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Computational Safety Evaluation of Universal Dyer

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ABSTRACT

The dryer was modeled and analyzed with Midas NFX software. The material of the cabin part and the trays are made of mild steel and properly insulated with asbestos. The velocities of air at the four different inlets 1, 2, 3 and 4 are 50.4028m/s, 51.2968m/s, 62.9867m/s and 54.4643m/s respectively while the air velocities at outlets 1 and 2 are 53.3088m/s and 53.0761m/s respectively. With these flows maintained the issue of pressure buildup of air and ignitable vapour that can result in explosion and pose danger or put the life of the operator at risk is significantly reduced. The largest nonlinear total deformation was 0.005114mm which is too small to be considered as a threat to the operator and/ or the equipment. The possibility of explosion from overstaying of dried combustible solid was taken care of by the temperature controller which make sure that the temperature within the system never go higher than 60oC (140oF) and never go low than 40oC (104oF) depending on the settings. The air distribution was even and adequate as shown by the computational Fluid Dynamics (CFD) which also translated to even and adequate temperature distribution within the system as the fan is only blowing hot air.

Keywords: Explosion, Hazard, Safety, Dryer, Midas NFX

I. INTRODUCTION

The importance of dryer cannot be overestimated as it is used for varieties of operation across industries like food processing, pharmaceutical, paper coating, fertilizer, solvent coating, wood pellet plant etc. While considering the usefulness to humanity we should also look well from the design point, the safety of this indispensable equipment so that it should not pose serious threat to the users or the operators. The work is aimed at evaluating the safety of the universal cabin dryer mainly to dry agricultural products with the aid of Midas NFX software.

The dryer is a cabin dryer with tray section in which the material to be dryer is arranged, it used an indirect method of heating in which an electric heater heats the air in the heat chamber and a blower send the hot air through a well-insulated pipe into the tray sections carrying the materials. Its designed with an exhaust fan which double as the pressure relief. There could still be a possibility of explosion from pressure build up (of air or ignitable vapour) or hot dried solid over staying in the cabin hence the need to carry out the safety evaluation of the design with the aid of computer aided engineering to ensure safety of the user, the material and the building in which it is housed. Experience has shown that the incidences of explosion is mostly associated with direct heater dryers using fuel or organic heat transfer fluids however it can result from hot dried combustible solid or pressure build up in the system if not taken care of properly from the design stage.

A. Drying Operation Hazard

Drying operations present a lot of hazard both from the stand point of the safety of the product of the drying and the safety of operator to avoid accident that can disrupt or interrupt the operations and harm the operator and cause damages to the environment and incur more cost of productions or even cost lives [1]. Equipment that is well controlled to produce quality product often has reduced the kinds of malfunction that result in damage to property or exposure to personnel. Some of the common hazards of drying operations include:

- Fuel explosion
- Release of flammable vapors/solvents and organic heat transfer fluids
- Accumulation of materials
- Sparks e.g. Electro statics, friction or electrical
- Dust fire or explosion
- Discharge of hot product for downstream processes or storage

Fuel explosion and majority of the accidents from drying operation is associated with the direct firing dryers which can be taken care of from the design stage. Each type of dryer presents its own uniqueness in terms of operation and design features which make value for the materials they are meant to process but these differences presents issues in developing appropriate prevention and mitigation strategies [1].

Heating can be provided by combustion of a fuel directly into the drying chamber or indirectly by using another media to convey the heat to the drying section. The indirect method may employ air, steam, hot water or organic heat transfer fluids. With the exception of some sensitive materials that needs a vacuum and low temperature most dryers operate at atmospheric pressure.

The material handled can be combustible or non-combustible which has a significant impact on the hazards that need to be dealt with. For this work, the focus will be on dryers handling combustible solids (agricultural products and herbs and roots) as these present both fire and explosion hazards.

Small quantities of materials will be dried in batch tray dryers and these present little or no explosion hazard from the solids being processed but can present vapor explosion hazards if the fluid being removed is an ignitable liquid. They can also present fire hazards if overheated or spilled solids remain in the dryer for extended periods.

A continuous dryer is used for a large quantity of material and the type of dryers commonly used are Belt dryer, Rotating drum dryer, flash or ring dryer, Spray dryer and fluidized bed dryers.

An investigation of accidents involving dryer carried out by the United States of America National Fire Protection Association (NFPA) indicated that 40% of the dryers are spray dryer. The majority of those reported incidences had design problem i.e. some were design without pressure relief vent.

