OPTIMIZATION OF STEEL STACKS

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1. ABSTRACT

This paper presents an economical way to reduce the cost of a stack by reducing the stack height and incorporating an injection air system.

2. DESCRIPTION OF THE PROBLEM

This stack serves a steel plant in the Northern Europe . The min ambient temperature is –25°C and the max ambient air temperature is 35°C during the very short summer.
The smoke flow as well as the smoke temperature is depending of the furnace load.

Load	flow Nm3/hr	Temp. °C
Max mechanical load	150 000	353
Max operating Load	110 245	314
2/3 of Max operating Load	70 250	195
1/3 of Max operating Load	38 245	150

Table 1 : smoke flow and temperature

The requested natural draft under this different loading cases is affected by both flow rate and temperature.

Load	Requested natural draft mm WC
Max mechanical load	71 mm WC
Max operating Load	34 mm WC
2/3 of Max operating Load	9 mm WC
1/3 of Max operating Load	9 mm WC

Table 2 : requested natural draft at stack base

3. PRELIMINARY STACK DESIGN

All equipment of the stack have to be designed to the Max mechanical load even if the max normal working condition is much smaller.

In this worst case with an air ambient temperature of + 35°C a 144 m stack with a 3 m liner was requested . If the Max mechanical were occurring only during winter with an air temperature of –25°C only a 96.5 m stack could be sufficient.

The duct level at stack bottom is 2.7 m and the distance between stack axis and flange at limit of delivery where the draft has to be estimated is only

3.00 m

	Summer + 35°C	Winter – 25°C
Min stack height (m)	144 .0	96.5
Effective draft height (m)	141.3	93.8
Pure natural draft (mm WC)	-83.47	-81.47
Lost of draft in the ducting (mmWC)	0.06	0.06
Lost of draft in the elbow at stack inlet (mm WC)	2.55	2.55
Lost of draft on the total height of liner (mm WC)	5.45	3.63
Lost of draft at stack exit (mm WC)	5.13	5.13
Resulting draft at limit of supply (mm WC)	70.28	70.10

Table 3 : natural draft calculation

This stack is equipment with a steel liner having 3000 m diameter and 8 mm thickness. The liner is insulated by one layer of 50 mm mineral wool.

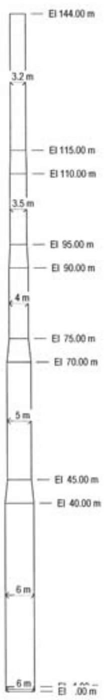

Fig 1 : General view of a 144 m self supporting steel stack

The estimated weight for this stack at the preliminary design stage were :

. stack including flanges, reinforcement =325 t
. steel liner = 95 t
. insulation = 1 400 m2
. concrete for foundation = 620 m2

4. ALTERNATIVE SOLUTION

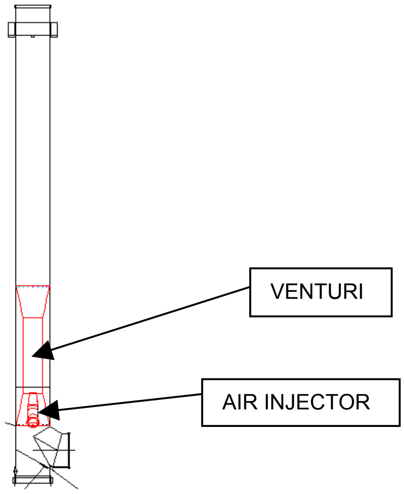

Fig 2 : General view of a 40 m self supporting steel stack with an injector

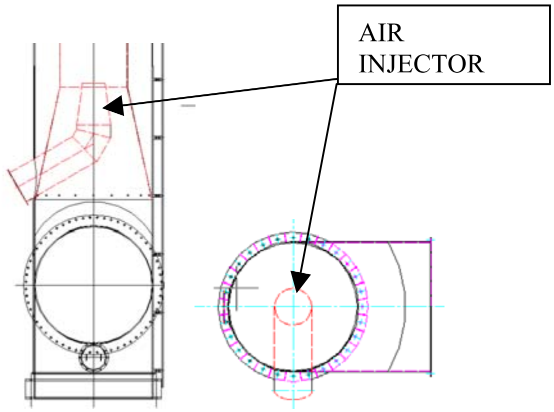

Fig 3 : View of the injection section

In this alternative, the stack is a single wall stack with an outer insulation with cladding. The liner was given the shape of a Ventury just above the injection air nozzle. The stack total eight is only 40 m (104 m less than in the first alternative) and the stack diameter is about 2.800 m .

