Coupling Failure between Compressors

Extreme care should be used in tightening coupling bolts and they probably should not be used over twice.

Jack C. Roney
Cooperative Farm Chemicals Assn.
Lawrence, Kans.

This paper could be more correctly entitled "Experience Pertaining to Near Catastrophe on 103-J Synthesis Gas Compressors" or "Thank God for a Catacarb Leak," but since I had the title before writing the paper, I will endeavor to explain conditions leading to the coupling failure.

CFCA has a typical 1000 ton/day Kellogg ammonia plant with De Laval Tandem steam turbines driving Clark centrifugal compressors for synthesis gas compression. The turbines are rated 24,000 hp with a normal speed of 10,600 rev./min.

A minor turnaround had been scheduled for December 17th to check cause of high vibrations on the suction end (high case end) of the low case compressor and the outboard end of the high case compressor as well as to check the governor drive gear on the condensing turbine; but, prior to shutdown, the unit was forced down on December 13th because of a leak in the Catacarb system necessitating shutting down of the back section of the plant.

Six bolts broken in a line

Inspection of the coupling between the compressors revealed that six of the ten coupling bolts were broken on the high case end of the coupling. There were no bolts broken on the low case end of the coupling. The broken bolts were all in a line; that is, there were no unbroken bolts between broken bolts. The bolts were supplied by the manufacturer of the coupling and were socket headed 3/8-in. ∅ x 1-1/16-in. long with 3/4-in. of NF threads (24) and fitted with a self-locking nut. The breaks on all but one of the six were in the thread area and all breaks were shear failures. There was not any necking down in the break areas. A hardness check of the broken bolts showed them to be in the 40 to 45 Rockwell C range in the center of the break with a 45 to 50 Rockwell C on the outside surface of the bolt. This compared favorably with a new bolt. We did not have a record of any change out of bolts on this coupling so it was assumed the bolts had been in service since the unit was started in the fall of 1971. It is known that the coupling was apart for turnaround in 1972.

Needless to say, you can imagine why I said this paper could have been entitled "Thank God for a Catacarb Leak," as complete separation of the coupling could have caused a major fire or catastrophe.

Misalignment was discovered

Checking the cold alignment of the train revealed that the low case compressor had moved 0.009-in. to the left of centerline on the discharge end (turbine end) and had moved 0.017-in. to the right of centerline on the suction end (high case end). The vertical alignment on the low case showed the discharge end to be 0.033-in. higher than the Topping turbine instead of a recommended 0.040-in. and the suction end to be 0.003-in. higher than the high case as compared to a recommended 0.005-in. higher.

In our opinion, the coupling failure was a result of, or at least aggravated by, the misalignment of the low case compressor. Readings taken during shutdown of October, 1972 indicate that the equipment was in alignment at that time.

A check on piping to and from the low case shows that it is also hard to visualize any way a torque could be applied to the case from movement or growth of the pipes. Consequently, we are at a loss to explain why the case moved.

Vibration readings taken on the shaft of the low and high case compressors using Bently proximity probes are listed in Table 1. Vibration readings indicate that the first problem started around November 28, 1973, and was aggravated on December 2, 1973, when we had jumps in vibra-

Table 1. Vibration readings made with proximity probes.

Date	Coupling End Topping Turbine	LOW CASE Discharge End	LOW CASE Suction End	HIGH CASE Discharge End	HIGH CASE Suction End
5/29/73	0.5	0.5	1.0	0.45	1.1
10/18/73	0.7	0.6	1.2	0.5	1.2
11/18/73	0.8	0.5	1.0	0.7	1.4
11/20/73	0.7	0.5	1.3	1.4	1.4
11/28/73	0.8	0.4	1.35	2.0	1.5
12/2/73	0.85	0.5	3.0	1.0	1.6
12/7/73	0.7	0.6	3.0	0.8	1.0
12/12/73	0.5	0.68	3.0	0.8	2.2

Table 2. Vibration readings after start-up.

Date	Coupling End Topping Turbine	Discharge End-LC	Suction End-LC	Discharge End-LC	Suction End-LC
12/20/73	0.8	0.7	0.8	0.7	1.5

tion levels. Today, with more confidence in our equipment, we would shut the unit down for inspection after a sudden increase in vibration levels or when the 3 mil level was reached.

The radial bearings on both compressors were checked and had not been damaged; however, the discharge end bearing of the low case compressor had a discoloration and was replaced. The thrust bearings had not been damaged. As bearing damage was not evident, the cases were not opened.

The coupling had a soft sludge build-up on the teeth; however, this did not prevent movement of the coupling.

Vibration after startup is shown in Table 2. One-half mil of the 1.5 shown on the Suction End of the HC is glitch, leaving an effective vibration of 1 mil. This indicates we have an unbalance problem in the high case which will be corrected when the unit is down; however, the alignment problem appears to have been partially corrected. Checks are now being made by optical alignment either periodically or with increasing vibration levels to determine the alignment of the train or movement of individual components. Optical checks have shown that on our particular unit from cold to hot the condensing turbine grows 0.035-in., the Topping turbine grows 0.055-in., the low case compressor grows 0.019-in., and the high case grows 0.014-in.

Optical checks on the horizontal alignment show that for our particular unit the condensing turbine moves 0.008-in. to the right of centerline, the Topping turbine moves 0.002-in. left of centerline at inlet and to 0.006-in. right of centerline at exhaust end. The low case compressor moved 0.005-in. to the right of centerline and the high case compressor moved 0.003-in. to the left of center.

A second optical check showed that vertical readings may vary as much as 0.005-in., depending on operating conditions, but horizontal readings will not vary over 0.003-in. unless something has shifted.

Conclusions

Coupling bolts can be overstressed to the point of failure. Alignment can be a significant factor in overstressing of bolts. Optical alignment is one tool that can be utilized for better alignment. Vibrational analysis is another tool that equates condition of equipment. Extreme care should be used in tightening coupling bolts and they probably should not be used over twice.

RONEY, J. C.

DISCUSSION

Q. I have a couple of questions. (1) How much free float do you have in this coupling, if any at all? (2) Do you on your Bently probe system have an XY probe setup and did this point ever go through anything more than a critical vibration on the last startup?

RONEY: The free float on this coupling is between 3/16 and 1/4 of an inch. We have Bently probes and they are XY's. The readings that are in the paper are maximum. The probes are not true vertical and horizontal as they are 45% off the centerlines. The last question:

Q. The last question was did it go through any abnormal critical vibration on the prior startup?

RONEY: No.