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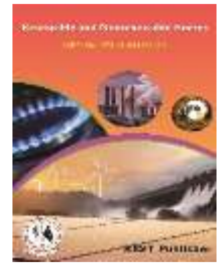

Structural and Functional Assessment of an IOT-Enabled Smart Silo

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Abstract: *Silos are on-site storage containers used for the storage and distribution of various types of mixtures. Silos of this type come in a variety of sizes, making them ideal for use. A silo can be a permanent structure, or a portable model that can be relocated when necessary. A storage silo can be structured to hold no more than a few tons of dry product, or be designed to efficiently hold several hundred tons. Generally, larger silos are permanent structures that cannot be moved. These simple storage devices can usually be set up in a matter of hours, then dismantled once the project is complete. The main objective of the project is to design a silo where silo weight can inform your silo level on your mobile through GSM/GPRS modem. This type of silo is called as Smart silo which will help to manage inventory and logistics in better way, improving overall business efficiency and cost saving. For the Smart Silo design Creo3.0 formerly known as PRO-E is used for this project, all individual parts of the silo are modeled in Part module and assembled in the Assembly module using bottom-up approach. The model converted into IGES file format which will be used for Analysis. For the analysis the FEA software ANSYS16.0 was used with different materials.*

Keywords: *Silo, Silo design, PRO-E, Analysis, FEA, ANSYS.*

1. INTRODUCTION

A silo is a structure for storing bulk materials. It is derived from the Greek word named Siros, pit for holding grain. They are used for bulk storage of grain, coal, cement, carbon black, woodchips, food products and sawdust. They are used in many agricultural, mining, food and chemical industries.

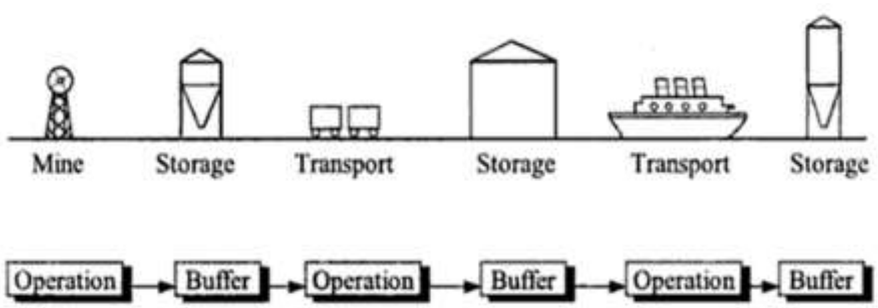

FIGURE 1. Operation of silo

There are many types of silos namely cement silos, bag silos, tanks, bins, concrete stave silos, low oxygen tower silos etc.

Cement Silo: Cement silos are on-site storage containers used for the storage and distribution of various types of cement mixtures. Silos of this type come in a variety of sizes, making them ideal for use at many kinds of construction sites. A cement silo can be a permanent structure, or a portable model that can be relocated where necessary. A cement storage silo can be structured to hold no more than a few tons of dry cement product, or be designed to efficiently hold several hundred tons. Generally, larger silos are permanent structures that cannot be moved. These are likely to be found at concrete plants, where the finished product is stored until it is time for shipment.

Sand And Salt Silos: Sand and salt for winter road maintenance are stored in conical dome-shaped silos. These are more common in North America namely in Canada and the United States.
TOWER SILO:

Tower silos containing silage are usually unloaded from the top of the pile, originally by hand using a silage fork, which has many more times than the common pitchfork. Bottom silo un-loaders are utilized at times but have problems with difficulty of repair. An advantage of tower silos is that the silage tends to pack well due to its own weight, except in the top few feet. However, this may be a disadvantage for items like chopped wood. The tower silo was invented by Franklin Hiram King.