The injection air is introduced by mean of a high pressure fan . The fresh air velocity at injection nozzle is between 90 m/s a 120 m/s .

	Max Meca.	100% of Load	2/3 of Loaf	1/3 of Load
Injection air Nm3/hr	102200	69800	/ NA natural draft	/ NA natural draft
Requested electrical power	420 kW	147 kW	NA	NA

Table 4 : requested electrical power

Statically speaking the case where the plant is at 100% load during the summer period will occurs max 6 weeks per year. The total electrical consumption if we take 0.050 €/Kw hr would be :

Cost =147*24*6*7*0.05 =8 334 €uros

. stack including flanges, reinforcement =34 t
. steel liner = NA
. insulation with cladding = 355 m2
. one pressure fan with engine
. concrete for foundation = 48 m3

5. COST COMPARISON

	140 m Stack	**40 m stack**
Steel	325 t * = €	34 t * = €
Insulation	1400 * 20 = 28 000 €	NA
Insulation with cladding	NA	355 * 100 = 35 500 €
High pressure fan	NA	1 *22 000 = 22 000 €
Foundation block	620 m3* = €	48 m3* = €
Electrical consumption for 20 years	NA	20*8 334 = 166 680 €
Total	€	€

Table 5 : Cost comparison

As a result over a period of 20 year the cost of the 140 m working under natural draft is much higher than the cost of the 40 m stack operated 6 weeks a year with injection air device (Venturi)

6. ADDITIONNAL REMARK

The stack is very close (3.0 m from the flange at limit of supply) as a result it was impossible to make a transformation piece so that to limit the width of the opening in the stack. The inlet was made in a circular shape with the same diameter as the stack. The bottom stack thickness had to be increased so that the max stress to be within the acceptable yield stress. Traditional shell reinforcement such as vertical stiffeners and rings stiffeners are of very small efficiency to to the fact the inlet opening is 180° wide.

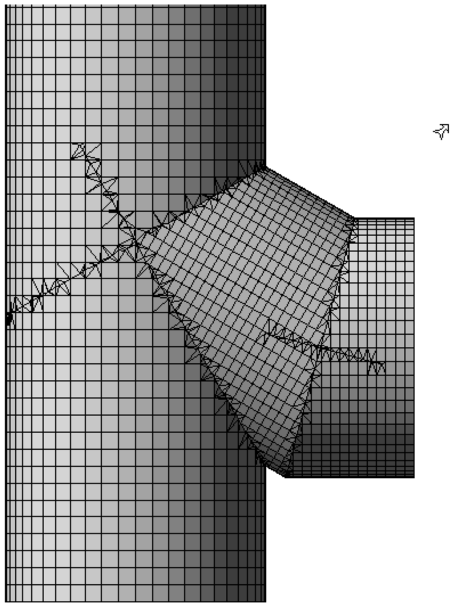

Fig 4 : View of the stack inlet

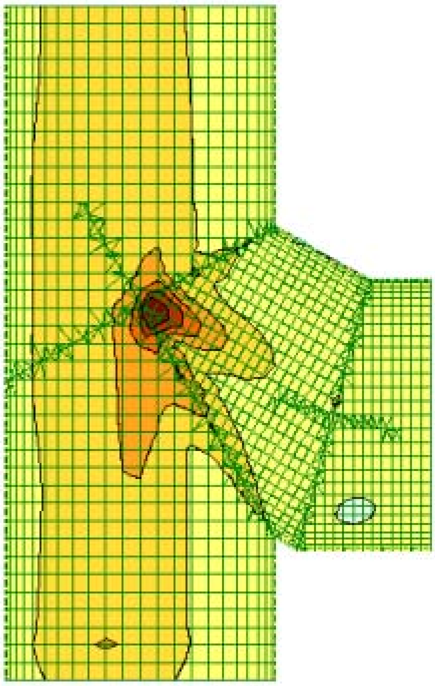

Fig 5 : Equiv. Stress Contour with wind perpendicular to inlet .

