Indian J. Fert., Vol. 8 (8), pp. 16-22 pages (7 pages)

Causes of Downtime in Ammonia-Urea Plants

Manish Goswami, V.K. Goyal
and
S. Nand

The Fertiliser Association of India, New Delhi
tech@faidelhi.org

The current analysis is ninth in series since FAI started monitoring downtime first time for 1984-87 period. The downtime analysis was carried out for 29 ammonia and 27 urea plants for the year 2008-11. The planned downtime, forced downtime and on stream days were collated and compared with the previous two surveys. Reasons for loss of production due to factors related to plant and equipments as wells as external to plants were segregated. Section wise analysis of plant and equipment related problems causing downtime have been provided and causes for downtime are also brought out. The present paper identifies areas that need attention in order to improve on stream factors in view of aging of the plants.

1. INTRODUCTION

Currently, there are 32 ammonia and 34 urea plants in operation which produce about 13.5 Million tonnes of Ammonia and 22.2 Million tonnes of urea. The vintage of the plants varies from 12 to 44 years. In view of aging of the plants, special efforts are required to run the plants continuously and maintain the efficiency levels. Downtime in any continuous operating plant is not desirable. Any breakdown or stoppage would lead to huge loss in terms of production and efficiency. FAI has been monitoring the on stream performance of industry since eighties and the current study is ninth in series. The data is analyzed for 3 years period to capture even infrequent or one time failures. The present survey was carried out for the 2008-2011 period. The survey covered 29 ammonia and 27 urea plants representing about 89% and 88% of total production respectively for the 3-year period. The paper presents the downtime analysis of the ammonia and urea plants with respect to number of shutdowns, duration of planned shutdown, duration of forced shutdown, on-stream days, etc. The section-wise analysis for ammonia and urea plants has been carried out and causes of the major failures have been identified. The data have been reported in DDPY which stands for downtime in days per plant per year.

2. DOWNTIME ANALYSIS OF AMMONIA PLANTS

The survey covered 29 ammonia plants of the total 32 presently in operation. **Table 1** presents the characteristics with respect to vintage, feedstock and size of the surveyed plants.

2.1. Number of Shutdowns

The total number of shutdowns taken by ammonia plants due to plant related and business related problems have been reported in terms of shutdowns per plant per year (SPY). The number of shutdowns for the present survey period was lower at 6.1 SPY compared to 6.3 SPY and 6.5 SPY for the periods 2005-08 and 2002-05 respectively. The longest run of an ammonia plant during six year period of 2005-2011 was 423 days.

2.2. Planned Turnaround

The average planned turnaround

Table 1 – Vintage, size and feedstock of ammonia plants

Vintage		Size		Feedstock	
Years	**No.**	**MTPD**	**No.**	**Type**	**No.**
40 or more	2	<900	5	Gas	22
30 -40	6	900 to <1500	11	Naphtha	4
20 -30	11	≥1500	13	Fuel Oil	3
10 -20	10				
Total	**29**		**29**		**29**

or annual turnaround (ATR) days for ammonia plants were 18.0 days per plant per year (DPY) for 2008-11, which are lower than the previous two survey periods. During 2005-08 and 2002-05, ATR were 21.7 DPY and 19.1 DPY, respectively. During 2008-11, the gas based plants took ATR for 13.8 DPY however, it was 31.3 DPY in case of naphtha and fuel oil based plants. The higher than required ATR was undertaken by the naphtha and fuel oil based plants due to restriction by government not to produce beyond 100% capacity. This is also reflected in lower on stream days for these plants.

2.3. Reasons for Loss of Production

The data for loss of production due to forced downtime were collected. The forced downtime can be stoppage due to plant related and external problems. The plant related problems includes problem due to mechanical, electrical, instrumentation, process and miscellaneous failures of plant and equipments. The external reasons for downtime are other than plant problems such as shortage of raw materials, failure of external power, shortage of water and labour problems.

