance companies quickly determined that their policy would attract the wrong type of risk-takers and took it upon themselves to develop not only risk mitigation procedures but a full Computational Fluid Dynamics (CFD) simulation engine. Through GRSim, expecting couples could lay out the locations of smoke poppers, confetti, BBQ grills, and flammable objects so that it may run a variety of wind pattern sims to determine the amount of risk for their insurance policy. While the provided software uses a $1K a year per user license, and the median Gender Reveal fire risk will ruin a good boot stamping out a grass fire, the upward tail expected risk of the average Gender Reveal party may exceed $5K due to the enormous risk of the party going wild. It turns out, apparently, this policy allows the insurance company to determine that every user didn't use the software correctly…surprise surprise… Thus we must show it wasn't our misuse.

3. Numerical Methods

In order to generate the governing equations of our simulation the first principle of physical laws was used to determine Newtonian fluid motion to include conservation of mass, momentum, and energy. Despite the advertising of the smokeless pink powder poppers, our smoke reveal canons was fit best with a low-mach number fluid motion, so Favre-filtered equations were used. This paper leverages research from [6] which utilizes the Fire Dynamics Simulator to improve upon the GRSim.

3.1 Turbulence Model

The back end of the GRSim implements Large-Eddie Simulation (LES) to handle sub-models at a sub-grid length scale despite the simulation engine handling our half-acre backyard. This allows for large and small Eddie currents to be handled by GRSim. Turbulent viscosity was determined using a Smagorinsky subgrid-viscosity model [7]. Because we were more concerned with hotter objects causing turbulence, an additional model was integrated into the simulation developed by Lisa Smithers [8] to model optical turbulence from a hot new intern in a Cranberry-Lemon optics lab. If the model can model an object as hot as Todd, we think it can model the heat of our smokeless pink poppers.

Fig 3: Todd

3.2 Combustion Model

While the GRSim uses the single-step combustion model taught in high school, the model from the FDS utilized in [6] implements a two-step model representing the mixture fraction approach which models fuel and oxygen burn instantly when mixed. As we will discuss later, the contents of our pink smokeless poppers, when in the presence of an ignition source, will combust instantly at the density observed in my party. Following the insurance policy procedure, we waited for the wind to die down for an under-ventilated environment which further research after my claim was rejected by Guardian Umbrella revealed is the worst-case scenario for these pink smokeless poppers [9].

In a single-step combustion reaction mechanism, fuel and air combust immediately while the two-step combustion model tracks the CO intermediate product as shown in the following equations.

Step 1: $C_xH_yO_zN_aM_b + v_{O_2}O_2 \rightarrow v_{H_2O}H_2O + v_{CO}CO + v_s soot + v_{N_2}N_2 + v_M M$

Step 2: $v_{CO}\left(CO + \frac{1}{2}O_2\right) \rightarrow v_{CO}CO_2$

3.3 Radiation Model

While a traditional radiation heat transfer model involves the emission of EM waves from the ignition source to the solid fuel and the O_2 gas particles, the tragic consequences of my gender reveal party involved practically a gaseous form of $C_2 + O_2$ and other highly combustible carbon-based powders shot out at a high velocity from our eighteen tube poppers. It did not help that it was a hot day and we had left our tube poppers in the sun to heat up. With the pink powder-based fuel mixed ominously within the oxygenated environment, an updated radiation model to the GRSim showed that we should have never been allowed to use those poppers in any environment even though they were explicitly allowed by my insurance policy!

To allow GRSim to accommodate our pink poppers, ordinary differential equations were integrated in discretized control volumes to calculate the band-mean absorption coefficients using the unfortunately named gray gas assumption. As a cursory analysis of the radiation cloud was analyzed, it appeared that the highly reflective pink powder highly accelerated the exploding fireball, and I may have not been writing this paper if we were expecting a son and we used a less reflective blue powder.