FIGURE 2. Tower silo

Mechanism of silo:

Loading: Silo bags are filled using a traveling sled driven from the PTO of a tractor left in neutral and which is gradually pushed forward as the bag is filled. The steering of the tractor controls the direction of bag placement as it fills, but bags are normally laid in a straight line. The bag is loaded using the same forage harvesting methods as the tower, but the forage wagon must be moved progressively forward with the bag loader. The loader uses an array of rotating cam-shaped spiraled teeth associated with a large comb-shaped tines to push forage into the bag. The forage is pushed in through a large opening, and as the teeth rotate back out, they pass between the comb tines. The cam-shaped auger teeth essentially wipe the forage off using the steel tines, keeping the forage in the bag. Before filling begins, the entire bag is placed onto the loader as a bunched-up tube folded back on itself in many layers to form a thick pile of plastic. Because the plastic is minimally elastic, the loader mechanism filling chute is slightly smaller than the final size of the bag, to accommodate this stack of plastic around the mouth of the loader. The plastic slowly unfurls itself around the edges of the loader as the tube is filled. The contents of the silo bag are under pressure as it is filled, with the pressure controlled by a large brake shoe pressure regulator, holding back two large winch drums on either side of the loader. Cables from the drum extend to the rear of the bag where a large mesh basket holds the rear end of the bag shut.

Unloading: The main operating component of the silo un-loader is suspended in the silo from a steel cable on a pulley that is mounted in the top-center of the roof of the silo. The vertical positioning of the un-loader is controlled by an electric winch on the exterior of the silo.

For the summer filling of a silo, the un-loader is winched as high as possible to the top of the silo and put into a parking position. The silo is filled with a silo blower which is literally a very large fan that blows a large volume of pressurized air up a 10-inch tube on the side of the silo. A small amount of water is introduced into the air stream during filling to help lubricate the filling tube. A small adjustable nozzle at the top, controlled by a handle at the base of the silo directs the silage to fall into the silo on the near, middle, or far side, to facilitate evenly layered loading. Once completely filled, the top of the exposed silage pile is covered with a large heavy sheet of silo plastic which seals out oxygen and permits the entire pile to begin to ferment in the autumn. In the winter when animals must be kept indoors, the silo plastic is removed, the un-loader is lowered down onto the top of the silage pile, and a hinged door is opened on the side of the silo to permit the silage to be blown out. There is an array of these access doors arranged vertically up the side of the silo, with an unloading tube next to the doors that has a series of removable covers down the side of the tube. The un-loader tube and access doors are normally covered with a large U-shaped shield mounted on the silo, to protect the farmer from wind, snow, and rain while working on the silo. The silo un-loader mechanism consists of a pair of counter-rotating toothed augers which rip up the surface of the silage and pull it towards the center of the un-loader. The toothed augers rotate in a circle around the center hub, evenly chewing the silage off the surface of the pile. In the center, a large blower assembly picks up the silage and blows it out the silo door, where the silage falls by gravity down the un-loader tube to the bottom of the silo, typically into an automated conveyor system. The un-loader is typically lowered only a half-inch or so at a time by the operator, and the un-loader picks up only a small amount of material until the winch cable has become taut and the un-loader is not picking up any more material. The operator then lowers the un-loader another half-inch or so and the process repeats. Once silage has entered the conveyor system, it can be handled by either manual or automatic distribution systems. The simplest manual distribution system uses a sliding metal platform under the pickup channel. When slid open, the forage drops through the open hole and down a chute into a wagon, wheelbarrow, or open pile. When closed, the forage continues past the opening and onward to other parts of the conveyor. Computer automation and a conveyor running the length of a feeding stall can permit the silage to be automatically dropped from above by each animal, with the amount dispensed customized for each location.

Safety: Silos are hazardous, and people are killed or injured every year in the process of filling and maintaining them. The machinery used is dangerous and with tower silos workers can fall from the silo's ladder or work platform. Several fires have occurred over the years.

2. LITERATURE SURVEY

Can Balkava, Erol Kalkan and S.Bahadir Yuksel, “Finite Element Analysis and Practical Modeling of Reinforced Concrete Multi-Bin Circular Silos,” Journal of silos.Stress resultants in overlapping wall regions (intersection walls) of multi-bin circular silos require a significant computational effort to determine forces due to structural continuity. This paper presents a practical equivalent beam model for computing design forces along the silo walls when subjected to various internal and interstice loadings. The equivalent beam model of intersection wall was developed based on the effective length concept, and verified in a comprehensive series of finite element (FE) analyses of a cluster of four silos for various silo-wall thicknesses. The influence of wall thickness on hoop forces and bending moments acting on interstice and external walls were also examined, and simple empirical expressions were presented for design applications. The proposed beam model yields an accurate estimation of bending moments and hoop forces with a maximum 7% deviation compared with those obtained from detailed FE models. Siti Ilyani Rani, Jolius Gimbun, Badhrulhisham Abdul Aziz, “Prediction of Particles-Air Movement in Silo during Filling Operation,” Journal of silos.Awareness of dust explosion hazards during silo filling operation is important for safety measures. Thus, information on particles-air flow field is required to assess the likelihood of the hazard. Flow field visualization via experimental investigation associated with difficulties and risks. Hence, in the present study, a modeling formulation using commercial computational fluid dynamics (CFD) code, FLUENT software was employed to predict an insight of flow field distribution, in terms of mean and root mean square (RMS) velocities vectors in cylindrical silo during axial filling. According to the simulation results, predicted flow field has a great influence to the silo height and distance to the silo wall due to gravitational force and movement of fugitive dust and re-circulation of air. The results showed that the predicted data were in very good agreement with experimental data obtained from the literature. The maximum error was around 10%. The study has gone some way towards enhancing our understanding of the particles-air behavior inside industrial equipment during filling operation.

