Indian J. Fert., Vol. 11 (2), pp.16-22 (7 pages)

Causes for Loss Time in Ammonia-Urea Plants

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Continuous operation of Ammonia and Urea plants is pre-requisite for achieving high operational efficiency. There are several causes of interruption in operation. These could be breakdown of plant and machinery, shortage of raw materials and utilities, labour problem and other reasons like high inventory and natural calamity. In order to address the problems, it is essential that causes of interruption are identified and their effect is quantified. With this objective, FAI has been carrying out the analysis of downtime in ammonia and urea plants for several years. The data for planned downtime, forced downtime and on stream days were calculated and compared with the data of previous surveys. Factors responsible for loss of production due to problems in plant and equipments as well as external to plants are segregated and analyzed. A detailed analysis of each section of the plants has been done in regard to problems due to plant and equipments. The present study, tenth in series, evaluates data of 28 ammonia and 27 urea plants for 2011-14 period for various causes of downtime. The paper presents the results of the study and identifies areas that need attention of plant management to further improve reliability and operational efficiencies of ammonia and urea plants.

1. INTRODUCTION

During 2013-14, 14.3 million tonnes of ammonia was produced by 37 ammonia plants. Of the total production, about 13.1 million tonnes ammonia was used to produce 22.7 million tonnes of urea through 32 urea plants during the year. In the same year, the production of urea accounted for 60.6% of the total domestic production of fertilisers. Operating urea plants have vintage of 15 to 49 years. Continuous operation and maintaining these plants at same efficiency level requires continuous efforts for upgradation, repair and replacement of equipments. Therefore, it would be useful to isolate causes of forced downtime in the plants. To meet this objective, FAI has been carrying out study every three years on the causes of the loss time in the industry since 1984. The current study is the tenth in series for the year 2011-14. The data are analyzed for 3 year period to capture even infrequent or one time failures. The survey covered 28 ammonia and 27 urea plants representing about 90% of ammonia and 94% of urea total production for the 3-year period. The paper presents the downtime analysis and specific indicators have been worked out. These include number of shutdowns, duration of planned shutdown, duration of forced shutdown, on-stream days, etc. The section-wise analysis of downtime has been carried out and causes of the major failures have been identified. The data have been reported in downtime in days per plant per year (DDPY).

2. LOSS TIME ANALYSIS IN AMMONIA PLANTS

2.1. Sample Characteristics

The survey covered 28 ammonia plants and all of them are now based on reforming process. There were four fertiliser plants based on partial oxidation of fuel oil and all of these have been converted to natural gas steam reforming process by 2013. Since only partial replacement (front end) of the ammonia was undertaken during feedstock conversion, vintage of the plants has been retained as original commissioning year. **Table 1** presents the characteristics with respect to vintage and size of the surveyed plants. The feedstock of 27 plants was natural gas while one was operating on naphtha.

2.2. Number of Shutdowns

The total number of shutdowns have been reported as shutdown per plant per year (SPY). During the survey period 2011-14, total

Table 1 – Vintage and size of surveyed Ammonia Plants

Vintage		Size	
Years	**No.**	**MTPD**	**No.**
40 or more	1	<900	3
30 -40	8	900 to <1500	10
20 -30	9	≥1500	15
15 -20	10		
Total	**28**		**28**

number of shutdowns taken by ammonia plants were higher at 7.0 SPY compared to 6.1 SPY and 6.3 SPY for the periods 2008-11 and 2005-08, respectively. Major reason for the increase was higher number of shutdowns due to equipment problems in the present survey period (5.5 SPY) than previous survey (4.7 SPY). The longest uninterrupted run achieved by an ammonia plant during 2008-14 period was 613 days. Another plant achieved 484 days continuous operation during the same period.

