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"Crack Propagation and its rectification on Spray Powder Separator (Cyclone)"

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Abstract— A gas-solid cyclone separator is a separation device that separates solid particles from a gas phase using a centrifugal force field. In traditional spray drying a cyclone separator is often included in a succeeding separation step, after a spray drying chamber. This thesis a study and analysing crack propagation in Cyclone Insert cone, It includes brain storming, collection of data, finding solutions by verification of parameters, material & FEM.

Keywords— ***Spray Drying, Powder separation, cracks in process equipment's, cyclone, Material Testing, Autodesk Inventor, Fatigue analysis, Static Analysis, CFD output, ANSYS WORKBENCH***

I. INTRODUCTION

Cyclone separators are used in food powder manufacturing industries to separate solid particles by cyclonic effect. There are change in velocities and pressure at inlet and outlet of cyclones and Air in with fine powder form cyclonic effect and move outward from small opening cone called Insert cone which gives change in velocity.

Here we are studying & analysing various reasons for crack propagation on Cyclone separator Insert cone

.

Figure 1. Crack on cyclone Insert cone

1. Particles hit the wall of the cyclone, decelerate, and separate from the air stream.

2. Particles fall under gravity towards catch-pot at the base of the cyclone.

3. Clean air passes to extraction source.

4. Captured particles in the catch-pot are removed for batch loss reconciliation, disposal or reintroduction to the process (subject to QA and validation).

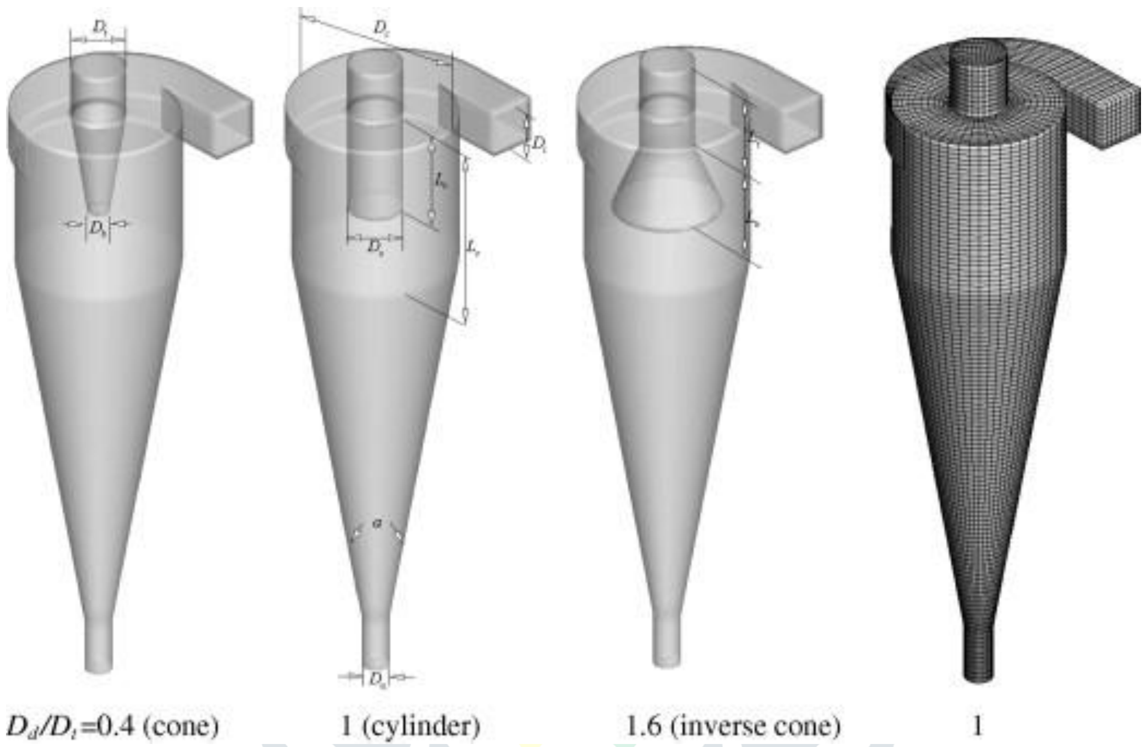


Figure 2. Various types in cyclone

Purpose The purpose for this thesis is to investigate how spray drying is possible in cyclone separators. The changes of pressures Involved, Material study, Factors involved at time of production at customer site, FEM Analysis