3. MODELING

Computer-aided design and drafting (CADD), is the use of computer technology for the process of design and design-documentation. Computer Aided Drafting describes the process of drafting with a computer. CADD software, or environments, provides the user with input-tools for the purpose of streamlining design processes; drafting, documentation, and manufacturing processes. CADD output is often in the form of electronic files for print or machining operations.

Introduction To Creo 2.0: CREONGINEER (Pro/E) is developed by PTC Company and CREO Elements combined. It is a program that is used to create precision three-dimensional computer models. The 3-D parts created on CREO use a technique known as solid modeling. Other important definition used to classify Pro/E is: feature-based parametric bi-directional associative software. CREO is a fully parametric CAD program This means that the geometry of features (e.g., holes, slots) on a part have to be fully specified in terms of size, shape, orientation, and location.

Modeling of smart silo:

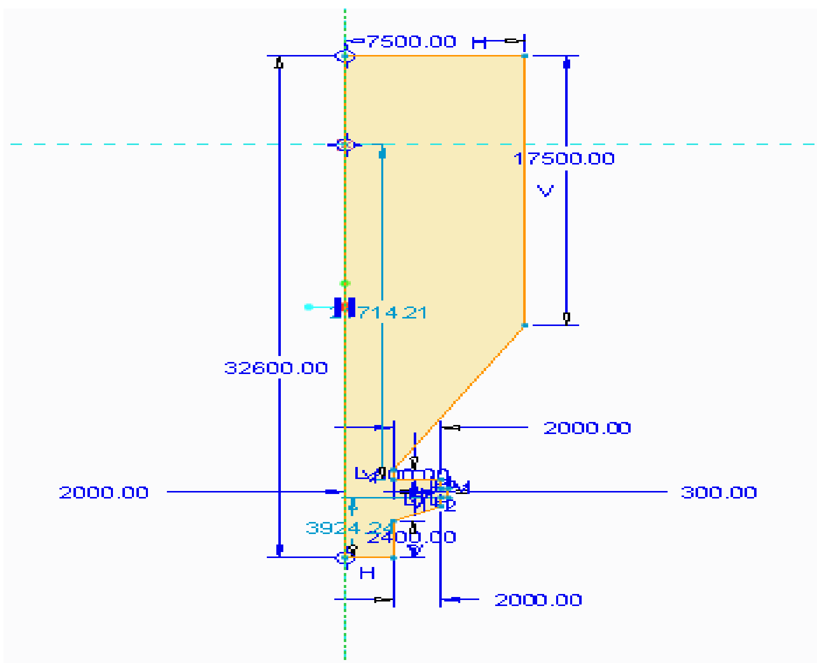

FIGURE 3. Section creation for revolve operation

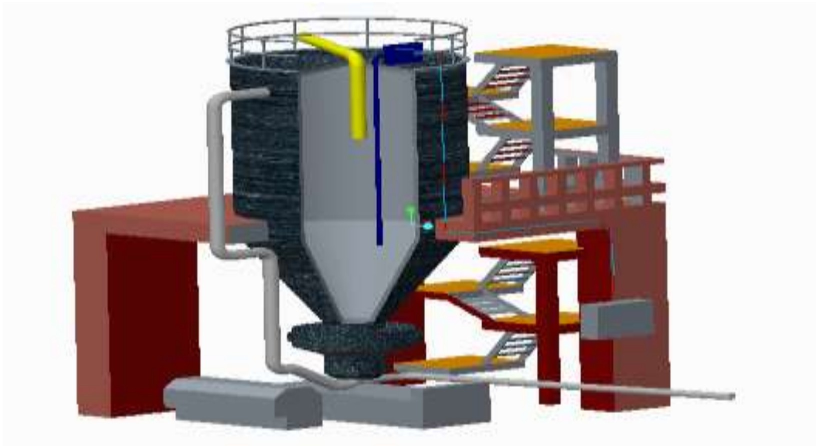

FIGURE 4. Smart silo

Procedure*:*

Extrude: To add or remove the material in the orthogonal direction
Extrude -- placement -- selection of the sketch plane -- draw the sketch -- mention the depth -- preview -- ok
Revolve: To add or remove the material in counter clock wise direction
Revolve -- placement -- select the sketch plane -- create the centre line -- draw the required sketch -- mention the angle -- preview -- ok
Sweep: To add or remove the material along the profile with a specified section at the starting point of the trajectory.
Sweep -- select the sketch -- create or edit sweep section -- create a section at the starting point of the section -- preview -- ok.

Helical Sweep: To add or remove the material along the profile with a specified section at the starting point of the trajectory with respect to center line in counter clock wise direction.

Helical sweep -- references -- define helix sweep profile -- select the sketch plane -- create an open profile -- create center line -- create or edit sweep section -- draw the section at the starting point of the trajectory -- ok.

Hole: To remove the material as per user preferences and also as per ISO standards.
Hole -- placement -- specify the two references -- mention the type of the hole -- preview -- ok
Round: To make sharp edges as round
Round -- select the edges to be round -- specify the required radius -- preview -- ok
Chamfer:To make sharp edges as flat
Chamfer -- select the edges to be flat -- specify the two distances or distance and angle -- preview -- ok
Mirror:To create the duplicate object with reference to a datum plane or flat surface.
Select the object -- select the mirror tool which was highlighted -- select the reference plane or surface -- preview -- ok.

