Design and development of a low-cost fluidized bed seeding generator

Naresh Kumar M, Gousik R, Sri Vijay Prabhu and Kannan B T
Department of Aerospace Engineering, SRM Institute of Science and Technology, Kattankulathur, Chennai, Tamilnadu, India 603 203.

E-mail: skyinventorbt@gmail.com, btk@alumni.iitm.ac.in

Abstract. The latest developments in hardware and software for laser-based flow diagnostics enable the investigation of complex flow phenomena under enclosed, high-temperature and even pressurized conditions. However, the successful application of a velocimetry technique strongly depends on the presence of appropriate light-scattering tracer particles (seeding) in the flow. In this study, the design and development of a Seeding Generator is effectively carried out with perfect measurements considering the flow characteristics. Compressed air testing was done based on the laser sheet visualization and the flow field was visualized. The results show that the fabricated seeding generator will be able to supply seeding particles for flows from subsonic to supersonic regimes.

1. Introduction
Back in the 1950s, people had come up with different designs and methods of introducing contaminants viz. solid and liquid particles into the atmosphere for varying purposes. This includes the experiment on research of aerosol behavior with the atmosphere, testing the air filters used in automobiles and in Air pollution control [1]. In the early 21st century, the idea of using these aerosol generators for flow analysis had been triggered. People have designed various aerosol generators, called seeding generators, depend upon its area of application, operating conditions and seeding particle (contaminants). With the advancement in technology and development of PIV (Particle Image Velocimetry), the seeding generator started to evolve with its extended area of application like the flow analysis automobile and aviation industry. Most importantly, the type seeding to be used is always the first priority. Depending on the flow velocity, operation condition and its chemical and physical properties (specific gravity, size etc.), the particle is chosen. Attempts have been made to design and fabricate a seeding generator for introducing solid, liquid and gaseous contaminants into the airflow for research in aerosol. Different models and the operating principles have been developed to seed the flow with contaminants in the fields such as Chemical Engineering, Respiratory Physiology, Air pollution control (analysis of smoke Filters), Analysis of air in Industry, Engineering application like Flow visualization. Different seeding generators employ different operating principles depending upon the seeding contaminants and their concentration required for that experiment. For the past few decades, seeding generators using solid contaminants have been popular for it can be used in the analysis of the air pollution control systems.

The main principle lie behind them is the dispersion of dry powder in the air for the production of aerosol. Particle of varying size and specific gravity are being used. The particle being selected should
weigh lower enough to follow the path faithfully as well as large enough to scatter light? In the real case, compensation has to be made which depends on production and visualization facilities available. Sufficient energy has to apply so as to reduce the agglomeration of the solid particles. The present work is based on the requirement for seeding air flows with lower cost and simplicity.

2. Design
From the literature survey i.e. information collected from various articles and books, an appropriate design is chosen as shown in figure 1. With the basic design, some modifications have been considered for improvement in flow field inside the chamber for enhanced mixing [3]. The designs in the literature had sintered brass or glass as a plate which allows the flow in one direction which is against the gravity. The present design utilizes a truncated cone shaped sintered brass filter to inject air in a complex way that creates better mixing inside the chamber.

![Figure 1. Fluidized bed seeding device for high-pressure applications](image)

From the preliminary design, a 2D sketch was developed (refer to figure 2 and 3), which is quite different from the former design suggested by the literature, as per the requirements and its operating conditions. The major dimensions of the designed device is mentioned in the figure. After the verification of design, a CAD model of the seeding generator was prepared in CATIA. In CATIA, the basic modelling was done in part design. The 2D sketch was drawn using sketcher with appropriate dimensions and then it is padded to 3D object. The individual components designed were like the main cylinder, pipelines, elbows, sintered metal filter, filter holders, fittings etc. separately and the parts were assembled in the Assemble module of CATIA.

Initially, the frustum shaped metal filter was chosen instead of a circular one. This was considered as the frustum shape that would induce turbulence to the flow when compared to that of the circular one. A threaded adapter was used to secure the filter for withstanding high pressure. A valve is attached to the bypass line to adjust the concentration of the seeding particle depending on the visualization requirements. The main cylinder is closed at the top using a threaded lid instead of a
flange, as in the base design, so as to facilitate ease of removal of the metal filter in case of any damage and also to load the powder for seeding. Finally, another valve is used in the outlet line for regulating the outflow that can control the amount of seeding to be injected in the flow field.