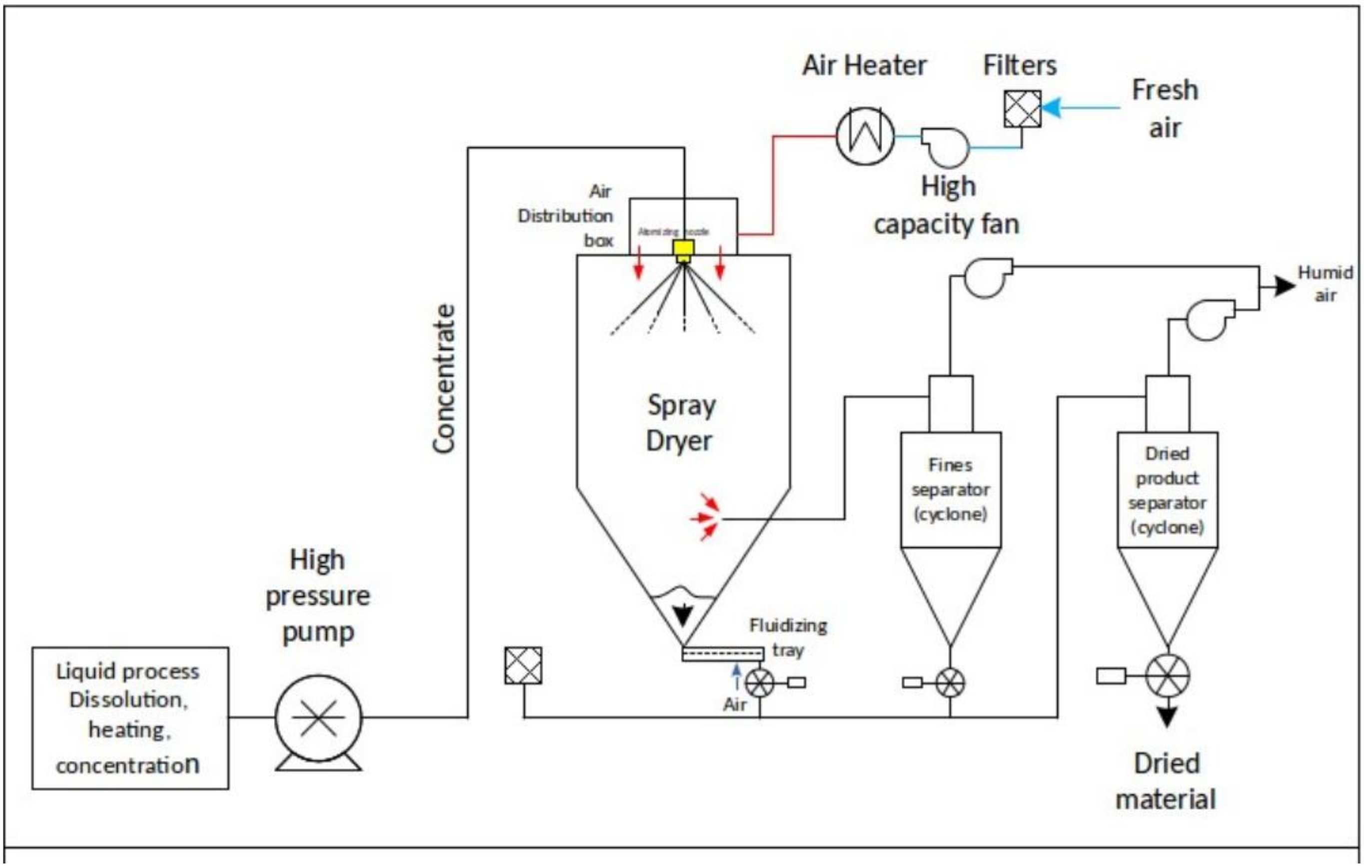


Figure 3: Working principle of Spray drying with Process flow diagram

The following drawing is a simplified flowsheet of a common spray drying process with co-current air / product flow in the spray dryer chamber and open air cycle. There are more complicated and performant spray drying technologies but the representation below somehow constitutes a minimum for an industrial line.

Independently of the degree of complexity of the factory, the spray drying process is made of 5 main steps described thereafter.

Here various process are involved such as ;

1. Wet Process
2. Atomization
3. Drying
4. Solid separation

Here as we are going to analyze Separator lets concentrate on that.

Separation.

Industrial spray dryers are able to reach several tons / h and have typically large drying chambers and several nozzles. However, there is also on the market laboratory spray dryers (mini spray dryers) that are very useful for research work, or simply to get a 1st idea of a product and its easiness of drying before scaling up to the industrial line.

2. PROBLEM STATEMENT & BRAIN STORMING

1. Crack in Insert cone. – When? What? How?

   When these cracks observed?
   What must be reason?
   What parameters to be check?
   How to analyze?

2. Parameters such as Pressure difference between Inlet and outlet of cyclone, Temperature need to be verified.

3. Brain storming with technical team at site, Internal technical team, Quality team and design team performed and various possibilities are generated and action will be taken.

Results OF Brain Storming.

- Focus of study will be to study and analyze the reason for cracks and how it can be optimized. These can be divided on following ways.
  - Data for operating parameters; Pressure, Temperature etc.
  - Study on data for any shocks observed.
  - Testing material.
  - Is dried product is corrosive?
- If all above stages are ok, then focus on ;
- IV. FEM analysis with respect to operational data and CFD inputs.
- CFD Analysis will be performed by CFD team & FEM Analysis will be done by me.

  Upon solution achievement; fabrication methods at site.

3.1.1 Data for operating parameters; Pressure, Temperature etc.

As mentioned in Manufacturing process Chapter.

Pressure drop across cyclone is between 1000 to 2000 Pa.

Mostly cyclones are calculated using design parameters which are above operational parameters.

Design Temp; 120- 150 DegC**

Pressure Shock Approx. 0.2 to 0.5 Bar**

Vacuum. 1500 Pa**

Pressure difference between Inlet and outlet depending on type of product.

Against above standard data; Verification has been done for component in operation. At check point it seems correct values, but real time analysis to be performed when crack is observed.
For real time analysis; I made a checklist to discuss with peoples involved on verification of parameters to understand how crack was detected, time and change in parameters observed.

3.2 Study on data for any shocks observed.

Recent Article from Bharti Vidhyapith Technology,Mumbai on crack propagation & Process study from K. Masters Handbook.

Any defect or crack on the surface of process equipment like pressure vessel can lead to a fatal accident during operation, so it needs to be crack analysis. The present work has done to review the methods and techniques to analyze the process equipment like pressure vessel. Hence procedure could be developed to analyse or to test process equipment like pressure vessel on the basis of operating parameters by using techniques like SIFs by validate the results with the FEA results.

From discussion and brainstorming with inside stake holders of my company.

As our components are designed as per process parameters and validated with FEA analysis. It was time to study different approach for parameter which cause a crack.

