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Retrofitting multijack tensioners on a combustion gas turbine generator

Consider this technology for difficult bolting applications

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Global competition has been moving the hydrocarbon processing industry to ever-higher levels of efficiency and production rates. This has led to an increased demand on both equipment and manpower to produce higher reliability and shorter turnaround times. One major problem occurs when dealing with high-temperature and pressure equipment is its bolting and unbolting. This is due to the very large torque required to properly seal the joint and the difficulty of its application, especially in the field.

One of the main gas turbine generators in a large refinery has been notoriously known for being very hard to bolt and for developing leaks when bolted. A number of methods are available to help with bolting problems, but for this particular application none could be used. Multijack tensioners (MJTs) seemed to be very promising to help in lessening some of these problems. Consequently, replacement bolts were specified, designed, manufactured and installed on the unit to see if they could help with the problem.

The basics. Fig. 1 shows a sketch of a typical bolted connection. When the bolting is tightened, the main body of the bolt (or the stud if there is a stud and two nuts) elongates. The increase in bolt length introduces tensile stresses into the bolt or stud. At the same time, the distance between the nuts decreases by the same amount. This produces compressive stresses in the flange faces, which hold the flange together and prevent leaks.

The tensile stress in the stud is produced by the rotation of the nut or bolt. Essentially the bolt is a tool that converts the torque applied into stress in the stud or bolt. This induced stress is called preload. The torqueing value required to achieve a certain preload varies and depends on many factors. This includes the friction coefficient between the nut and bolt, the cross-section of the bolts as well as many other factors. By far the biggest contributor to the required torque is the bolt or stud cross-sectional area. Fig. 2 and Table 1 show the different values recommended from one gas turbine manufacturer for casing bolts. These torquing values are representative of most other manufacturers as well as many local and industrial standards.

As can be seen from the table and the plot, the torquing value required to set a bolt to its proper preload is a very nonlinear function of the bolt diameter. While it only takes 369 ft lb to seat a bolt to 45,000 psi preload when its diameter is 1 in., it takes 3,313 ft lb (8.9 times as much!) to set a 2-in. diameter bolt to the same preload. In fact, the required torque is a third power of the bolt diameter if other parameters are kept constant.

Hand tools can be used to apply the required torque with relative ease and accuracy for smaller diameter bolting. However, as bolting diameter—and consequently torquing requirement—gets higher, methods for applying the required torque get more and more extreme. For example, it is quite common to use large sledgehammers and field-made “tools” to bolt and unbolt large joints. In fact, sometimes so much force is required that cranes and/or other heavy equipment have to be used to tighten large nuts or free seized bolts.

Apart from providing totally inaccurate preloading to the joint and possibly causing joint failure, these extreme methods have major safety concerns especially when the bolting is in confined or awkward areas. In fact, there are many reported cases of serious injuries as a consequence of trying to bolt or unbolt a large bolt or stud. In addition, the inaccurate, uneven and often insufficient bolting stress will sometimes lead to serious joint leaks that will be a major problem.

A number of methods have been proposed and used to help in solving or easing the large-diameter bolting problem. Some of the most common are:

- Bolt heating: In this method, the studs have a specially designed heating cavity in their center. The principle is to heat the bolt or stud using special heating rods and tighten it while it is hot. The rods are later removed and the preload will gradually develop as the bolt cools to the casing temperature. This method, although helpful in many
cases, requires special studs and heating elements and has a large torque requirement. In addition, torque accuracy can be limited in many cases, though it is generally better than standard bolting practices.

- Hydraulic stud tensioning: This bolt tightening method relies on stretching the bolt stud a certain amount to induce the proper preload in it. After that, the bolt or nut is tightened by hand until it touches the flange face. The bolting is complete when the hydraulic tension is removed and the nut holds the preload in the bolt. This method can be used for more than one bolt at the same time, which can be very advantageous especially when bolting gasketed flanges. On the other hand, this method can be inaccurate (especially for short studs), and it can’t be used for all types of bolting. In addition, special hydraulic tensioning devices and associated pumps and auxiliaries have to be purchased and maintained.

- Hydraulic bolting: It is identical to normal bolting except that the normal torque is applied using a special hydraulic mechanism. Again, this method works in many applications but can’t always be used, especially when there are space limitations. Apart from not having a high accuracy of preload, they suffer from some of the same limitations of normal bolting including thread galling. And like hydraulic stud tensioning, there is the upfront cost of the hydraulic mechanism. This can be significant.

**Multijack tensioners.** Multijack tensioners (MJTs) are a relatively new method of trying to deal with the problems described in the previous section. MJTs are special patented design fasteners that replace existing bolts or nuts. The main idea behind MJTs is very simple: to tighten a number of smaller jacks instead of one large bolt or nut. Fig. 3 shows a cross-section of an MJT that will help to visualize how it works.

The figure shows a cross section of just one of the many forms of MJTs. The main parts are common to all MJTs and they are:

- A number of high-compressive strength jacking bolts that are tightened when the bolts are installed. These jacking bolts are embedded in the body of the MJT and push against the bottom washer.
- A special hardened washer located between the bolt and the flange body. The jacking bolts push against this washer when they are tightened, creating a gap between the bolt body and the washer.
- Some have internal threading that holds the stud like a standard nut. When the jacking bolts are tightened, the nut is pushed away from the flange. This causes the stud to be pulled to the proper bolt preload.