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	5.5	10.6	12671
2	Power Plant/Supply	0.7	0.6	409
3	Shortage of Raw Materials	0.3	2.9	2113
4.	Labour Problems	0.0	0.0	0
5.	Water Problems	0.1	0.2	130
6.	Other Reasons	0.5	0.7	903
	Total	**7.1**	**15.0**	**16226**

2.3. Planned Turnaround

The average period for planned turnaround for maintenance for ammonia plants was 23.1 days per plant per year (DPY) for 2011-14, which is longer than the previous two survey periods. During 2008-11 and 2005-08, the average turnaround periods were 18.0 DPY and 21.7 DPY respectively. The reasons for higher plant turnaround during 2011-14 period was longer shutdown required by fuel oil based plants for conversion to natural gas. Longer duration shutdown was also taken by 6 other ammonia plants for completion of major revamp activities. A few plants also stopped production after reaching certain level of production (cut off quantity). Production beyond this quantity was not viable due to pricing policy for urea. This shutdown period was often merged with period for planned shutdown.

2.4. Reasons for Loss of Production

The data for loss of production due to forced downtime covered downtime due to plant related and external problems. The plant related problems include mechanical, electrical, instrumentation, process and miscellaneous failures of plant and equipments. The external reasons for downtime include shortage of raw materials, failure of external power, problems in offsite and utilities, shortage of water and labour problems.

During the present survey period of 3 years a total 1.28 million tonnes of ammonia was lost due to various unforeseen reasons. This loss is about 3.5% of the total capacity of surveyed ammonia plants. Number of shutdowns, forced downtime and loss of production in terms of MT/plant/year are given in **Table 2**. Plant related problems or the internal factors accounted for 70.0% of the total forced downtime resulting in loss of 12671 MT of ammonia per plant per year. Shortage of raw materials caused 19.3% and power problem caused 4.0% downtime in ammonia plants. The rest downtime was due to factors like high inventory, shortage of working capital, problems in offsite and utilities, etc. Only one plant reported shutdown due to shortage of water.

The forced downtime for the present period has come down to 15.0 DDPY as compared to 16.8 DDPY in 2008-11 and 17.5 DDPY 2005-08.

2.5. Loss Time due to Plant Related Problems

The plant related problems have been further isolated into mechanical, electrical, process, instrumentation and miscellaneous problems as given in **Table 3.** It was observed that overall plant related downtime in days per plant per year (DDPY) was same during 2011-14 as in 2008-11 at 10.6 DDPY but slightly lower than 11.0 DDPY in 2005-08. The mechanical failures caused significantly lower downtime of 7.8 DDPY (2011-14) compared to 8.8 DDPY in the previous survey. Significant increase was noticed in the downtime due to process and instrumentation failures. Twenty five plants have reported downtime due to instruments problems in ammonia plant. One plant faced downtime of 4.5 days

Table 3 – Downtime in Ammonia Plant due to plant related problems

(DDPY)

Sl. No.	Reasons	2002-05	2005-08	2008-11	2011-14
1	Mechanical	5.9	7.6	8.8	7.8
2	Electrical	0.8	0.6	0.3	0.3
3	Process	1.4	1.4	0.6	1.2
4	Instrumentation	0.6	0.6	0.9	1.1
5	Miscellaneous	6.1	0.9	0.0	0.2
	Total	**14.8**	**11.0**	**10.6**	**10.6**

due to instrumentation problem in its captive power plant.

2.5.1. Downtime due to Mechanical Problems

The Section-wise breakup of mechanical failures for ammonia plants is given **Table 4**. A downtime of 615.2 days was reported for 27 reforming plants for 3 years period. The total downtime days are higher than previous surveys as in the present survey number of plants have increased due to conversion of plants based on partial oxidation to reforming process.

Synloop and refrigeration section reported highest downtime days of 157.6 days and contributed 25.6% to the total downtime for 3 years period. Problems in waste heat boiler (WHB) were encountered by eight plants and contributed 48.2% of the downtime in this section. Reasons reported are leakage in boiler tubes, gas inlet line and valve and purge valve of synthesis loop boiler. Four plants faced problems in reactor, out of which 2 were in S 50 reactor. A plant faced downtime of almost 17 days due to rupture of high pressure steam line.