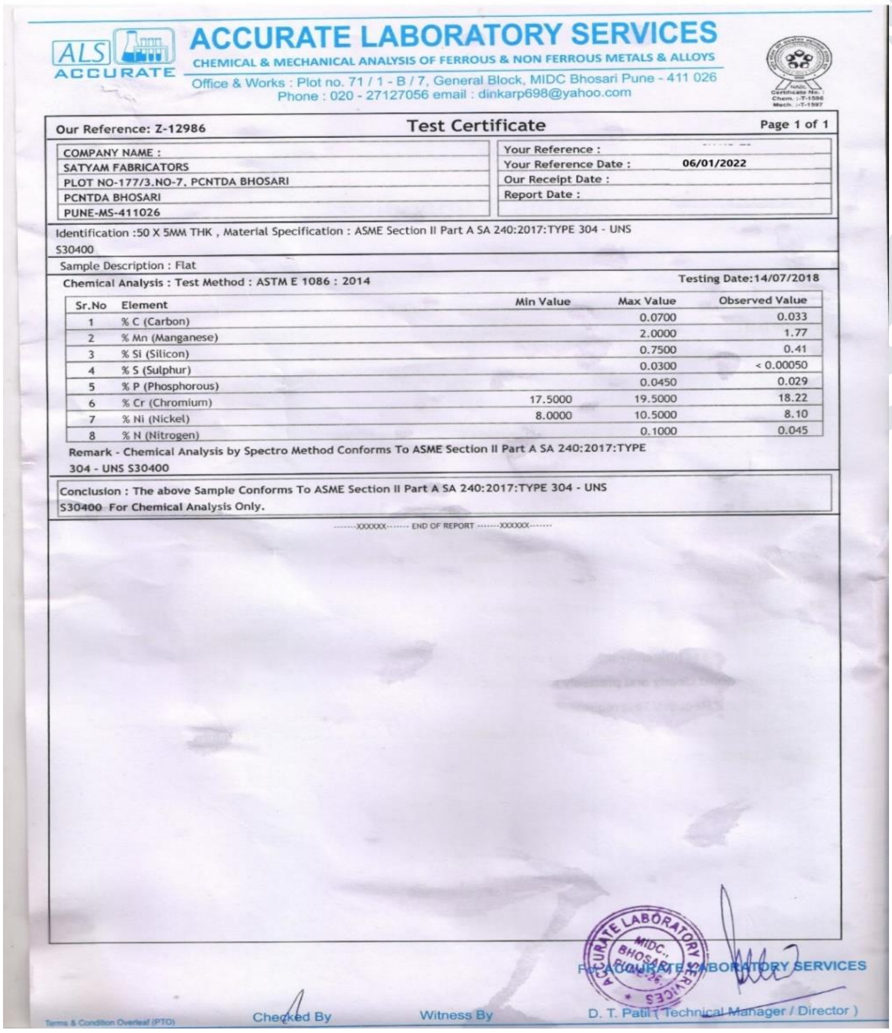
Crack in any process equipment can occur if process parameter goes beyond design parameters, Sudden shock waves, large pressure differences

Crack can occur also, if material selection is incorrect or used material is not as per requirement which may corrode if not stainless steel.

3.3 Testing material.

Chemical and Mechanical test has been performed for fractured material. Test report snaps are shown in fellow figures,

Chemical for 5mm thick Material.



ACCURATE LABORATORY SERVICES

CHEMICAL & MECHANICAL ANALYSIS OF FERROUS & NON FERROUS METALS & ALLOYS

Office & Works : Plot no. 71 / 1 - B / 7, General Block, MIDC Bhosari Pune - 411 026

Phone : 020 - 27127056 email : dinkarp698@yahoo.com

Our Reference: Z-12986 — Test Certificate — Page 1 of 1

COMPANY NAME :	Your Reference :
SATYAM FABRICATORS	Your Reference Date : 06/01/2022
PLOT NO-177/3.NO-7. PCNTDA BHOSARI	Our Receipt Date :
PCNTDA BHOSARI	Report Date :
PUNE-MS-411026	

Identification :50 X 5MM THK , Material Specification : ASME Section II Part A SA 240:2017:TYPE 304 - UNS S30400

Sample Description : Flat

Chemical Analysis : Test Method : ASTM E 1086 : 2014 — Testing Date:14/07/2018

Sr.No	Element	Min Value	Max Value	Observed Value
1	% C (Carbon)		0.0700	0.033
2	% Mn (Manganese)		2.0000	1.77
3	% Si (Silicon)		0.7500	0.41
4	% S (Sulphur)		0.0300	< 0.00050
5	% P (Phosphorous)		0.0450	0.029
6	% Cr (Chromium)	17.5000	19.5000	18.22
7	% Ni (Nickel)	8.0000	10.5000	8.10
8	% N (Nitrogen)		0.1000	0.045

Remark - Chemical Analysis by Spectro Method Conforms To ASME Section II Part A SA 240:2017:TYPE 304 - UNS S30400

Conclusion : The above Sample Conforms To ASME Section II Part A SA 240:2017:TYPE 304 - UNS S30400 For Chemical Analysis Only.

-------XXXXXX------- END OF REPORT -------XXXXXX-------

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Chemical for 3mm thick Material.

ALS ACCURATE

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Our Reference: Z-12068 — **Test Certificate** — Page 1 of 4

COMPANY NAME :	Your Reference :
SATYAM FABRICATORS	Your Reference Date :
PLOT NO-177/3.NO-7, PCNTDA BHOSARI	Our Receipt Date : 06/01/2022
PCNTDA BHOSARI	Report Date :
PUNE-MS-411026	

Material Specification : ASME Section II Part A SA 240:2017:TYPE 304L - UNS S30403

Sample Description : Plate Size :3.00(Thickness)

Tensile Test : Test Method : ASME Section II-A:SA 370 : 2015 Testing Date:08/07/2018

Parameter	Min Value	Max Value	Observed Value
Test Temperature (ºC)			Ambient
Test Specimen Type			Flat
Average Width (mm)			12.50
Average Thickness (mm)			2.96
Average Area (Sq. mm)			37.00
Gauge Length (mm)			50.00
Yield Load (KN)			12.48
Ultimate Load (KN)			23.24
Final Gauge Length (mm)			79.11
Yield Stress (N/mm2 or MPa)	170.00		337.30
Ultimate Tensile Stress (N/mm2 or MPa)	485.00		628.11
% Elongation	40.00		58.22
Fracture Location			W.G.L
Fracture Type			Ductile

Remark - Tensile Test Conforms To ASME Section II Part A SA 240:2017:TYPE 304L - UNS S30403

Chemical Analysis : Test Method : ASTM E 1086 : 2014 Testing Date:06/07/2018

Sr.No	Element	Min Value	Max Value	Observed Value
1	% C (Carbon)		0.0300	0.029
2	% Mn (Manganese)		2.0000	1.07
3	% Si (Silicon)		0.7500	0.24
4	% S (Sulphur)		0.0300	< 0.0010
5	% P (Phosphorous)		0.0450	0.030
6	% Cr (Chromium)	17.5000	19.5000	18.25
7	% Ni (Nickel)	8.0000	12.0000	8.59
8	% N (Nitrogen)		0.1000	0.061