The loss of production of ammonia due to forced downtime was 17672 metric tonnes per plant per year. This amounts to a total loss of 1.52 million tonnes of ammonia production over 3 years period which is about 4.2% of the total capacity of surveyed ammonia plants. **Table 2** represents number of shutdowns, forced downtime and loss of production in terms of MT/plant/year. It may be seen that plant related problems or the internal factors accounted for 62.7% to the total forced downtime causing a production loss of 11920 MT per plant per year. Shortage of raw materials caused 11.2% downtime in ammonia plants. The rest downtime was due to factors like high inventory, shortage of working capital, etc. Two plants also faced shutdown due to shortage of water.

Table 2 – Reasons for loss of production in ammonia plants

Sl. No.	Category	No. of shutdown (SPY)	Downtime days (DDPY)	Loss of production (MT/plant/yr)
1	Plant related problems	4.7	10.6	11920
2	Power plant/supply	0.6	0.6	630
3	Shortage of raw materials	0.3	2.0	2445
4.	Labour problems	0.0	0.0	0
5.	Water problem	0.02	0.2	108
6.	Other reasons	0.4	3.5	2569
	Total	**6.1**	**16.8**	**17672**

The forced downtime was lower at 16.8 DDPY than 17.5 DDPY in the previous survey period of 2005-08 but somewhat higher than 2002-05 survey period where it was 16.0 DDPY.

2.4. Plant Related Problems or Internal Factors

Downtime due to plant related problems were analyzed and is shown for three survey periods in **Table 3.** It was observed that overall plant related downtime has reduced from 14.8 DDPY in 2002-05 to 10.6 DDPY in 2008-11. However, significant increase was noticed in the downtime due to mechanical failures. The downtime due to mechanical problems increased to 8.8 DDPY in 2008-11 from 5.9 DDPY in 2002-05. Increase was also noticed in the downtime in instrumentation due to problems such as PV valve struck up, malfunctioning of transmitters, false alarms, etc.

2.4.1. Failures Due to Mechanical Reasons

2.4.1.1. Reforming Plants

The analysis of plant breakdown due to mechanical failures for ammonia plants were analyzed in detail (**Table 4**). A total of 566.4 days of downtime was recorded for 22 reforming plants for 3 years period. The reported downtime of 122.5 days for three years was highest in secondary reforming section and accounted for 21.6% of the total downtime. Nine plants faced problems related to waste heat boiler which accounted for almost 70% (85.4 days of 122.5 days) of downtime in secondary reformer section. One of the plants

Table 3 – Downtime in ammonia plant due to major reasons (DDPY)

Sl. No.	Reasons	2002-05	2005-08	2008-11
1	Mechanical	5.9	7.6	8.8
2	Electrical	0.8	0.6	0.3
3	Process	1.4	1.4	0.6
4	Instrumentation	0.6	0.6	0.9
5	Miscellaneous	6.1	0.9	0.0
	Total	**14.8**	**11.0**	**10.6**

Table 4 – Mechanical failure downtime in ammonia plants (Based on reforming process) for 2002-2005, 2005-08 and 2008-11

Major Sections	(2002-05) (Days)	(24 plants) %	(2005-08) (Days)	(24 plants) %	2008-11 (Days)	(26 plants) %
1. Pre-treatment section	8.0	-	20.3	3.8	1.2	0.2
2. Pre-reformer	15.8	-	11.2	2.1	0.0	0.0
3. Primary reformer	72.4	13.1	85.6	16.0	84.3	14.9
4. Secondary reformer	48.7	47.9	13.6	2.5	122.5	21.6
5. Purification	46.0	3.7	53.6	10.0	59.4	10.5
6. Synloop & refrigeration	21.2	7.6	116.7	21.8	78.0	13.8
7. Syngas compressor	28.0	9.6	161.5	30.2	76.4	3.5
8. Other compressors & turbines	87.0	8.6	30.5	5.7	92.3	16.3
9. Miscellaneous major equipments	73.0	9.5	41.9	7.9	52.5	9.3
Total	498.7	100.0	534.9	100.0	566.5	100.0

faced downtime of 8.9 days due to detachment of refractory inside reformed gas waste heat boiler. Tube leakage in waste heat boiler was the most common problem faced by almost all the nine plants. Hot spot on secondary reformer top dome air inlet nozzle and manhole cover and leakage in BFW control valve flange were other reasons for higher downtime in secondary reformer section.