Purification section followed Synloop and Refrigeration section with downtime of 148.6 days i.e. 24.2% of the total downtime for three years. Problems in carbon dioxide removal section encountered by 13 plants contributed 77.0% (114.6 days) of this downtime. That is why the downtime in purification section has almost doubled than the previous survey period. One of the plants reported 62 days downtime due to failure of absorber packing in CO_2 removal section. Another plant reported downtime due to hydraulic turbine problem and heavy leakage in aMDEA section which resulted in high pressure drop in secondary reformer. In 2011-12, the same plant faced problem of CO_2 stripper ejector steam generator and cannel cover leakage. In another plant, Benfield reboiler tube leakage occurred 5 times leading to downtime of about 14 days in 2012-13. Leakage of GV re-boiler and semilean solution flow control valve led to downtime of more than 11 days in one plant. In one of the revamped plant, GV section after commissioning caused downtime of 7.5 days in 2012-13. Other plants reported a number of problems in CO_2 removal section which included leakage in the GV solution outlet line of CO_2 absorber, MDEA solution cooler gasket leakage, tripping of benefield section, methanol leakage from bypass line isolation valve upstream flange and shearing of semi lean pump shaft.

Two plants faced problem in HT shift section. One of them reported heavy gas leakage and fire at outlet line weld joint of 1st converter in CO-shift section while other had trim heater flange fire. Only one plant reported downtime in LT shift due to leakage in tubes of BFW preheater in 2012-13. As immediate measure the plant plugged the tubes and later in 2013-14 planned turnaround, the exchanger was replaced. One plant took shutdown due to leakage in Methanated Gas Cooler in 2012-13. The leakages were repetitive even after complete retubing of exchangers. Finally a new exchanger with SS MOC (tubes, tube sheet and baffles only) was procured and installed in December 2013. In another incident in the same plant, Methanated Gas Heat Exchanger was chocked due to GV mist carry over from GV absorber and solidified in tubes.

A significant downtime of 91.8 days was contributed by syngas compressor to the total downtime. A total of 19 plants reported problems in synthesis gas compressor. High vibration in HP barrel and turbine was the common reason. Fire near seal oil pump resulted in shutdown of 2.5 days in one plant. Another plant reported 7.2 days downtime in

Table 4 – Mechanical failure downtime in Ammonia Plants (Based on Reforming Process) for 2002-2005, 2005-08, 2008-11 and 2011-14

Major Sections	(2002-05) (24 plants) (Days)	%	(2005-08) (24 plants) (Days)	%	2008-11 (26 plants) (Days)	%	2011-14 (28 plants) (Days)	%
1. Pre-treatment section	8.0	-	20.3	3.8	1.2	0.2	0.0	0.0
2. Pre-reformer	15.8	-	11.2	2.1	0.0	0.0	0.0	0.0
3. Primary reformer	72.4	13.1	85.6	16.0	84.3	14.9	63.9	10.4
4. Secondary reformer	48.7	47.9	13.6	2.5	122.5	21.6	91.8	14.9
5. Purification	46.0	3.7	53.6	10.0	59.4	10.5	148.6	24.2
6. Synloop and refrigeration	21.2	7.6	116.7	21.8	78.0	13.8	157.6	25.6
7. Syngas compressor	68.0	9.6	161.5	30.2	76.4	3.5	96.0	15.6
8. Other compressors and turbines	87.0	8.6	30.5	5.7	92.3	16.3	44.6	7.2
9. Miscellaneous major equipments	73.0	9.5	41.9	7.9	52.5	9.3	12.8	2.1
Total	**498.7**	**100.0**	**534.9**	**100.0**	**566.5**	**100.0**	**615.3**	**100.0**

2013-14 due to gasket leakage in second stage knock out drum. Other compressors and turbines also contributed about 7.2% of the total downtime due to mechanical failures. Ten plants encountered problems in process air compressors and 6 in refrigeration compressor.

Secondary reformer contributed to 14.9% while primary reformer accounted for 10.4% downtime. There was no downtime reported in pre-reformer. Most plants did not take pre-reformer in line as sufficient gas was available (domestic + imported) and naphtha was not used. The waste heat boiler problems in secondary reformer were reported by 4 plants with average downtime of 9.8 days. Cause of all the downtime incidents was leakage in the waste heat boiler. Secondary reformer shell failure was noticed in one plant leading to a downtime of about 29 days. Primary reformer ID/FD fan problems were faced by six plants while three plants reported leakage in reformer tubes.