Remark - Chemical Analysis by Spectro Method Conforms To ASME Section II Part A SA 240:2017:TYPE 304L - UNS S30403

Hardness Test : Test Method : ASME Section II-A:SA 370 : 2015 Testing Date:07/07/2018

Type	Identification	Location	Scale	Indentor	Ball Dia	Load(Kg)	Min	Max	R1	R2	R3
HRBW	--	Surface	B (Red)	Ball	1/16"	100		92.00	86.0	86.0	87.0

Remark - Hardness Test Conforms To ASME Section II Part A SA 240:2017:TYPE 304L - UNS S30403

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From testing reports it seems that material used for fabrication is as per requirement so crack is not due to wrong material.

As above scenario satisfies the requirement then next step will be verification of Cyclone worst condition scenario for crack propagation.

We Myself and our Global design team has collected date for worst scenario for CFD as well as FEM analysis.

4. FEM ANALYSIS

4.1 REFERENCE DOCUMENT

Regulations, Codes and Standards

No.	Document No.	Title
1	EN13445 PART-2	Design and Manufacturing Code
2	ASME SEC-II PART-D,2015	Materials (for yield strength and tensile stress values).

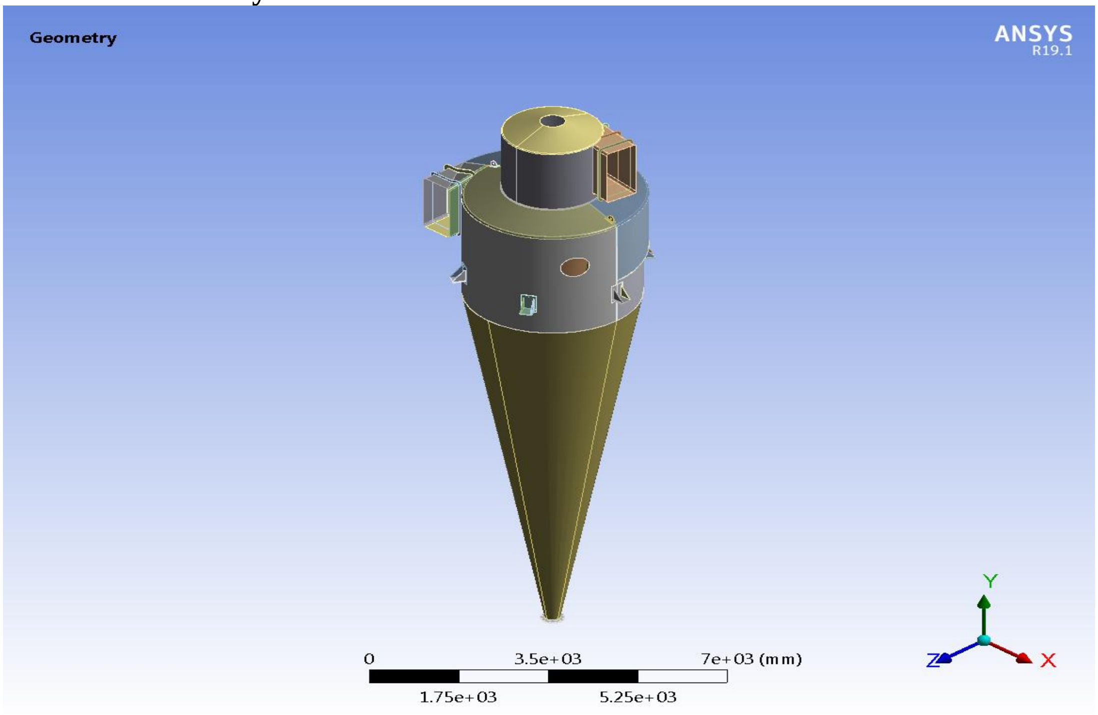
4.2 Design Parameters

1. Design Pressure (External and Internal) as per requirements
2. Design Temperature as per requirements
3. Pressure drops
4. Material of construction