After secondary reformer section, primary reforming section contributed 14.9% to the total downtime. Failure of primary reformer tubes, BFW pre-heater tube leakage, damage of convection duct and flue gas ID fan bearing duct and high vibrations in ID fan due to refractory dust deposition were reported cause of downtime in the plants. Two plants replaced all the primary reformer tubes after these failed due to aging. Another plant reported incidence of downtime of 7.1 days due to convection section ID fan tripping due to overload.

In synloop and refrigeration section, 13.8% of total downtime was caused due to leakages in synloop boilers, mechanical failure of S-50 converter and leakage in other exchangers. Downtime of almost 15 days was reported in one of the plants due to leakage problems in intercoolers of syn gas compressor. The tubes and tube sheets supplied by the OEM were made of carbon steel and were failing frequently due to aging. Plant replaced all the exchanger tubes with duplex tube arrangement during turnaround in April 2010. Mechanical failures in S-50 converter caused catalysts to enter the synthesis gas increasing pressure drop leading to shutdown in one plant.

Purification section included HT shift, LT shift, CO_2 removal and methanation sections. Two third of the downtime of 59.4 days in purification section was faced in the CO_2 removal section. Downtime of 5.6 days was observed in a plant due to leakage of flange of Vetrocoke reboiler of GV solution line. The plant replaced the old gasket with new one. In another plant, leak from MDEA stripper due to corrosion, erosion and pitting caused a downtime of 7.8 days. The defective portion was provided with SS cladding from inside and CS plate covering from outside. Another plant observed leakage in Benfield re-boiler tubes which were plugged and seal welded.

A number of plants faced problems in syn gas compressors although the syn gas compressors contributed only 3.5% to the total mechanical downtime. Major causes identified were syn gas turbine inlet steam governing valve spindle failure, syn gas compressor seal oil leakage, interstage cooler leakage, high axial displacement, syn gas turbine ESV struck up, high vibration in HP case and high thrust bearing temperature and problem in syn gas governing system. Other compressors and turbines accounted for 16.5% of the total downtime. A number of plants have reported downtime in process air compressor due to tripping of gas turbine drive and high vibration in turbine and gear box.

2.4.1.2. Gasification Plants

In the gasification plants, the highest downtime was observed in synloop and refrigeration section followed by air separation unit **(Table 5)**. The synloop and refrigeration accounted for 66.1% of the downtime while air separation unit contributed 23.3% to the downtime in gasification plants. Air compressors tripping due to high vibrations, damage of stationary guide blades and wires of air compressors were reported causes of downtime. Heavy leakage from bottom dome weld joint of waste heat boiler resulted fire in ammonia synthesis section in one of the plants. Syn gas oil seal

Table 5 – Mechanical failure downtime in ammonia plants for 2002-05, 2005-08 and 2008-11 (Based on Gasification Process)						
	2002-05 (4 Plants)		2005-08(4 Plants)		2008-11 (3 plants)	
Major sections	**Downtime (Days)**	**Downtime %**	**Downtime (Days)**	**Downtime %**	**Downtime (Days)**	**Downtime %**
1. Gasifier	1.0	16.5	1.0	0.3	0.5	0.3
2. Air Separation Unit	12.0	20.7	63.5	21.1	45.8	23.3
3. Purification	7.0	12.0	45.3	15.1	10.1	5.1
4. Synloop & Refrigeration	2.0	3.4	133.0	44.2	130.1	66.1
5. Syngas Compressor	23.0	38.9	12.3	4.1	10.3	5.2
6. Other Comp. & Turbines	2.0	2.9	0.6	0.2	0.0	0.0
7. Misc. Major Equipments	12.0	20.2	45.0	15.0	0.0	0.0
Total	**59.0**	**100.0**	**300.7**	**100.0**	**196.5**	**100.0**

damage, tube and intercooler end cover leak and breakage of LP valve servomotor pin were some other causes of failures in synthesis section.