4. ANALYSIS

Finite Element Analysis: It was first developed for the use of aerospace and nuclear industries where the safety of structure is critical. Today growth in the usage of method is directly attributable to the rapid advances in computer technology. As a result commercial finite element packages exist that are capable of solving the most sophisticated problems, not just in structural analysis, but for wide range of phenomena such as steady state and dynamic temperature distributions, fluid flow and manufacturing processes such as injection molding and metal forming. Finite element analysis is used in new product design, and existing product refinement. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, Finite Element Analysis may be used to help in determining the design modifications to meet the new conditions.

Types of Analysis: There are different types of analysis that are used in industry: Structural, Modal, Harmonic, Transient and Spectrum.

Introduction To Ansys Software: The purpose of a finite element analysis is to model the behavior of a structure under a system of loads. In order to do so, all influencing factors must be considered and determined whether their effects are considerable or negligible on the final result. Many software's are used for this purpose. ANSYS, Pro-E, Uni-graphics, NISA, MSC, NASTRAN etc.

The ANSYS program is self-contained general purpose finite element program developed and maintained by Swanson Analysis Systems Inc. The program contains many routines, all interrelated and all for main purpose of achieving a solution to an engineering problem by Finite Element Method.

ANSYS provides a complete solution to design problems. It consists of powerful design capabilities like full parametric solid modeling, design optimization and auto meshing, which gives engineers full control over their analysis.

The following are the special features of ANSYS software:

- It includes bilinear elements.
- Heat flow analysis, fluid flow and element flow analysis can be done.
- Graphic package and extensive preprocessing and post processing.

The following shows the brief description of steps followed in each phase:

TABLE 1. Various stages of Ansys

Pre- Processor Phase	Solution Phase	Post Processor Phase
Geometry definitions	Element matrix formulation	Post solution operation
Mesh generation	Overall matrix triangulation	Post data print out
Materials definition	Wave front	Post data display
Constraint definition	Displacement, stress, etc.	--
Load definition	Calculations	--

TABLE 2. Structural Analysis

S.NO	Materail	Load	Equivalent Stress	Total Deformation
1	Galvanized Steel	25000 N	0.022365 M Pa	0.00488 mm
2	Stainless Steel	25000 N	0.022132 M Pa	0.005 mm
3	RCC	25000 N	0.02531 M Pa	0.00476 mm

TABLE 3. Thermal Analysis

S.NO	MATERAIL	Temp	Total Heat Flux	Directional Heat Flux
1	Galvanized Steel	250	0.0133	0.0108
2	Stainless Steel	250	0.004813	0.0044
3	RCC	250	0.00105	0.000756

TABLE 4.