The advantage of MJTs is that torque required to achieve the target preload using the jacking bolts is much less than that required to preload the big nut or bolt. Table 2 shows the jacking bolt torqueing required versus the original bolt for one particular application. In addition, the last column shows the torque advantage, which varies from 26:1 to 273:1 for larger diameter bolting!

**Retrofitting MJTs onto combustion gas turbine.** Industrial combustion gas turbines are well known for being especially hard to bolt and unbolt. Not only are the bolts and nuts very large, they are not forgiving and will leak when not preloaded properly since the flanges are metal-to-metal with no gaskets. The problem can be exacerbated when the bolts are in a hard-to-access area or lack heating holes for thermal tightening.

One particular unit in a refinery suffered from all of these problems with a large number of its bolts. Some bolts literally took...
ours to bolt and unbolt, especially when they had not been
opened in a long time. Sometimes bolts could not be freed and
would have to be cut with a torch to be removed. In addition, the
nut was notorious for developing hot air leaks after being over-
headed and, consequently, would have to be shut down for bolt
tightening. Even then the leak would not completely disappear,
ince the casing faces were distorted due to previous leaks.

All of these problems made this unit a very good candidate
to replace the original turbine bolting with MJT s. The first step
was to decide which bolts to replace with MJT s during the next
unit overhaul. The unit had many bolts and it would have been
neconomical to replace them all. Instead, efforts were concen-
trated on selecting a few large-diameter bolts in inaccessible
and critical areas to be replaced. Fig. 4 shows a cross-section of
the gas turbine case, with arrows pointing to the bolts that were
elected to be changed. As can be seen from Fig. 5, these bolts
are situated at the corners of the casings and are among the
largest in diameter (2 in.). Furthermore, the original bolts had
a square hexagonal socket cap, which meant that a special socket had
be used to torque them. It was felt that replacing these bolts
would not only take care of the most problematic bolts in the area
but also have the most positive effect on reducing leaks.

Once it was decided which bolts would be retrofitted with
MJT s, a custom design was developed with help from the manu-
facturer. The bolt would have to fit in the recessed area
intended for the original bolt. It would also have to allow
enough clearance above it to access the jack bolt. Since
detailed drawings for the bolts and the casing were not avail-
able, detailed measurements of some spare bolts along with the
casing had to be taken. Once these details were collected, they
were sent to the manufacturer. It came up with a design simi-
lar to what is shown in Fig. 6.

The next step was to come up with an appropriate material
for this application, taking into account both the designed
preload of the bolt and the temperature that the bolts will have
to withstand. After some background search as well as con-
sultation with different turbine manufacturers, a preload close
to the original design was selected that would help in minimizing
the leak problem. Actual casing operating temperature was
measured by taking a thermal image of the unit when it was run-
ning (Fig. 7). Consequently, an estimate of the maximum tem-
peratures the bolting will be exposed to over its life was deter-
mined. Samples of the original bolting material were analyzed
to try to guess its composition and the design constraints of the
original bolting designer. A final selection of bolting materi-
als was reached with help from the MJT manufacturer as well
as in-house company engineering expertise. Finally, the designed
bolts were manufactured and installed in a major unit overhaul.

**MJT Assessment.** We found that they were more expensive
than the original OEM bolts (about 40% more in this particu-
lar application). In addition, most machinists do not know how to properly
install MJT s, so some time has to be spent explaining the proper
installation sequence. Having said this, we feel that MJTs have performed very well in our particular application. Time required to stall bolts has shrunk from about 30–60 min. to less than 5 min. per bolt. Moreover, all the problems that we were facing with the original bolts have now disappeared. No heavy hammering or heating with torches is required to set these bolts. In our application, the required torque has decreased from the original 3,313 lb to 65 ft lb (an advantage of more than 50:1). This new torque can be easily and accurately applied by hand. This is achieved with confidence that the bolts were tightened to the target preload.

As has been mentioned earlier, this turbine had a long history of developing leaks in its horizontal and vertical flanges. In the past, the leaks were so severe that they have caused unevenness in the turbine casing (Fig. 8). After MJTs were stalled and the unit was run, some clear leaks did develop but only in the areas where the new bolts were not installed on the casing. This shows that these bolts are as good or most likely better than the original bolts in applying the proper preload and preventing hot air leaks on the casing.

The decision to use MJTs should not be automatic; each bolting problem should be evaluated separately to decide if they can be used and are worth the engineering effort to retrofit them to solve the problem. Other bolting methods are very useful and effective in many applications. In our opinion, however, MJTs should be at least considered for large or especially critical bolting applications to improve safety and reliability. They should be considered for new installations that require large bolts or high torquing values and preloads.

ACKNOWLEDGMENTS

Many thanks go to a number of engineers working in various departments of Saudi Aramco for suggesting and supporting this project, particularly A. R. Al-Khawaiter from Aramco and the engineering staff at Superbolt Inc.

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