Synthesis gas compressor downtime was due to failure of barrel diaphragm 'O' ring and seal damage, low seal oil level, high shaft vibrations on LP turbine side bearing, oil leakage from seal oil header due to crack. Failure of thrust bearing and high vibrations of turbine lead to downtime in nitrogen compressor.

2.4.2. On stream Efficiency in Ammonia Plants

The efficiency of an ammonia plant is reflected from high on-stream days achieved during the year. The average on-stream days for all the ammonia plants was 330.1 days per plant per year (DPY) for 2008-11, which is higher than 326.2 DPY of the previous survey period of 2005-08 but same as in 2002-05 period. The near stagnant on-stream days in ammonia plant were due to higher planned turnaround days in naphtha and fuel oil based plants as explained earlier. The on-stream days for all the gas based plants were 341.6 DPY while for naphtha and fuel oil based plants it was only about 312 DPY for 2008-11. A break up of plants into four quartiles showing the on stream factors for gas based ammonia plant is shown in **Figure 1**. It may be seen that the best 25% plants achieved 349.5 DPY while the figure for the lowest quartile is 331.8 DPY.

Operating, Service and Reliability factors were also calculated to assess the on stream efficiencies of ammonia plants. Operating factor indicates the time a plant was on-stream during the year. Service factor determines the availability of the plant if business related (external factors) had not caused any downtime. Reliability factor points out that the percentage of time the plant was on-stream excluding planned turnaround days and business related downtime (external factors) such as shortage of raw materials and utility, labour and water problems, etc. The definitions of factors are given below:

$$\text{Operating factor} = \frac{\text{total operating days}}{365} \times 100$$

$$\text{Service factor} = \frac{\text{total operating days}}{\text{365-business related downtime}} \times 100$$

$$\text{Reliability Factor} = \frac{\text{total operating days}}{\text{365-Business related downtime \& annual turnaround}} \times 100$$

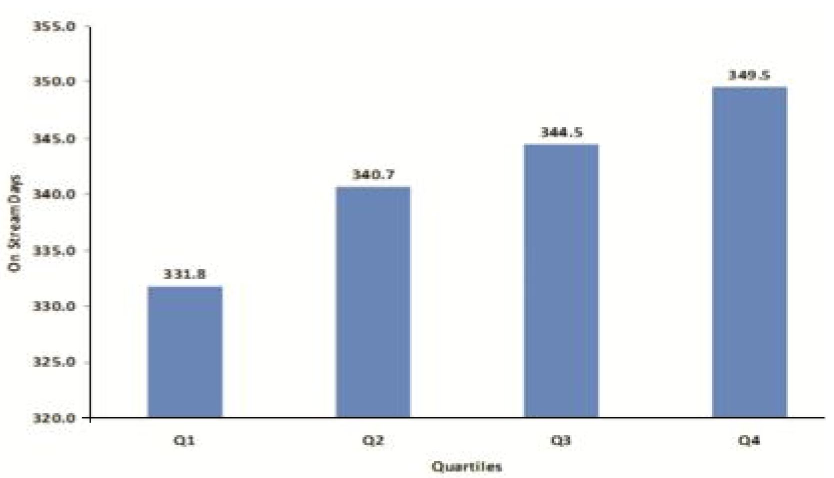

Figure 1 – Quartiles of on stream days for gas based ammonia plants

Table 6 – Reasons for loss of production in urea plants

Sl. No.	Category	No. of shutdown (SPY)	Downtime days (DDPY)	Loss of production (MT/plant/yr)
1	Plant Related Problems	4.7	8.1	10894
2	Power Plant/Supply	1.9	0.9	1532
3	Shortage of Raw Materials	3.0	10.9	20305
4.	Labour Problems	0.0	0.0	0
5.	Water Problem	0.01	0.1	78
6.	Other reasons	0.7	1.1	1429
	Total	**10.4**	**16.8**	**34238**