![Figure 2. Initial 2D sketch of Seeding generator](image1)

![Figure 3. Assembled Section of designed parts](image2)

3. Manufacturing
Threading operation was carried out in Lathe Machine at one end of the cylinder (top) with depth of cut about 0.25-0.75mm. The threading is done for 3 inches in length for the top end. In the main cylinder, two holes of ¾ inch are made by drilling, using a radial drilling machine, on either side of the cylinder at a height of 3 inches from the bottom. In parallel, the sintered metal filter was tightened to its adapter and is welded to a circular plate by brass welding. This filter assembly was then welded to the main cylinder to at a height of 4 inches from the bottom by arc welding.

This process was carried out with most care so as to have thick weld without leaving an air gap. The main cylinder was placed over a flat plate for proper balancing and it was firmly welded along the joints. The inlet, outlet and bypass valves along with pipelines and other fittings were assembled with the main cylinder. The top closing was done by threading (same as the main cylinder) a cylindrical metal component of 6 inches in diameter and welding it over a flat plate. The inlet, exit and bypass
valves were secured by adhesives. The threaded parts of all components are rolled with Teflon. The finished product can be seen in figure 4.

4. Working Mechanism

4.1. Seeder Setup
When the setup was made ready, the seeding particles (coarse particle) were filled inside the main cylinder. The seeding particles were filled to a level that covers the sintered metal filter where it forms a bed. After the filling of seeding particles, the top lid was closed tightly. The hose from the compressor is connected to the inlet of the seeding generator. The hose has to be connected tightly to avoid leaks. Before pumping the air through the chamber, slightly open the inlet and outlet valve. Once the compressor valve is opened, the air move into the seeding generator such that the outflow air carrying the seeding particles can be observed. As per the requirement (amount of seeding particles), the inlet, bypass and the outlet valve is adjusted accordingly. Trial and error method can be used to find the best usage for the given requirement.

![Figure 4. Complete Equipment Picture](image)

4.2. Working Principle.
The airflow through the inlet is directed to the sintered metal filter. As the airflow through the filter, the fine pores present in the filter make the flow turbulent by which it carries the coarse particle along with it. The filter used in this generator has the shape of the frustum such that the flow has both radial and axial components of velocity which will lead to higher level of turbulence. The bypass is adjusted to change the concentration of the seeding particles in the flow.

5. Results and Visualization
Results were analysed on the basis of two methods laser visualization (figure 5) and pressure check. Both the results were compared and conclusions were drawn.
5.1. Visualization using Laser.
The Visualization setup is made with green Laser Sheet falling over the top surface of the outlet of the seeding generator as the exit flow from the orifice is focused to visualize the seeding particles. The shadow of the exit nozzle is captured in order to align the laser sheet exactly lies on the surface of the exit nozzle (see figure 6).

Figure 5. Laser Sheet Setup.

Figure 6. Laser light from top view.

Figure 7. Laser sheet showing Jet flow.
Through which perpendicular image is captured to visualize the seeding particle which comes out as smoke like jet flow (figure 6 and 7) when operated under pressure of 5-6 bar. Increasing the pressure inside the chamber will result in increased velocity of seeding particles. An increase in the amount of seeding particle will lead to an increase in concentration of the seeding particle in the fluid flow.

6. Conclusion
Fabrication of the Seeding Generator from the preliminary design to the finished product was carried out successfully. Quality of the fabrication and testing of the equipment is carried under various pressure ranging from 5-8 bar as the equipment is designed to work under 10 bar. Laser-based visualization of seeding particles is done in order to check the density of seeding particles for various pressure ranges.

Application of the work
- Visualization of flow patterns over the models and to enhance the effect of aerodynamic flow characteristics.
- The development of this equipment will help in PIV, as seeding generator plays a vital role in PIV techniques.
- Flow characteristics through various nozzles under various Reynolds numbers.

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7. References
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