Small downtime was reported due to other miscellaneous equipment such as leakage in auxiliary boiler and BFW exchanger tubes, breakdown in BFW pump turbine, tripping of cooling water pump and refrigeration compressor turbines.

2.5.2. On stream Efficiency in Ammonia Plants

High on stream efficiency of ammonia plants is important for achieving high productivity and energy efficiency. During the present survey, the average on-stream days for all the ammonia plants was 327.3 days per plant per year (DPY) which is lower than 330.1 of the previous survey period of 2008-11. The lower on-stream days in ammonia plant were due to higher planned turnaround days in some plants due to prolong annual turnaround for changeover of feestock, revamp activities, policy constraints and non-availability of feedstock. **Figure 1** depicts the quartiles of average on stream days for all ammonia plants of the present survey. It may be noted that the highest average on stream days of 347.6 days were achieved by the 25% of the plants (Q1) and 338.7 on stream days achieved by next 25% plants (Q2). The next two quartiles plants operated on average 329.6 days and 293.5 days respectively during the three year period. The last two quartiles (Q3 and Q4) include plants which took longer shutdown for revamp and feedstock changeover.

Operating, Service and Reliability factors were 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:

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

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

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

During the period 2011-14, the ammonia plants have an operating

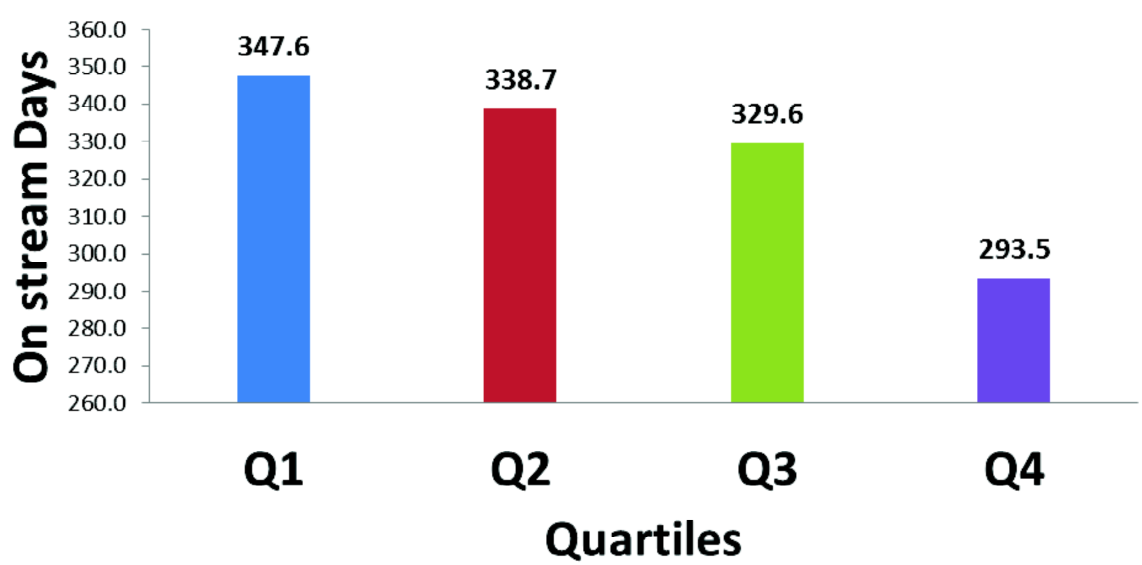

Figure 1 – Quartiles of on stream days of ammonia plants

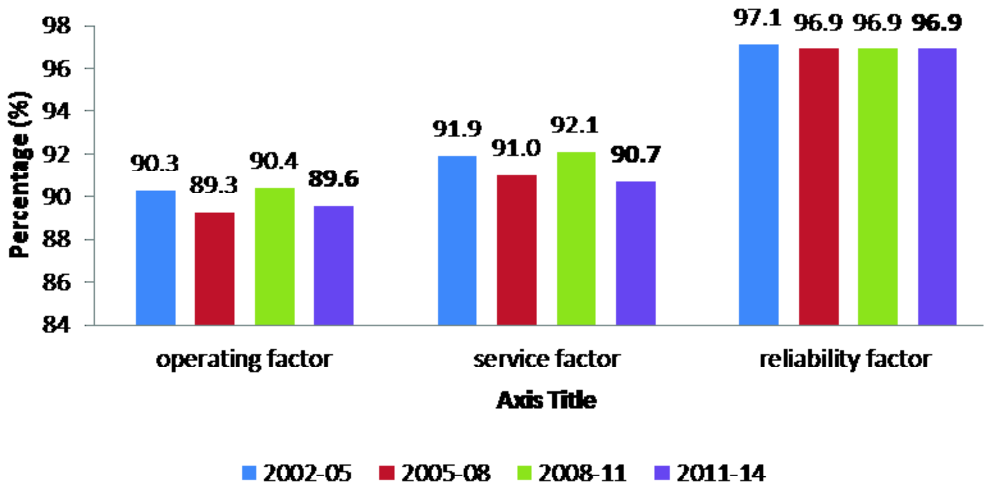

Figure 2 – Operating, service and reliability factors for ammonia plants

factor of 89.6%, service factor of 90.7% and reliability factor of 96.9%. There was slight reduction in Service factor due to rise in loss time for business related problems. The operating and reliability factors are about the same for the last four survey period as shown in **Figure 2**.

3. REASONS FOR LOSS TIME IN UREA PLANTS

All ammonia plants barring one covered in the survey have integrated urea plants. The downtime analysis was carried out for 27 urea plants.

3.1. Number of Shutdowns

The total number of shutdowns per plant per year (SPY) in 2011-14 was higher at 11.7 SPY compared to 10.4 SPY during 2008-11 period but same as for 2005-08.

3.2. Planned Turnaround