The ammonia plants have an operating factor of 90.4%, service factor of 92.1% and reliability factor of 96.9% during 2008-11. As shown in **Figure 2**, all these factors remained at almost in the same range during the last three survey periods.

3. DOWNTIME ANALYSIS OF UREA PLANTS

The survey includes 27 urea plants. The downtime analysis similar to ammonia plant was carried out for urea plants.

3.1. Number of Shutdowns

The total number of shutdowns per plant per year (SPY) in 2008-11 was 10.4 compared to 11.8 SPY for 2005-08 and 2002-05 periods.

3.2. Planned Turnaround

The planned turnaround for urea plants were 20.3 days per plant per year (DPY) in this survey which are higher than 19.3 DPY in previous survey (2005-08) but lower than 21.4 DPY in 2002-05. As reported in ammonia plants, planned turnaround was higher in naphtha and fuel oil based plants due to restriction on production. The gas based plants reported planned turnaround of 15.0 DPY while naphtha and fuel oil based plants reported turnaround of 35.1 DPY.

3.3. Reasons for Loss of Production

Various reasons for loss of production as well as number of shutdown and duration of shutdown due to each reason are given in **Table 6**. The 27 plants suffered loss of production of 34238 MT per plant per year which translates into a cumulative loss of 2.6 million tonnes of urea for the three years period. Major losses, were due to shortage of raw materials and plant related problems which accounted for about 62% and 32% loss respectively. The downtime due to shortage of raw materials was 10.9 DDPY and plant related problems was 8.1 DDPY. The plant related problems includes failures due to mechanical, electrical, process, instrumentation, etc and are covered in detail.

3.4. Reasons for Forced Shutdown Due to Plant Related Problems

Plant related downtime for urea plants was higher than the previous survey (2005-08) but