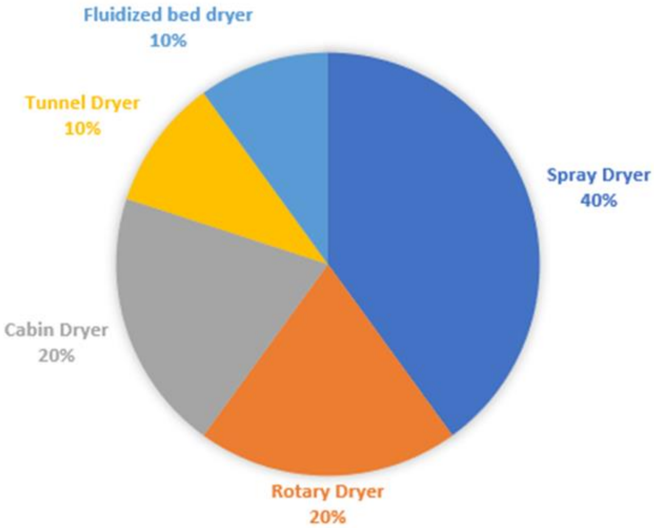

Figure 1 : Percentage of Dryer Type involved in Explosion Incidents

In most cases spray dryers used in the food and chemical process industries poses more danger to personnel, the equipment and the products due to its nature of operation [2].

The statistics of industrial accidents show that drying should be regarded as a potentially hazardous operation that has brought a number of reported incidents with serious results for personnel and equipment. Approximately 8-9% of all dust explosions in the food industries are related to drying operations [4]. The other data for the period of 1967 – 1983 in the German sugar industry indicate that drying contribute to 37% of all accidents where as in the French milk industry an average of four major accidents in spray dryer were reported annually [4]. Based on 89 accidents that happened in 1965 – 2000, 415 people were injured and 16 fatalities were reported in the accident data base [4]. It is worth to note that in most cases of spray dyer accidents in the food industry was observed whereas an explosion experienced in less than ten percent (10%).

Since dryer sections require use of high temperatures and pressures, they must be treated with caution. The nature of the dryers' function and required operating care make it important that they should be given close attention in the industry safety program. If unsafe conditions exist, the dryers must be shut down until the condition is corrected. The operators have to think safe and should be on guard against potential hazards. They should be a complete instructed on the proper use of the equipment and potential dangers of the heating systems, high pressures and high temperatures associated with dryer operation.

TABLE I. DRYER ACCIDENTS

Date	**Location**	**Equipment**	**Specific Detail**	**Cause**	**Consequences**	**Injuries/ Fatalities**
Oct.,7, 2005	Lauderdale, FL	Dryer	Clothe Dryer	Ignition of gas leak	Explosion	1 person injured, Burns & Trauma
Nov.,16, 2009	Box Holm, IA	Dryer	Medium size grain dryer	N/A	Explosion & fire	2 people seriously injured
Jun.,11, 2010	Elkford, BC, Canada	Dryer	Coal dryer	N/A	Explosion, Fire building damaged	No injuries

April,17, 2011	stone Ridge, NY	Dryer	Clothes Dryer	Dryer operation ignited propane leak	Explosion, Damage to house	No injuries, Pets was singed
Jul.,11, 2013	Tamarac, FL	Dryer	Clothes dryer	Gas dryer was being filled with clothes when it exploded	Explosion & fire ball	2 people with 1st degree burns
Dec.,12, 2013	Ford City, PA	Dryer	Clothes dryer	N/A	Explosion, minor chemical spill (detergent)	No injuries
June,29, 2014	Liberal, KS	Dryer	Corn dryer (ethanol plant)	Natural gas explosion in combustion chamber of dryer	Explosion, Damaged to the building	No Injuries

Source: [3]

Report have it that most of the dryers involved has been in operation for over ten years before the incidents. It is therefore recommended that a trained and responsible person be designated at the dryer to oversee its safe operation, maintenance and inspection programs. Inspection and careful evaluation of dryer air distribution system cover assembly is recommended as a routine preventative maintenance practice [5].

Since dryers are primarily heating units, the information on heating source, fuel, location of heating source and operating temperature range are all important. This aspect is completely dependent on the usage of these equipment. The temperature requirements of every operation are different. Dryers fall into the lower operating range temperatures compared to furnace or oven, mostly less than (260°C) 500°F. The above reports of various incidents involving dryers underline the importance of safety from explosion hazards in dryers and in the ancillary equipment.