The urea plants also reported higher turnaround period as in case of ammonia due to policy consideration in 2012-13 and conversion to natural gas of four plants and major revamp activities in several other plants. The planned turnaround period for urea plants were 22.0 days per plant per year (DPY) in this survey compared to 20.3 DPY in 2008-11 and 19.3 DPY in 2005-08.

3.3. Reasons for Loss of Production

Table 5 details the causes for loss of production as well as number of shutdown and duration of shutdown. The 27 plants suffered loss of production of 25947 MT per plant per year which translates into a cumulative loss of about 2.0 million tonnes of urea for the three years period. Shortage of raw materials that is non-availability of ammonia was the major contributor to the downtime of 6.7 DDPY (46.5%). The plant related problems accounted for about 32% of the loss of production with downtime of 4.6 DDPY. The other reasons such as interruption in ammonia plant, utilities, etc., contributed 16.7% of downtime. The plant related problems include failures due to mechanical, electrical, process, instrumentation, etc., and are analyzed in detail.

3.4. Analysis of Forced Shutdown due to Plant Related Problems

The total downtime per plant per year was the lowest at 14.4 DDPY compared to previous periods. The figures were 21.2 and 20.2 for 2008-11 and 2005-08 respectively. Plant related downtime for urea plants was also significantly lower than the previous surveys periods on account of reduced loss time due to mechanical problems.

Mechanical reasons for shutdown of the urea plants were the lowest of the last 3 survey periods. The mechanical downtime was 3.4 DDPY during the present period

Table 5 – Reasons for loss of production in urea plants (2011-14)

Sl. No.	Category	No. of shutdown (SPY)	Downtime days (DDPY)	Loss of production (MT/plant/yr)
1	Plant Related Problems	4.8	4.6	8766
2	Power Plant/Supply	1.4	0.7	1047
3	Shortage of Raw Materials	2.7	6.7	11668
4.	Labour Problems	0.0	0.0	185
5.	Water Problem	0.0	0.0	0
6.	Other reasons	2.9	2.4	4281
	Total	**11.7**	**14.4**	**25947**

while it was 6.9 DDPY in 2008-11. One of the reasons for lower downtime is due to significant reduction in incidents of reactor and stripper problems. Many plants took action to repair and replace these equipments and hence improved their reliability. Downtime due to other problems related to electrical, process, instrumentation and other miscellaneous equipments remained at about same level as in the previous survey periods. (**Table 6**).