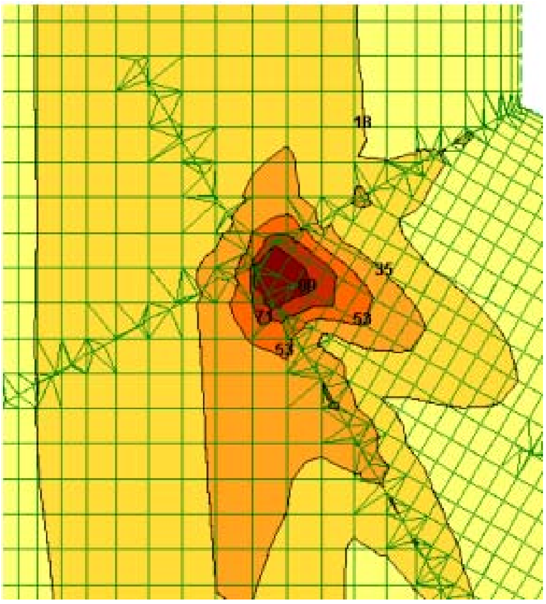

Fig 6 : Equiv. Stress Contour with wind perpendicular to inlet – detail

When the wind is perpendicular to the opening then the max equiv. Stress is about 80 Mpa - OK

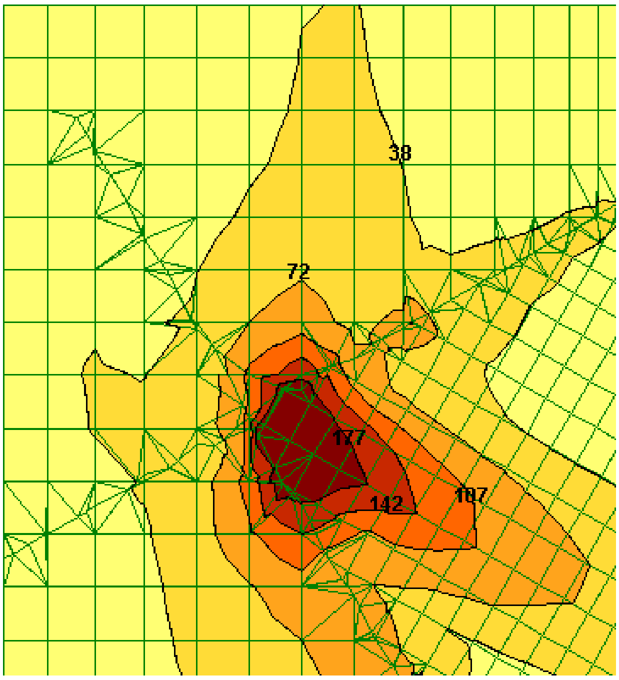

Fig 7 : Equiv. Stress Contour with wind in the direction of the to inlet – detail

When the wind is the direction of the opening then the max equiv. Stress is about 212 Mpa - OK

It has to be considered the effect of a large opening with respect to the stack vibration. If the stack is considered without opening then the first mode natural frequency is 1.59 Hz. (stack bottom thickness increased)

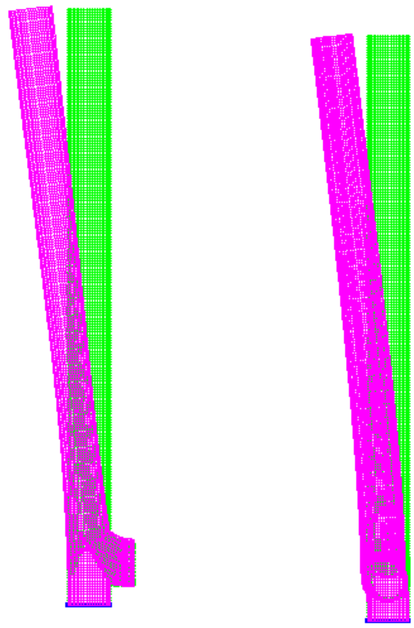

Fig 5 : Mode shape for the first mode in inlet direction and perpendicular to inlet

Frequencies of natural vibrations

load.#	mode #	Eigenvalues	Frequencies		Period
			Circle freq. (1/s)	Frequency (Hz)	(s)
1	1	0.158	6.334	1.008	0.992
1	2	0.104	9.627	1.532	0.653

It appears that shell reinforcement perpendicular to the opening is very effective but in the direction of the opening there is still an important weakening.

As the stresses were acceptable it was decided not to increase the reinforcement but to make a very special liquid damper design (Multitech design) working for two different frequencies as different as 1.00 Hz and 1.52 Hz.

7. CONCLUSION

Very big stacks operating with natural draft are always nice but it is sometimes a better solution to provide a small stack with an injection air device inside a liner designed as a Venturi. In that case the fan is working only few weeks per year .This solution is also better than a solution with forced draft where the fan is working continuously.