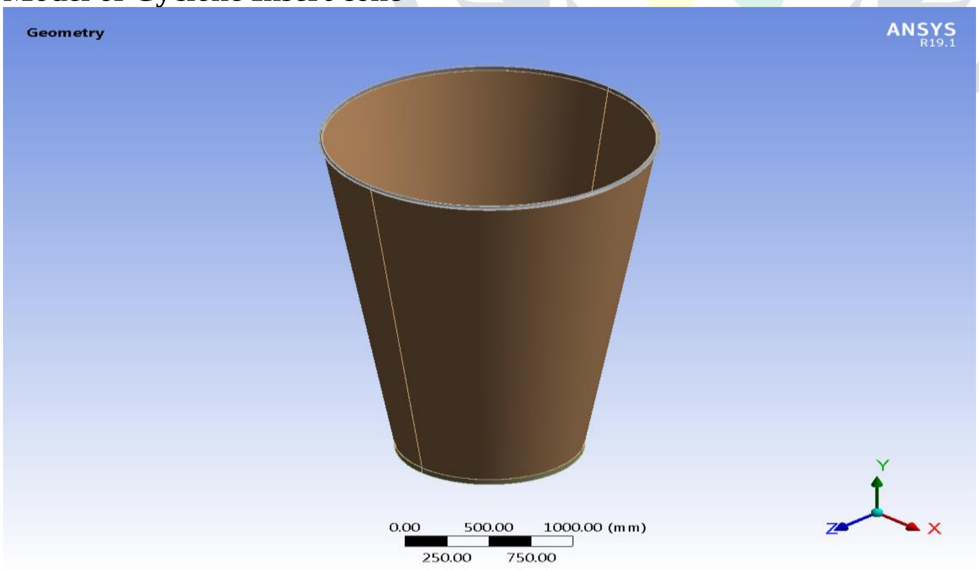
4.3 Cyclone Model

Drawing No.- XXXXXXXXXX

1. **Model of Cyclone**



Model of Cyclone Insert cone

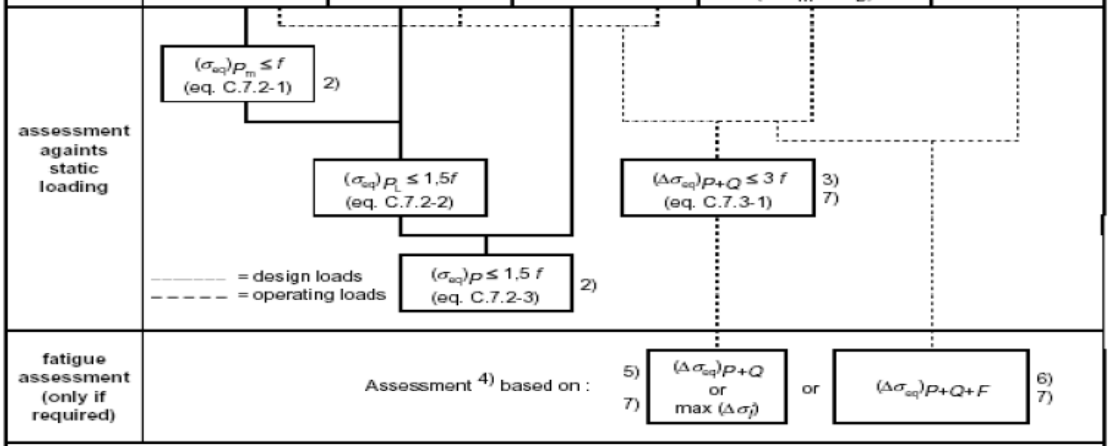


Component Name	Material	Young Modulus (MPa)	Poisson's Ratio	Allowable Stress (*S)(MPa)
Insert cone assembly	SS 304L	187.8×10^3	0.3	115

*S : Allowable Stress of material at design temperature

Acceptance Criteria

	Stress Categories				
	Primary stress			Secondary membrane + bending stress	Peak stress
	General membrane stress	Local membrane stress	Bending stress		
Description (For practical examples, see Table C-2)	Primary mean stress calculated across the wall thickness without taking into account discontinuities and stress concentrations. Caused only by mechanical loads.	Primary mean stress calculated across the wall thickness taking into account large discontinuities, but not stress concentrations. Caused only by mechanical loads.	Primary stress component proportional to the distance from the centroid of the solid wall section. Does not include discontinuities and stress concentrations. Caused only by mechanical loads	Self-equilibrating stress necessary to satisfy the continuity of the structure. Occurs at large discontinuities, but does not include stress concentrations. Can be caused by both mechanical loads and thermal effects.	a) Addition to primary or secondary stress because of stress concentration. b) Certain thermal stresses which may cause fatigue, but not distortion.
Symbol	P_m	P_L 1)	P_b	Q $(= Q_m + Q_b)$	F



1) $P_L = P_m$ does not occur at the point in question.

2) In assessment criteria given in equations (C.7.2-1) to (C.7.2-3), the value of the nominal design stress f shall be that relevant for the loading condition under consideration (normal operation, exceptional operation, proof test), as defined in clause 6.

3) If $(\Delta\sigma_{eq})P+Q$ is greater than $3f$, see C.7.6

4) Fatigue assessment shall consider all the applied cycles of various types, each of them being characterised by their own relevant stress range (see footnotes 5 and 6), mean temperature and mean stress (if relevant). Clause 18 (detailed fatigue assessment) should normally be used.

5) The primary + secondary stress range (named "structural stress range" in clause 18 on detailed fatigue assessment) applies to assessment of welded joints. In that case, either the equivalent stress range $(\Delta\sigma_{eq})P+Q$ or the maximum principal stress range $\max(\Delta\sigma_i)$ may be used.

6) The primary + secondary + peak stress range, named "total (notch) stress range" in clause 18 on detailed fatigue assessment, applies to assessment of unwelded parts.

7) It should be observed that, depending on the model used, the computer programs usually give directly the primary + secondary stresses ($P + Q$) or the primary + secondary + peak stresses ($P + Q + F$).

4.4 Meshing

All the components have been meshed with SOLID186 elements. SOLID186 is used for the three-dimensional modeling of solid structures. The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element has plasticity, stress stiffening, large deflection, and large strain capabilities.

SOLID186 Homogeneous Structural Solid is well suited to modeling irregular meshes (such as those produced by various CAD/CAM systems).The element may have any spatial orientation. It can be adjust itself in the required shape (Tetrahedral, pyramidal, prism etc.) depend upon the complex geometry of the part. Representation of solid 186 element with different shapes is given below in Fig.