3.4 Pyrolysis

To capture the gasification phase of our seemingly already gas pink powder, the Pyrolysis model was updated to ensure that our burning solid material was already gas. While the true gasification process involves multiple steps as in our combustion model, we assume a single-step process leaving alone the model implemented in the GRSim. As shown in the equation below, once applied to a gaseous cloud of hot pink dust, it makes no sense these poppers use powder and not smoke. Utilizing Arrhenius' form, the combustible process may be expressed in the equation below:

$$r_{i,j} = \left(\frac{p_{s,i}}{p_{s0}}\right)^{n_{s,ij}} A_{ij} exp\left(-\frac{E_{ij}}{RT_s}\right)$$

Where r(i,j) is the rate of reaction for the ith mass component and jth consumed reaction where p represents the pink cloud density of the powdered material. Finally the A/E components show the pre and post-exponential activation energy of the Arrhenius chemical process where the 8.314 J/(mol x K). As warned in [10], once estimated values for pink gender reveal smoke poppers are applied to the Arrhenius expression, a deadly eye-brow apocalypse-inducing fireball becomes inevitable once introduced to any sort of open flame or even a spark. To quote the analysis in [10] "When the Pyrolysis process begins in the pink gaseous cloud, there is no stopping it. If in a low to medium turbulence density, you better hope that there is no ignition source near the deadly cloud of pink powder because if there is, there is no amount of firefighting equipment that could prevent the deadly fireball even in expert hands. If it were controllable, it would be an unstoppable weapon of war."

3.4 Material Properties

While any exterior damage caused by the all-encompassing flaming fireball has been purely cosmetic or solved by sending my nephew to three sessions of child therapy, the primary discrepancy of the GRSim analysis was the destruction of my backyard gardening and craft shed. Because the non-jail-broken version of GRSim did not allow me to include all the material properties of my craft shed, I naturally had to add some functionality. By adding in the evidently highly flammable fabrics, and 70s wallpaper, the enhanced GRSim showed a vulnerability that the standard release CFD analysis did not show. By administering a simple calorimeter test on the primary materials found in my destroyed craft shed, the values necessary to analyze the effect of a potential fireball on the one space I have for myself. Results are shown in the table below.

Material	Pine Exterior	70s Wallpaper	Assorted Fabrics	Wooden Tools
Specific heat (kJ/kgK)	1.38	1.02	1	1.52
Conductivity (W/(mK))	0.14	0.13	0.1	0.1
Density (kg/m^3)	489	120	100	670
Heat of combustion (kJ/kg)	14500	15500	15000	523
A	1.89e10	2.8e14	4.28e14	1.92e10
E	1.51e5	1.8e5	2.02e5	1.62e5
Heat of reaction (kJ/kg)	430	2500	3000	440

Table 1: Material Properties for GRSim of my Craft Shed

4. Backyard Gender Reveal Party Reconstruction

As shown in the figure below the party poppers were all pointed away from my home and towards my craft shed as per my plan signed off by the fire marshal. Each popper organized in two rows of 9 were tilted at a five-degree angle off the vertical axis. Not included in the officially signed off Gender Reveal plan was, the sudden low breeze carrying the deadly pink dust clouds towards the cloud of confetti released in a swirl from its hopper bin away and back towards the leaf blower. Though we have no estimation of how strong the breeze was, it was only slight enough to carry the powder without dispersing the material into a low density cloud.

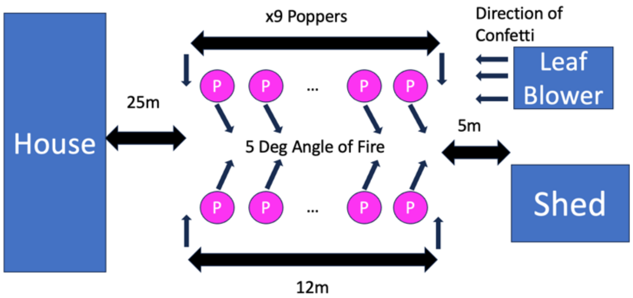

Figure 4: Backyard Configuration not drawn to scale.

4.1 Confetti Spread

As shown by the eight tilted black arrows in Figure 4, the leaf blower against the environmental wind of my backyard against the cold front produced an unexpected catalyst. Unfortunately for the already problematic GRSim, the mesh grid CFD solution was too small to detect the back spreading Eddie current carrying a dangerous amount of thin papered foil and confetti back into our family leaf blower.

4.2 Leaf Blower Engine Malfunction

For some sadistic reason, after-action reports found that the confetti used small wires of aluminum to straighten out the confetti with no regard for the potential risk of short-circuiting a nearby leaf blower. As shown in the Eddie Current simulation I cooked up myself with no help from the GRSim software which I now completely distrust, the back-Eddie currents of confetti would very likely filter in aluminum layered confetti through the air filtration unit of our leaf blower, and into the covered circuitry causing a spark. All it took was one spark.