Table 6 – Details of downtime in urea plants due to plant related problems (DDPY)

Reasons	2005-08	2008-11	2011-14
Mechanical	4.0	6.9	3.4
Electrical	0.6	0.3	0.4
Process	0.2	0.4	0.3
Instrumentation	0.3	0.3	0.3
Miscellaneous	0.2	0.3	0.3
Total	**5.3**	**8.1**	**4.6**

The details of mechanical failures for the present survey (2011-14) period are presented in **Table 7**. There has been significant reduction in the overall failures due to mechanical reasons. Heat exchangers, decomposers, stripper, reactor and carbon dioxide compressor were the main contributor to the downtime in decreasing order. Heat exchanger problem was encountered in 14 plants of the 27 covered in the Survey. The carbamate condenser tube leakage was the main cause of the downtime. In one plant, carbamate condenser leaked thrice in one year. It was repaired each time by plugging the leaked tube and finally was replaced during planned turnaround. Another plant faced about 10 days shutdown in 2011-12 due to tube to tube sheet joint leakage and now plans to replace it. One more plant faced leakage leading to outage of about 9 days.

Stripper was the second most prevalent cause of forced shutdown. In two plants the leakage of top liner occurred every year of the survey period leading to shutdown of almost 29 days and 8 days respectively. Twelve plants took forced shutdown due to reactor problem. Reactor liner leakage was the major cause faced by the plants.

Carbon dioxide compressor downtime increased from the previous survey periods as 19 plants faced the problems. High vibration, axial displacement, packing leakage, leakage in 3rd stage intercooler, oil leakage, low suction pressure and governor problems are reported as most common reasons for stoppage of compressor.

The downtime in ammonia pump is low but 10 plants faced problems in ammonia pumps. A few plants faced problems in slurry and other pumps, conveyer system, prilling tower scrapper and pipings and valves.

3.5. On Stream Efficiency of Urea Plants

On stream days for urea plants were reported as 328.9 days compared to 323.5 DPY in previous survey period. The on stream days improved on account of lower forced shutdown. The reasons for reversal of trend compared to ammonia plants was the lone ammonia plant without urea plant contributed more to forced shutdown on account of feedstock