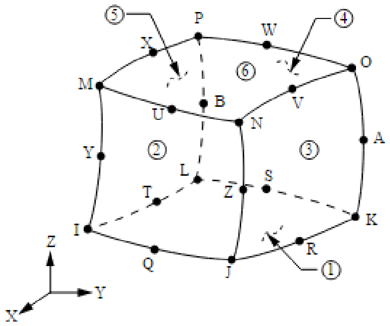


Fig. a General representation of solid 186

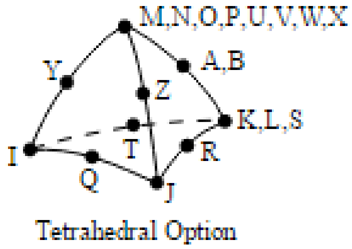


Fig. b Tetrahedral shape of solid 186

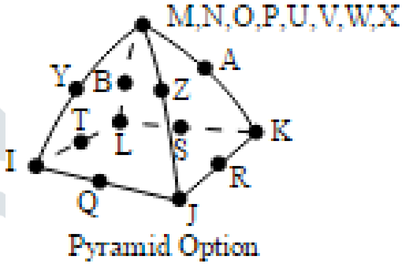


Fig. c Pyramidal shape of solid 186

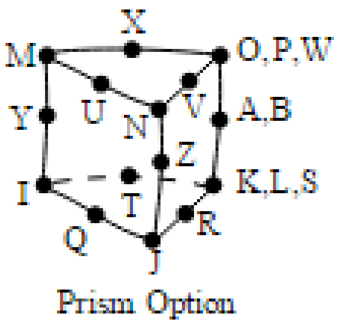


Fig. d Prism shape of solid 186

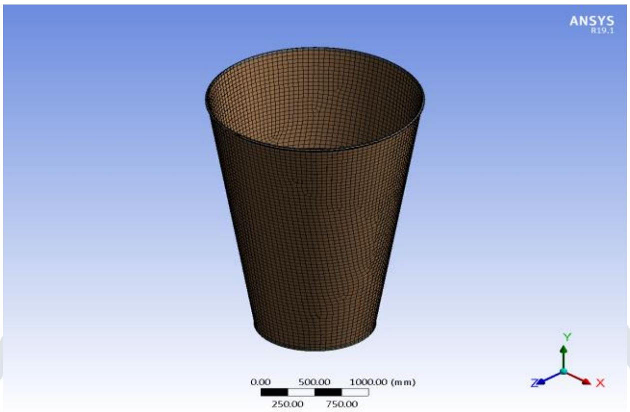
Element Type Used:-I) Tetrahedral Shape of Solid 186

II) Hexahedral Shape of Solid 186

Total No of Nodes = 52595

Total No of Elements = 9063

<u>Meshing of model</u>



Equivalent Stress = 154.51 MPa (Max)

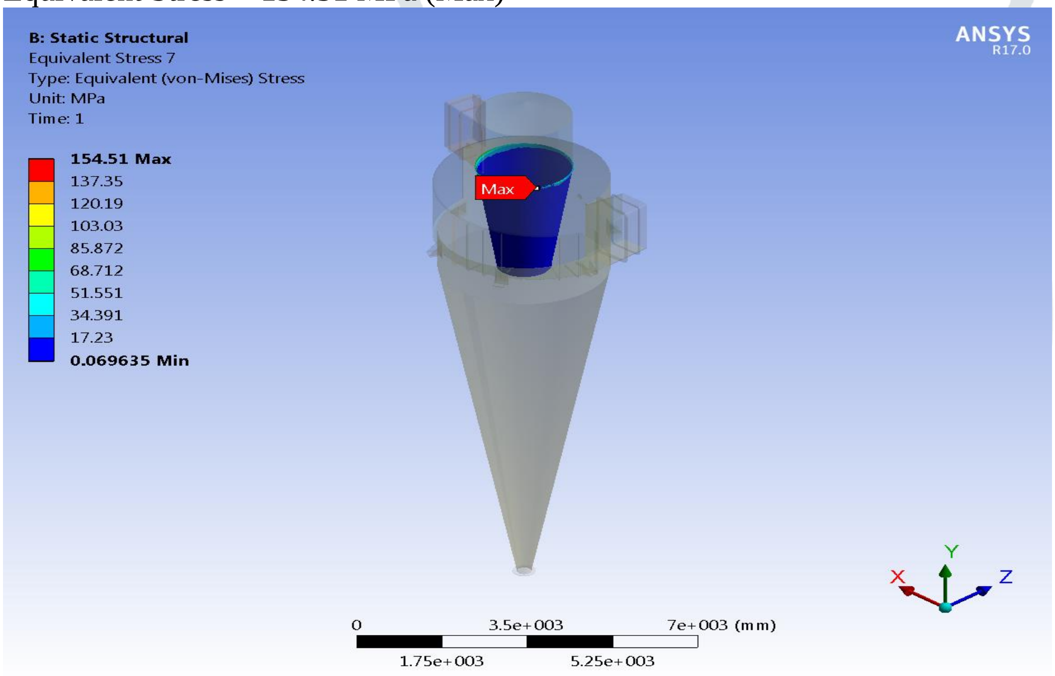
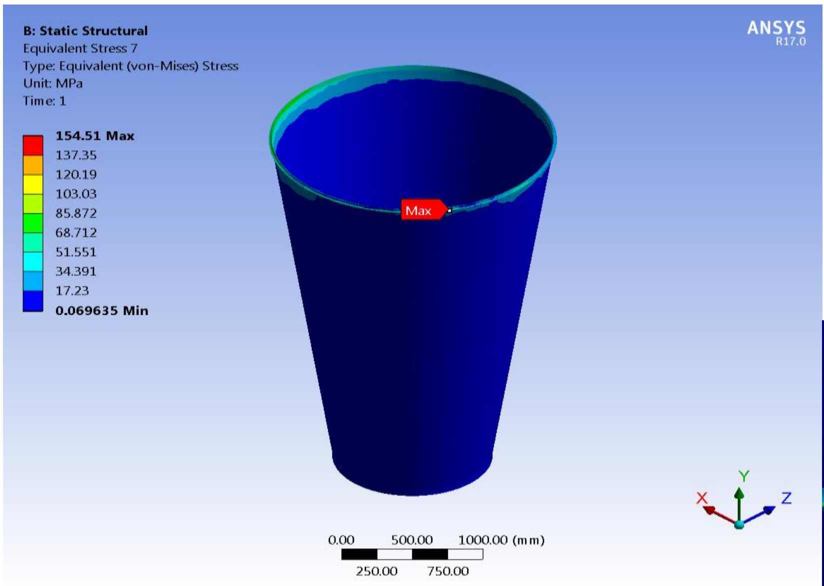
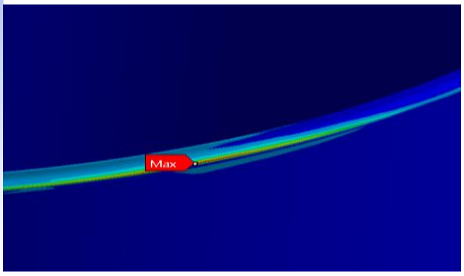