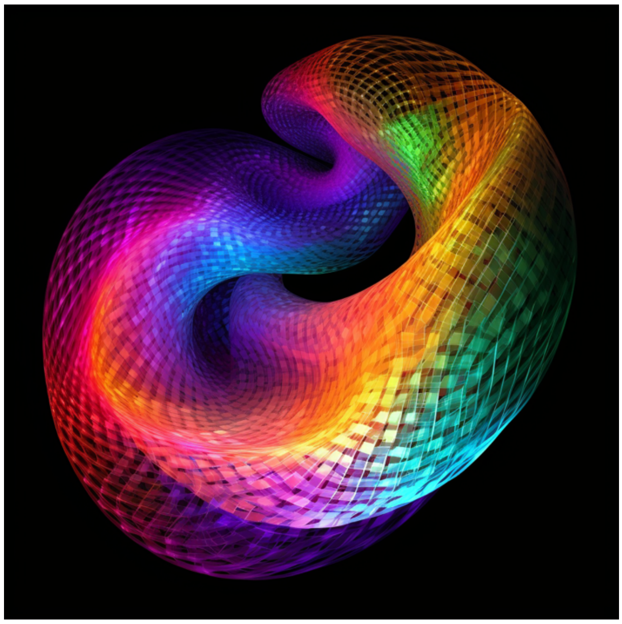

Figure 5: CFD Produced Mesh Grid of Leaf Blower Induced Confetti Eddie Currents

4.3 Pink Powder Cannon Spread

Given an initial propulsion of 20g of gunpowder in our pink party poppers, we modeled the powder density spread with an initial 100-200km/hr which showed a 10m spread away from the poppers around our backyard party. Adhering to the plan suggested and signed off by the fire marshal, we pointed the powder canon tubes directly up at a five-degree tilt toward the shed based on the measured wind patterns.

4.4 Mesh Sensitivity

Despite evidence shown in [11] that the dangerous mixture of fine-grain corn starch and pink Holi powder may cause an explosive atmosphere, the default conditions with the updated models from section two continued to show a safe gender reveal party. Though the simulation was numerically stable, GRSim was not sensitive enough. It was only until the mesh grid sensitivity was decreased from a 0.2m x 0.2m x 0.2m grid to a 0.01m x 0.01m x 0.01m grid in the jailbroken process (the maximum sensitivity capable) and run overnight on my works cluster that any danger was observed in simulation from the pink death cloud.

4.5 Uncontrollable Fire Spread to Craft Shed

After re-running the simulation in GRSim with the party poppers at the required sensitivity, the updated models from section two, the inclusion of the new leaf blower, and the confetti model ignition source, we determined the cause. Similar to my cousin's recorded video footage, the new GRSim results showed a rapidly expanding flame ball engulfing not just my father's eyebrows, our last good camping chair, and other innocent objects, but a sizeable and prolonged flame completely encapsulating my now destroyed craft shed.

5. Results and Discussion

Re-running the simulation in the default, and correcting configuration, the events of the disaster measured through recorded video footage were timed in relation to how fast each object was engulfed in flames. Results are shown in the table below.

	GRSim (default)	Recorded Footage	GRSim (Corrected)
Father's Eyebrows	N/A	0.12s	0.08s
Good Camping Chair	N/A	0.04s	0.02s
Twinky the Garden Gnome	N/A	0.23s	0.19s
My Hydrangea Bush	N/A	0.31s	0.29s
Bag Toss Hole	N/A	0.26s	0.24s
Crafting Shed	N/A	0.52s	0.51s

Table 2: Simulation vs Measured Results

Without the need for deep analysis, GRSim performed much better when calibrated far outside of the recommended defaults of my insurance policy. After 100 simulations, testing every possible wind pattern, not one default GRSim run resulted in a destructive fireball costing me a minimum of $13k and the sentimental value of my Hydrangea bush.

Once corrected the GRSim predicted the speed and spread of the fireball with extreme precision with a regular 10-40ms speed bias. The air was likely more humid than input in the simulation or some other unknown factor which slowed down the explosion in the real gender reveal party.

6. Conclusion

As proven in this paper, there is no feasible way anyone could have predicted the loss of my craft shed given the mandatory precautions of my insurance policy. It took extensive research and additional modeling work any reasonable policy holder should not have to undergo to mitigate the risk of a leaf blower ignited fire. Even in the presence of a spark, the default parameters of the GRSim could not predict the explosive atmosphere of a typical pink dust cloud at the default 0.2m^2 grid sensitivity. I'm not doing this analysis just for me and my shed but all of the victims out there getting stiffed by stubborn insurance agencies. It's time we fight back with science and a more robust Computational Fluid Dynamics simulation framework!

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