B. Description of the Dryer

The universal dryer is a batch convective dryer using heated air as the drying medium and operating in batch wise mode. The dryer is an indirect heat tray type achieving heat exchange through direct contact between the hot air and the material to be dried. The dryer is designed to operate under adiabatic condition. The gas/solid contacting pattern in the dryer is parallel flow in which the direction of air flow is parallel to the surface of the material bed. Contacting is primarily at the interface between the air phase and tuber bed, with possibly some penetration of air into the voids among the material near the surface. The material bed is in a static (stationary) condition. It is design to operate within the temperature ranges of 40°C (104°F) to 60°C (140°F) with the aid of a temperature controller.

II. METHODS AND MATERIAL

The dryer was modeled and analyzed with Midas NFX software. The material of the cabin part and the trays are made of mild steel and properly insulated with asbestos. The fluid (air) flow simulation, Nonlinear deformation of the cabin resulting from the pressure build up in the system were carried out to check the air flow and possibility of explosion due to pressure.

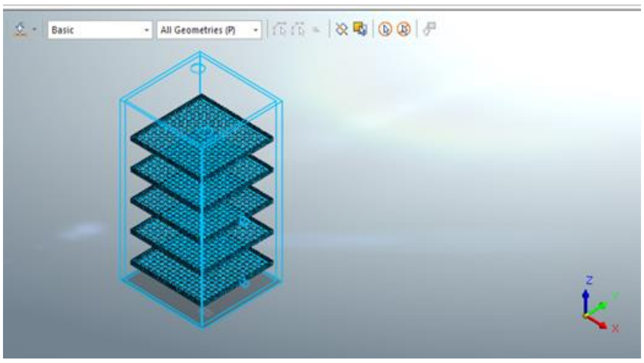

Figure 2 : Dryer Model

III. RESULTS AND DISCUSSION

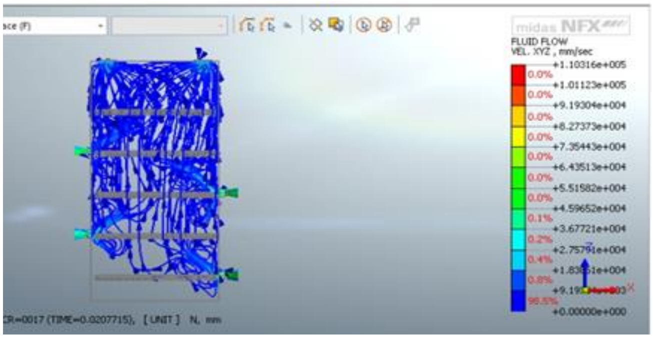

Figure 3: Dryer Airflow 1

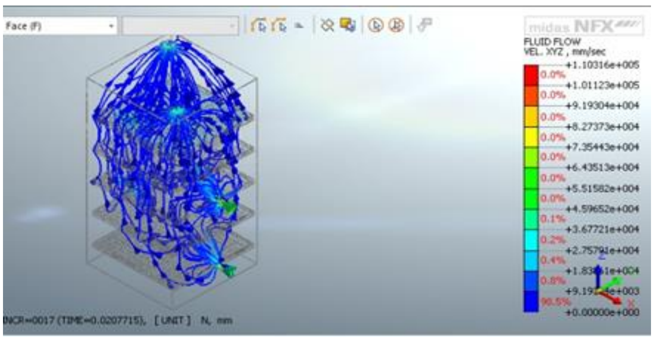

Figure 4: Dryer Airflow 2

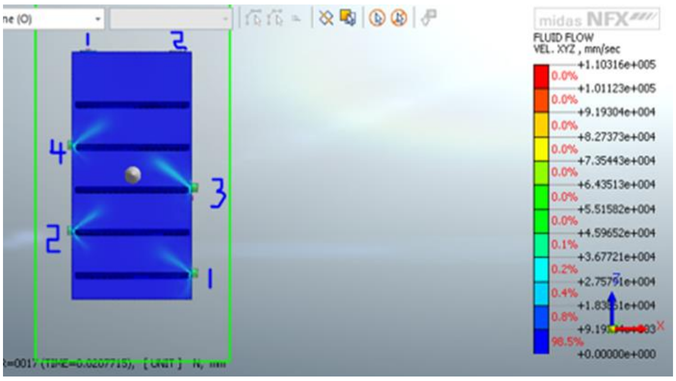

Figure 5: Dryer Airflow 3

Figures 2, 3 and 4 show the flow of air in the dryer as returned by Midas NFX. The air flows easily around the trays without any obstruction that could result to accumulations. The velocity of air at the four different inlets 1, 2, 3 and 4 are 50.4028m/s, 51.2968m/s, 62.9867m/s and 54.4643m/s respectively while the air velocity for outlet 1 and 2 as shown on the top of the figure 2C above are 53.3088m/s and 53.0761m/s respectively. With these flows maintained the issue of pressure build-up of air and ignitable vapour that can pose danger or put the life of the operator at risk is significantly reduced. The two vents which are diagonally located is very strategic to serve as a good pressure relief for the system. The air distribution was even and adequate as shown by the computational Fluid Dynamics (CFD) which also translated to even and adequate temperature distribution within the system as the fan is only blowing hot air.