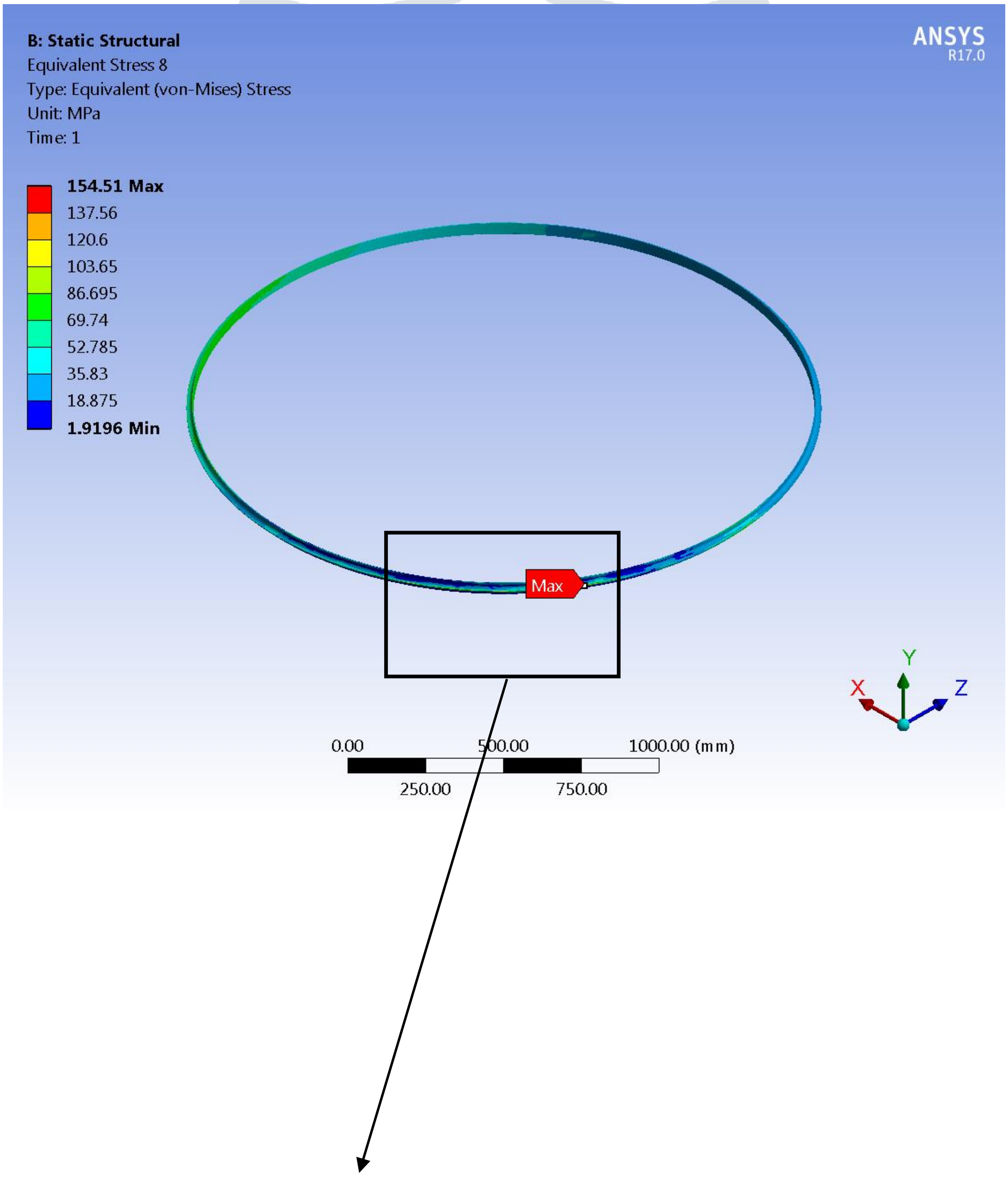
Figure 1 Equivalent stress

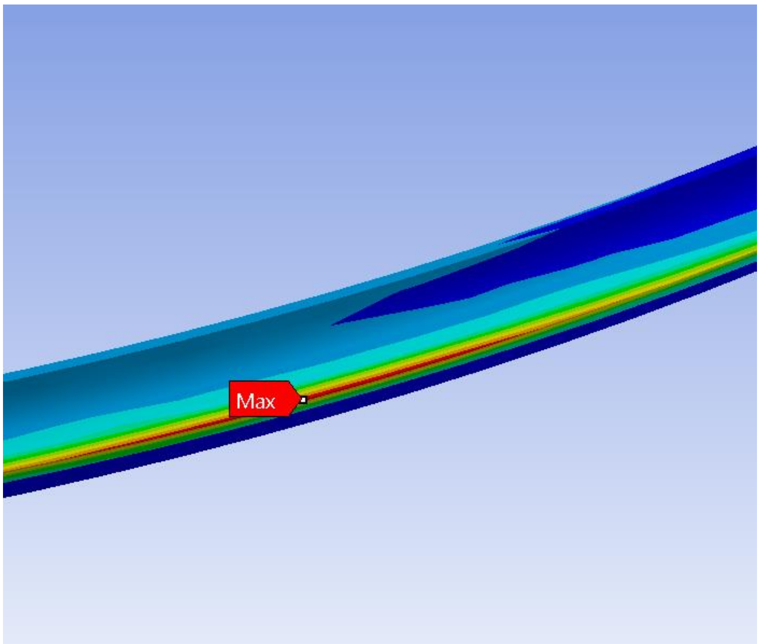
Total Deformation = 3.07 mm (Max)





- Equivalent Stress on Inert cone Ring = 154.51 MPa (Max)





Equivalent stress

4.5 Linearized Equivalent stress

Result-

Classification	Material	Allowable Limit	Allowable Stress (MPa)	Actual Stress (MPa)	Remarks
P_M	SS 304L	1.0 * S	115	19.94	SAFE
$P_M + P_B$	SS 304L	1.5 * S	172.5	36.61	SAFE

<u>Refer, - Acceptance Criteria for allowable stress limit.</u>

- Equivalent Stress on Cone Shell = 60.69 MPa (Max)