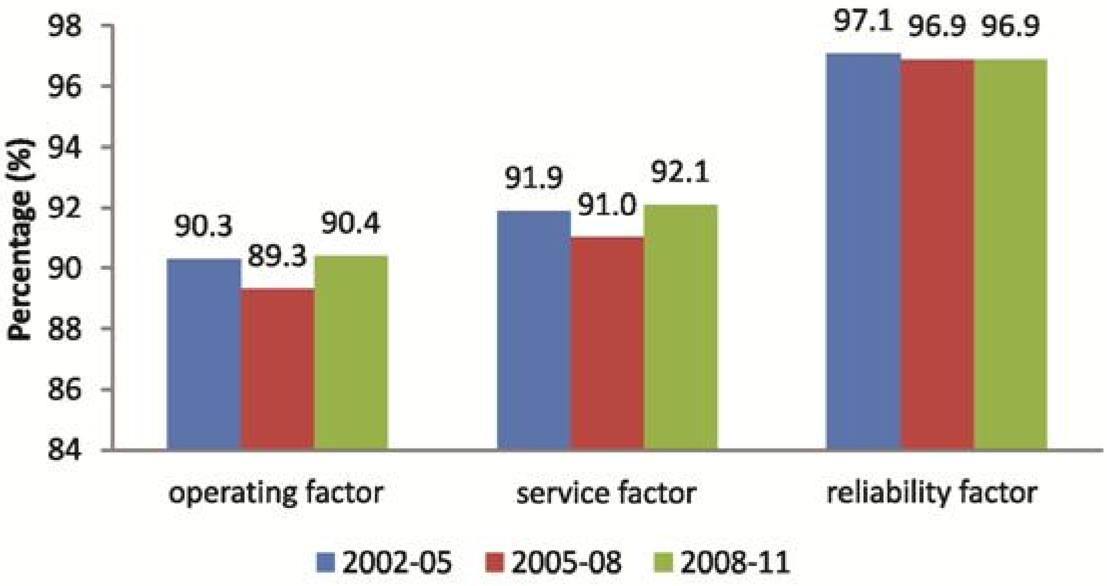

Figure 2 – Operating, service and reliability factors for ammonia plants

Table 7 – Downtime in urea plant due to major reasons (DDPY)			
Reasons	**2002-05**	**2005-08**	**2008-11**
Mechanical	5.9	4.0	6.9
Electrical	0.5	0.6	0.3
Process	0.5	0.2	0.4
Instrumentation	0.4	0.3	0.3
Miscellaneous	23.7	0.2	0.3
Total	31.0	5.3	8.1

lower than 2002-05 survey period. The downtime per plant per year were 21.2, 20.2 and 31.0 for 2008-11, 2005-08 and 2002-05, respectively.

Mechanical reasons for shutdown of the urea plants followed the same trend as for ammonia plants and outweighed the other reasons. The mechanical downtime increased from 4.0 DDPY in 2005-08 to 6.9 DDPY in 2008-11. All the other reasons like electrical, instrumentation and miscellaneous reasons contributed about 1.2 DDPY to the downtime **(Table 7).**

Table 8 shows the equipment wise downtime of urea plants for three survey periods viz. 2002-05, 2005-08 and 2008-11. Urea reactor contributed 40% to the downtime in urea plants. It has increased significantly from the last survey period. In one of the plants, downtime of 133 days was noticed for the period due to reactor liner repair job. Increase in downtime in heat exchangers and decomposer/ stripper from previous surveys were also noticed. A number of plants faced problems due to leakage in carbamate condenser, tube and tube sheet. Leakage problems were also reported in HP stripper off gas thermowell, liner at bottom dish end, etc.

Table 8 – Details of Downtime due to Mechanical Failure in Urea Plants			
Equipment Items	**2002-05**	**2005-08**	**2008-11**
1. Ammonia pre-heater	0.05	0.1	0.00
2. Ammonia Plants	0.05	0.11	0.09
3. Carbamate Pump	0.28	0.08	0.02
4. Slurry & Other Pumps	0.00	0.03	0.03
5. CO_2 Compressor	0.39	0.39	0.45
6. Autoclave/Reactor	0.58	0.52	2.73
7. Let Down Valve	0.00	0.79	0.00
8. Heat Exchangers	0.51	0.02	0.88
9. Decomposer/Stripper	1.44	0.04	0.91
10. NH3/CO2 Recovery Column	0.02	0.06	0.00
11. Absorber/Recovery Vessels	0.21	0.00	0.18
12. Evaporator/Crystalliser	0.06	0.00	0.00
13. Centrifuge	0.00	0.00	0.00
14. Steam Ejector/Vacuum Generator	0.06	0.00	0.01
15. Dryer/Cooler	0.08	0.00	0.02
16. Blower/Fan	0.04	0.03	0.01
17. Conveyer/Elevator	0.02	0.12	0.06
18. Prill Tower	0.19	0.04	0.06
19. Piping/Valves	0.43	1.05	0.16
20. Miscellaneous	1.24	0.41	1.19
Total	**5.88**	**4.15**	**6.80**

In one of the plants, 18.9 days of shutdown was taken due to damage of balance piston labyrinth of CO_2 compressor turbine. Initially, the plant replaced the rotor and refinned balance piston gland. Later, the rotor was assembled along with new LP wheel chamber and refinned balance piston gland. To avoid recurrence, the plant modified the HP wheel chamber by reducing the balance piston and housing fin heights with the help of OEM during annual turnaround. Other problems like high vibrations, fluctuation in turbine speed, breakage of compressor discharge NRV chair, etc. were also reported by plants.