S.NO	MATERAIL	Temp	Total Heat Flux	Directional Heat Flux
1	Galvanized Steel	250	0.0133	0.0108
2	Stainless Steel	250	0.004813	0.0044
3	RCC	250	0.00105	0.000756

5. RESULTS AND DISSCUSSIONS

Static Structural Analysis:

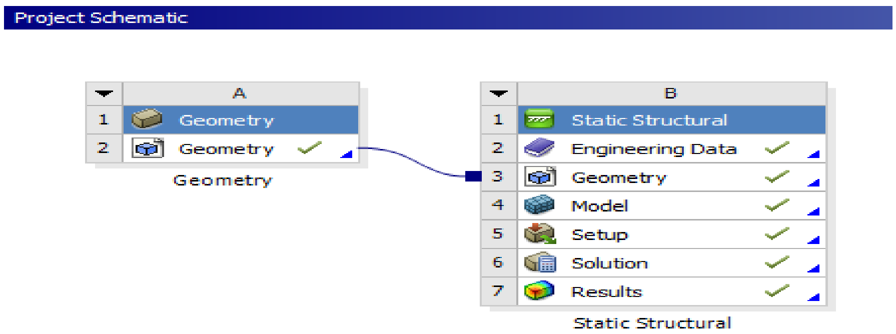

FIGURE 5. Project schematic

Imported geometry:

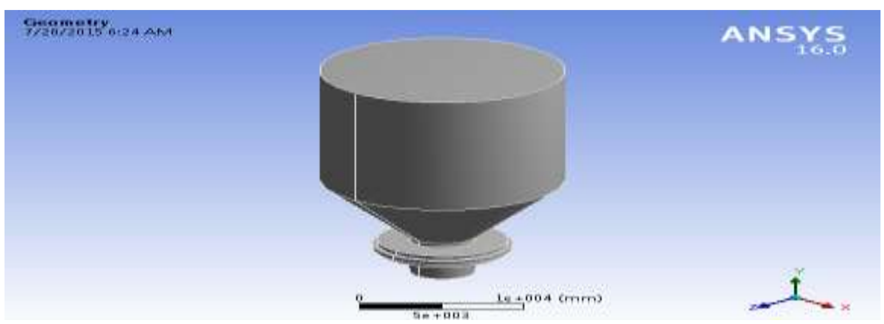

FIGURE 6. Imported Geometry

Material Application

For galvanized steel:

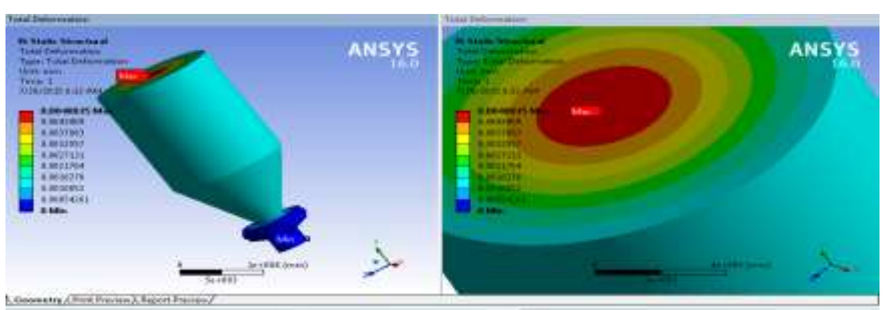

FIGURE 7. Total deformation of galvanized steel

For stainless steel material:

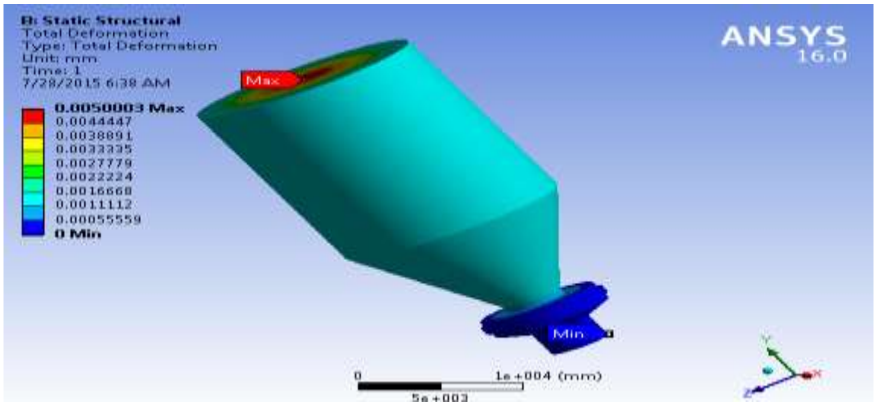

FIGURE 8. Total deformation of stainless-steel material

For RCC material:

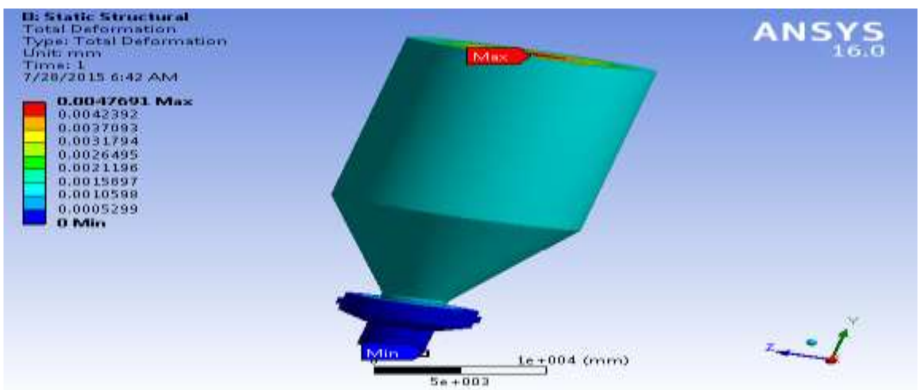

FIGURE 9. Total deformation of RCC material

Steady State Thermal Analysis*:*

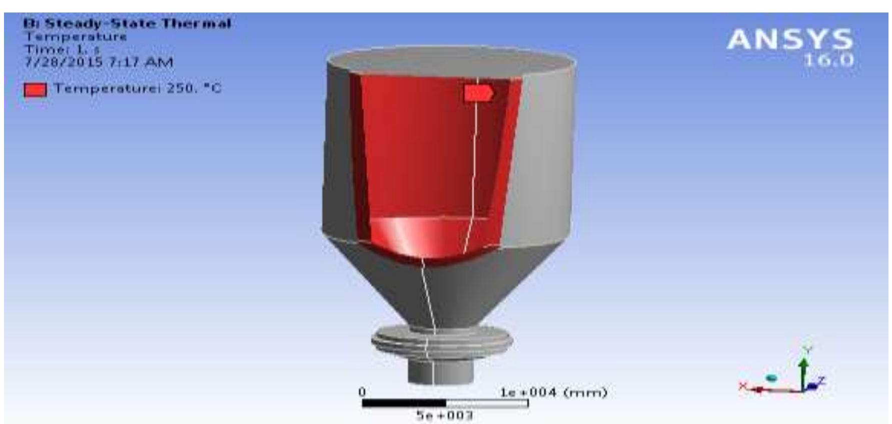

FIGURE 10. Temperature application

For galvanized steel:

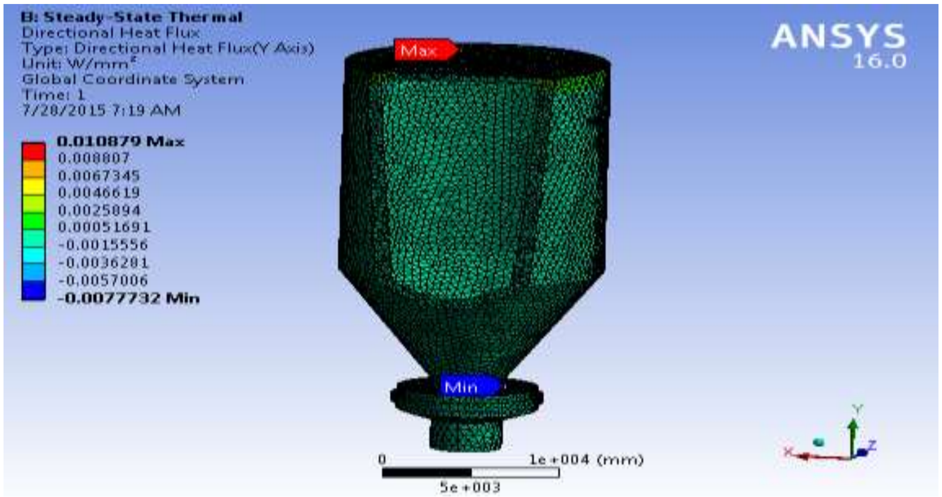

FIGURE 11. Directional heat flux

For stainless steel:

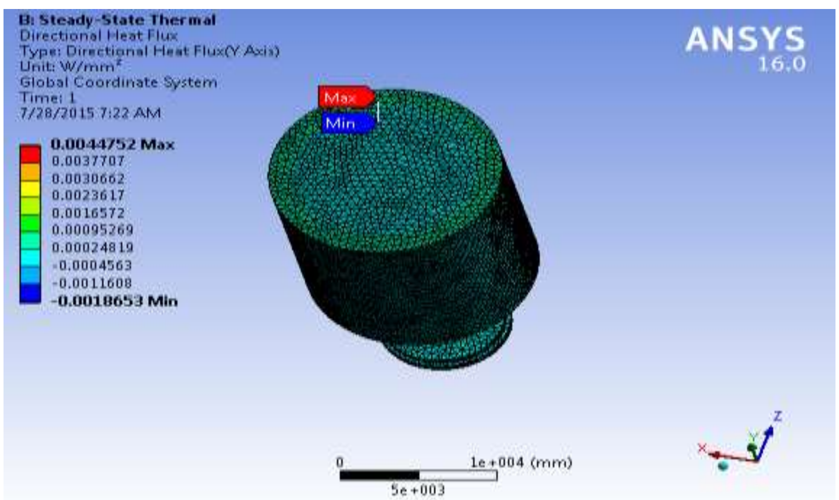

FIGURE 12. Directional heat flux of stainless steel

For RCC:

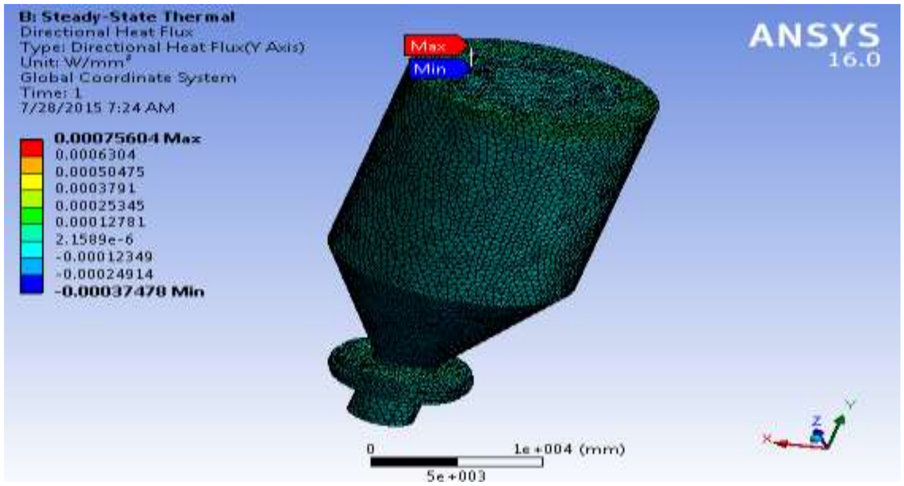

FIGURE 12. Directional heat flux of RCC

6. CONCLUSION

The present work has been taken up to study of three different materials i.e., galvanized steel, stainless steel and RCC. For Smart silo, the stainless steel is the best one when compare to the other two materials. The smart silo is the best of all silos which efforts to lower the cost of production are made on continuous basis in cement plant and other type of industries. These measures include high-capacity utilization, reducing down time, saving in energy consumption, minimizing maintenance cost, advanced automation level, waste heat utilization, etc. Modern processing techniques help to achieve these objectives to agreat extent. These techniques should be adopted preferably at plant installation stage.

Scope Of Future Work: The present work can be extended by system to monitor up to 8 digital and 4 analog inputs from silo weight monitoring silo/tank/hopper levels in RMC plant, Cement plant, power plant, Material handling and storage industry or any other industrial complex where mobile signals are available.

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