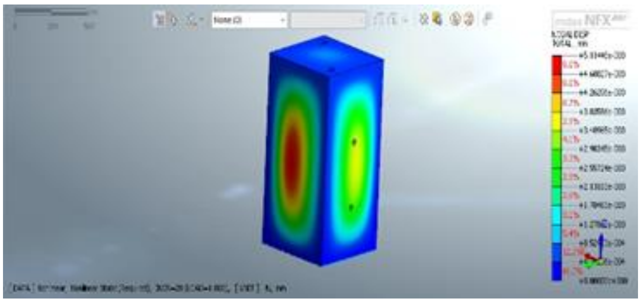

Figure 6: Dryer Deformations side A

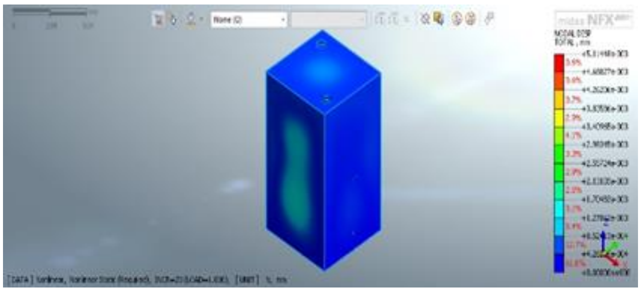

Figure 7: Dryer Deformations side B

The inside of the cabin was subjected to pressure resulting from the air flow and nonlinear static analysis was carried out to check the deformations that can come from the pressure within the system. The largest nonlinear total deformation was 0.005114mm which is too small to be considered as a threat to the operator and/ or the equipment as shown in Figs. 6 and 7. The proper air distribution within the system coupled with pressure relief vent contribute to the reduced pressure in the system. High pressure or sudden surge in the system that can cause sudden and large deformation.

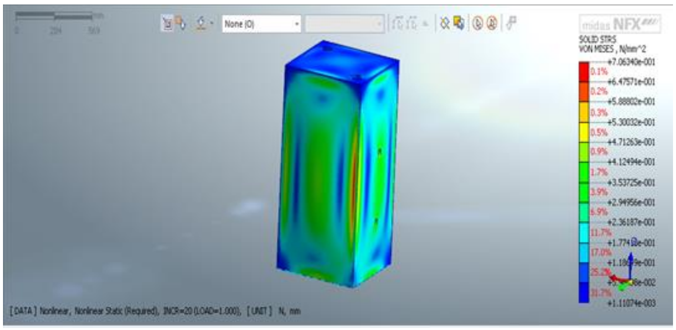

Figure 8: Stresses on the dryer

The most stressed part of the cabin as indicated by figure 8 has a stress of 7.0634Bar. That part shows the likely place where failure of material may start from. The part needs to be fortified for a longer service life.

IV. CONCLUSION

The safety evaluation of the universal cabin dryer has been carried out with aid of midas NFX. The airflow and the nonlinear deformation that can possibly result from the pressure built up in the system has been investigated and considered to be safe for the operator. The air distribution was even and adequate as shown by the CFD which also translated to even and adequate temperature distribution within the system since the fan is only blowing heated air. The possibility of explosion from overstaying of dried combustible solid was taken care by the temperature controller which make sure that the temperature within the system never go higher than 60°C (140°F) and never go low than 40°C (104°F) depending on the settings.

Future work will consider the use of other software like ANSYS [6-8] to compare its performance, then optimize the performance with different approaches involving mechatronics engineering [9-11].

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