The urea plants on-stream days at 323.5 DPY were lower than last survey period of 326.0 DPY but higher than 2002-05 (310.0 DPY). Reasons for low on stream days as explained for ammonia plants were due to restriction in production in non-gas based plants. The gas based plants had on stream days of 334.2 DPY while plants based on naphtha and fuel oil operated for 307.0 DPY for 2008-11. The on-stream efficiency factors have been calculated for urea plants and shown in **Figure 3**.

CONCLUSION

The paper presents detailed analysis of downtime due to both planned maintenance and forced downtime. The analysis identifies areas that plants need to focus on

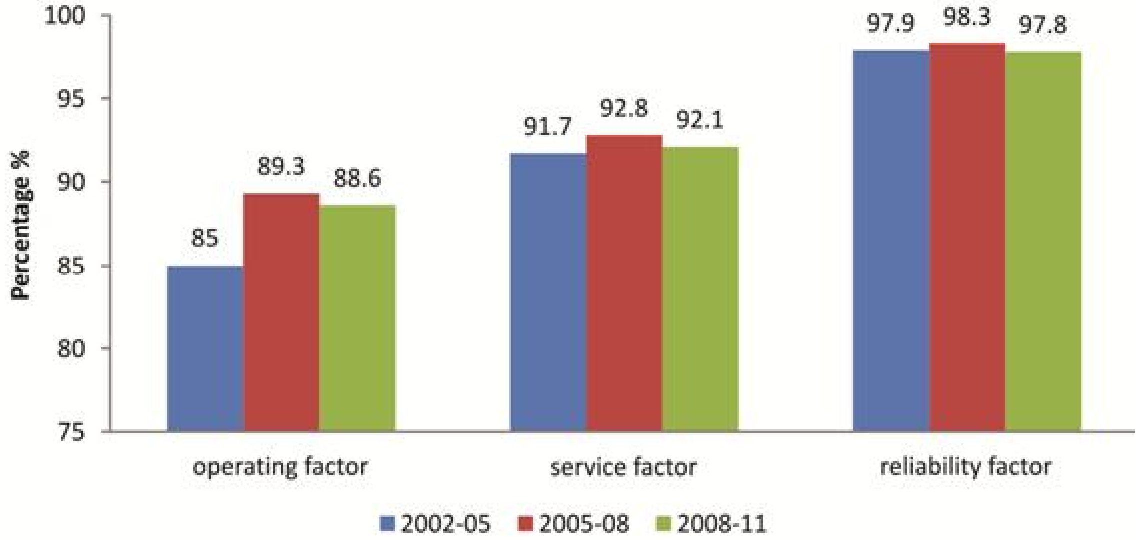

Figure 3 – Operating, service and reliability factors for urea plants

to improve on stream efficiency and reliability. The planned turnaround days and forced downtime have reduced in case of ammonia plants however they have increased for urea plants from previous survey period. This is also reflected in higher on-stream days for ammonia plants (330.1 DPY) from 326.0 DPY in previous survey. For urea plants on stream days were lower at 322.7 DPY from 326.0 DPY for the same period. It was observed that the downtime due to plant related problems have increased from previous survey periods in case of both ammonia and urea plants. The downtime due to mechanical failures were on rise from 7.6 DDPY in 2005-08 to 8.8 DDPY in 2008-11 for ammonia plants and 4.0 DDPY to 6.9 DDPY for urea plants for the same periods. Various causes reported by the plants points towards the aging of the plants. Major sections in ammonia plants where significant downtime was registered included primary and secondary reformers, syn gas compressors, heat exchangers and waste heat boilers. In urea plants reactor, strippers and CO_2 compressors encountered significant downtime. In addition to these sections of the plants, old equipments, piping, heat exchangers also need periodic assessment and replacement.

REFERENCE

1. S. Nand and Manish Goswami, Reliability and Efficiency in Operation of Indian Ammonia and Urea Plants, *Indian Journal of Fertilisers*, Vol. 5(12), pp 17-20 & 23-24, December 2009. ■