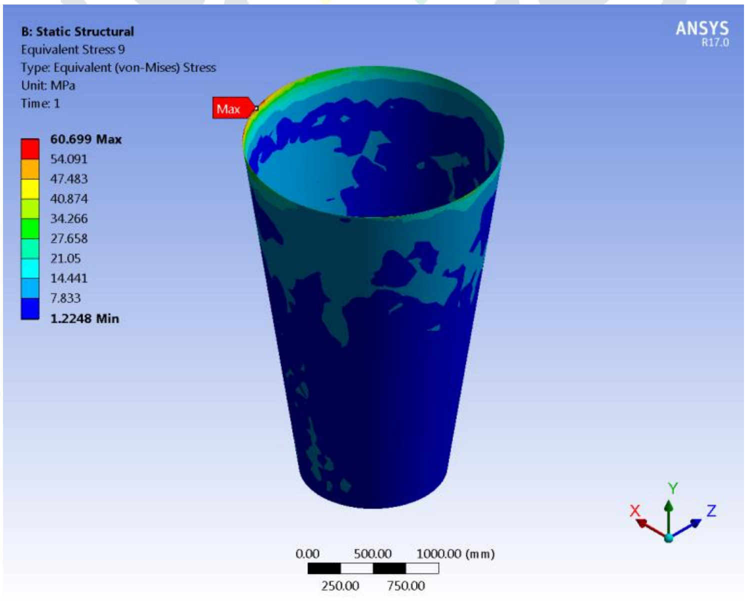


Figure 2 Equivalent stress

Result-

Classification	Material	Allowable Limit	Allowable Stress (MPa)	Actual Stress (MPa)	Remarks
P_M	SS 304L	1.0 * S	115	60.69	SAFE

Result

Classification	Material	Remarks
Insert Cone Ring	SS 304L	SAFE
Insert Cone Shell	SS 304L	SAFE

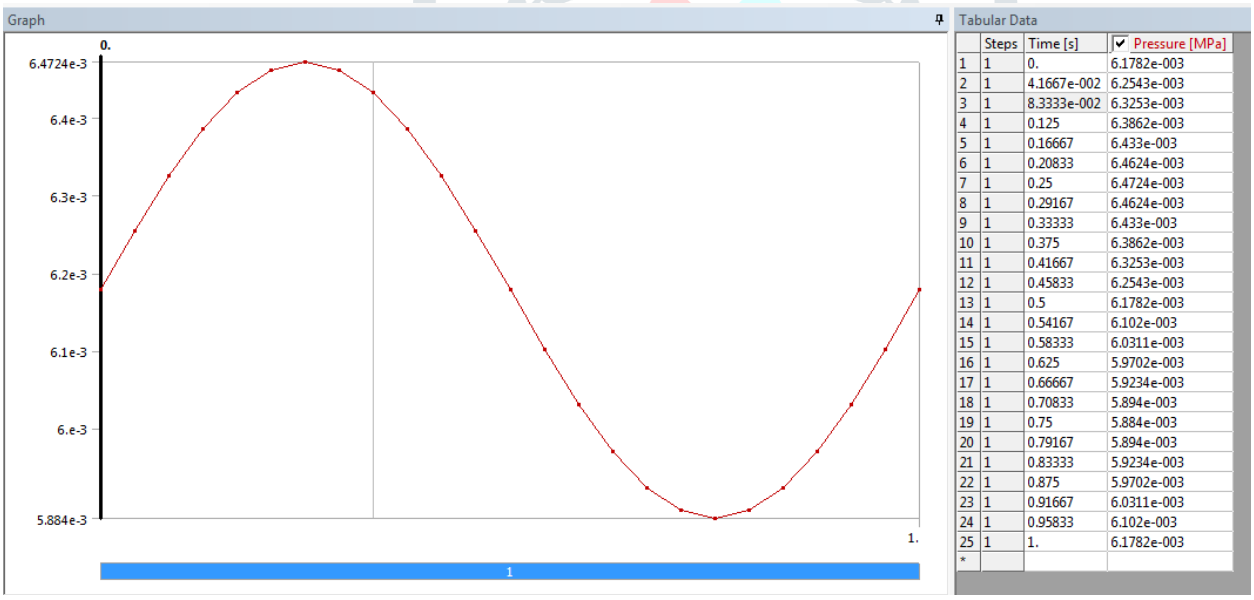
4.6 Fatigue Life Calculations

Given Condition for Operating condition is ,

Pvacuum = mmWG @ T=°C

Pressure fluctuation level, Δp = mmWG

From above we have plotted a different values for input pressure and applied on faces for determining the life of insert cone.



	Steps	Time [s]	Pressure [MPa]
1	1	0.	6.1782e-003
2	1	4.1667e-002	6.2543e-003
3	1	8.3333e-002	6.3253e-003
4	1	0.125	6.3862e-003
5	1	0.16667	6.433e-003
6	1	0.20833	6.4624e-003
7	1	0.25	6.4724e-003
8	1	0.29167	6.4624e-003
9	1	0.33333	6.433e-003
10	1	0.375	6.3862e-003
11	1	0.41667	6.3253e-003
12	1	0.45833	6.2543e-003
13	1	0.5	6.1782e-003
14	1	0.54167	6.102e-003
15	1	0.58333	6.0311e-003
16	1	0.625	5.9702e-003
17	1	0.66667	5.9234e-003
18	1	0.70833	5.894e-003
19	1	0.75	5.884e-003
20	1	0.79167	5.894e-003
21	1	0.83333	5.9234e-003
22	1	0.875	5.9702e-003
23	1	0.91667	6.0311e-003
24	1	0.95833	6.102e-003
25	1	1.	6.1782e-003
*			

Figure 3 Fluctuation pressure graph and respective values

The analysis is carried out and fatigue life is determined

5. CONCLUSION

- From above results, it is observed that all the induced stresses are within respective code limits mentioned above.
- So, it Crack might be observed due to sudden shock in process and it seems from discussion there was a trigger of explosion sensors which witness the shock pressure which might be reason for crack propagation.
- To safeguard the design on these kinds of unknown parameters; Separator's are made with stronger at certain critical areas.
- Similar changes have been done and from last couple of months it has been observed the component is running smoother without any further cracks.
- **This Cyclone Insert cone is safe for specified boundary conditions.**

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