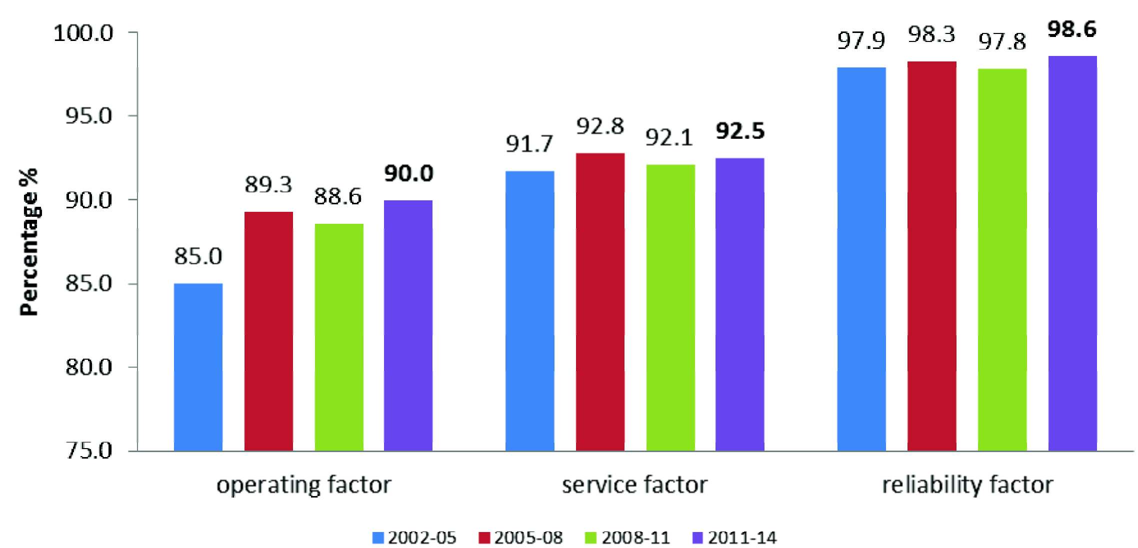

Figure 3 – Operating, Service and Reliability Factors for Urea Plants

Table 7 – Details of downtime due to mechanical failure in urea plants

Equipment Items	2002-05	2005-08	2008-11	2011-14
1. Ammonia Pre-heater	0.05	0.1	0.00	0.03
2. Ammonia Pumps	0.05	0.11	0.09	0.10
3. Carbamate Pump	0.28	0.08	0.02	0.03
4. Slurry & Other Pumps	0.00	0.03	0.03	0.06
5. CO_2 Compressor	0.39	0.39	0.45	0.51
6. Autoclave/Reactor	0.58	0.52	2.73	0.48
7. Heat Exchangers	0.51	0.02	0.88	0.78
8. Decomposer/Stripper	1.44	0.04	0.91	0.67
9. NH_3/CO_2 Recovery Column	0.02	0.06	0.00	0.00
10. Absorber/Recovery Vessels	0.21	0.00	0.18	0.11
11. Evaporator/Crystalliser	0.06	0.00	0.00	0.00
12. Centrifuge	0.00	0.00	0.00	0.00
13. Steam Ejector/Vacuum Generator	0.06	0.00	0.01	0.00
14. Dryer/Cooler	0.08	0.00	0.02	0.02
15. Blower/Fan	0.04	0.03	0.01	0.09
16. Conveyer/Elevator	0.02	0.12	0.06	0.02
17. Prill Tower	0.19	0.04	0.06	0.08
18. Piping/Valves	0.43	1.05	0.16	0.28
19. Miscellaneous	1.24	1.20	1.19	0.08
Total	**5.88**	**4.15**	**6.80**	**3.35**

limitation pulling down the overall average of on stream days of ammonia plant. The on stream efficiency factors have also been calculated for urea plants and shown in **Figure 3**. In case of urea, the on stream factor, and reliability factors were highest so far. The service factor remained at same level as previous two survey periods despite higher on stream days as the business related downtime (external reasons) was higher at 9.8 DDPY than previous survey of 8.7 DDPY.

4. CONCLUSION

The ammonia and urea plants downtime data were analyzed for planned maintenance, forced shutdown and on stream days. Planned maintenance time was highest at 23.1 DPY of the previous three surveys on account of revamp activities of three plants, feedstock conversion by four fuel oil based plants and prolonged shutdown due to limitation of pricing policy in a few ammonia plants. Similar trend was observed for urea plants.

Forced downtime due to mechanical problems was lower for both ammonia and urea plants than previous periods. In ammonia plant, it was slightly lower at 7.8 DDPY in 2011-14 than 8.8 in the previous survey. The urea plants showed significant reduction in mechanical failures from the previous survey. It was reported as 3.4 DDPY in the present survey compared to 6.9 DDPY in the previous survey period. Perhaps longer period of planned shutdown helped in reducing forced downtime due to plant related problems. The impact of planned maintenance and forced downtime is reflected in on stream days. The on stream days for ammonia plants in the present survey were lower (327.8 DDPY) compared to previous survey (330.1 DDPY) while for urea plants it is higher at almost 329 DDPY than previous period (322.7 DDPY).

The waste heat boiler in Synloop and refrigeration section, high vibration in syn gas compressor, CO_2 removal section and waste heat boiler in secondary reformer were major reasons for loss time in ammonia plant. In case of urea plants, the severity of problems was lower than previous surveys but problems in carbamate condenser, stripper, reactor, carbon dioxide compressor and ammonia pump were encountered in a number of plants. These equipments need attention of plant management. The long planned maintenance period affected the on stream factor of the ammonia urea plants. But on account of lower internal problems the reliability factor of the surveyed plants remained high at about 97% and 98.6% for ammonia and urea plants respectively.

It is to the credit of industry that forced downtime due to equipment problems came down inspite of aging plants. This has been possible due to continuous investment in up-gradation and carrying out preventive and predictive maintenance. It is unfortunate that policy related issues caused the shutdown of plants which resulted in loss of production.

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