10-year history of crane wheel assembly maintenance at Bethlehem’s Burns Harbor plant

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Defective crane wheel assemblies are the most common mechanical units replaced on a crane at the Burns Harbor plant. The following problems leading to the replacement of defective wheel assemblies are discussed in this article: worn flanges; bearing failures; lubrication; axle breakage; spalled wheels; and out of round wheel tread wear. Overcoming these problems improves crane availability, the crane operator’s ride and the crane’s overall operating reliability as well as providing a substantial reduction in maintenance costs.

There are over 200 electric overhead traveling (EOT) cranes currently in service at the Burns Harbor plant ranging in capacity from 10 to 435 tons. The typical crane bridge arrangement is a modified double A4 (Fig. 1). Four 600 series d-c motors are used, each located at a bridge corner with the diagonally opposite corner motors wired in series. This arrangement has the best possible tracking ability and results in the elimination of skewing on the long span crane, typically 117 ft-0 in. Typical bridge top speed is 400 to 450 fpm. Standard plant rail weights are 175 lb/yd for the bridge and 135 lb/yd for trolleys.

Crane wheel assemblies, as well as many of the other crane components, are included in the Burns Harbor plant duplication program for standardized spare parts. This program was developed to reduce the necessity for carrying a large inventory of spares.

Crane wheel assemblies have been standardized by using a cylindrical double-flange bearing capsule that is separate from the mounting bracket (Fig. 2). This design has been accepted by all crane manufacturers and allows the manufacturer the prerogative of utilizing mounting brackets at 30, 45 or 90° with any design desired for attaching the wheel assemblies to the trucks or end carriages.

A spare crane wheel assembly is available in inventory complete with axle, wheel, bearings, bearing capsules and couplings. The availability of a spare assembly enhances an effective maintenance program as the entire unit is replaced, minimizing crane downtime. There is a total of 2500 crane wheel assemblies in service at Burns Harbor (1600 bridge assemblies and 900 trolley assemblies). Only four different standard assemblies are required to provide spares for 85% of all assemblies replaced annually: a 24-in. bridge driver and idler; and a 27-in. bridge driver and idler.

Accompanying an increase in steel production over the 25-year history of the plant has been an increasingly higher crane wheel assembly failure rate until 1981. Annual costs for repairing wheel assemblies were in excess of $1 million during a base period from 1978 through 1981. There were also significant costs associated with crane downtime, maintenance man-hours for the wheel assembly replacement and periodic replacement of crane rails damaged by abrasive wear. Crane wheel assembly repair costs have represented from 24 to 50% of the total mechanical crane repair budget. For the past 11-year period it averaged 38%.

Fig. 1 — Crane bridge arrangement.

Fig. 2 — Double-flange bearing capsule used in crane wheel assembly.
Worn flanges

Through the collection of failure analysis data for a 4-year base period, 1978 through 1981, it was found that of a total of 230 wheel assembly replacements per year, 139 (60.8%) were because of worn flanges (Fig. 3). Flanges are abrasily worn by metal to metal contact of the wheel flange with the crane rail. A crane operating phenomena, named favorite side, was identified as the major contributing factor. This condition occurs when the entire crane bridge rides on one side of the rail, i.e., the crane wheel tread centerline does not coincide with the rail centerline, even though the gage and span of the runway rails are correct. The favorite side characteristic is typical of the bridge operation of Burns Harbor cranes.

Solving or controlling worn flanges was accomplished within a 2-year period through the application of wheel flange lubrication. Crane wheel flange lubrication is achieved with a lubricator that consists of a tube holder and spring unit that pushes a 1 x 1 x 6-in. long graphite stick against the wheel flange. (It was also found that 20% of the cranes required 80% of the wheel assembly replacements. These cranes were primarily in the plate mill, cold strip mill and hot strip mill storage and shipping buildings, and slab yards.) Lubricators were installed on 35 to 40 cranes throughout the plant with one lubricator installed on each wheel aimed at the wearing flange. Improvements rapidly followed. The installation of lubricators was complemented with thicker flanged wheels having a minimum surface hardness of 60 to 63 Rb.

Although flange failures have not been completely eliminated, the number has been significantly reduced from an annual average of 139 during the base period to 23 during the period from 1983 through 1988 (Fig. 4). Crane wheel assembly replacements for flange failures currently represent approximately 12% of the total replacements.

Cranes which previously had worn out flanges on the average of every eight months, are currently operating with wheels several years old. These same cranes also have lubricators that are lasting more than one year. There has been no flange wear. The flanges are as thick as when they were originally installed. They have a high gloss finish where, previously, they were galled and pitted. Crane rails having visible wear on the side of the head are no longer a common condition.

Another benefit obtained from the flange lubrication program is a substantial savings in energy: as one example, it is estimated that the equivalent cost in electricity required to wear one flange wheel to a point of failure is approximately $200 alone.

Bearing failures and lubrication problems

The Burns Harbor crane wheel assemblies are equipped with spherical roller bearings. Because bearings are rotating parts with many components, bearing failures were expected to be the most difficult problem to solve.

In the base period from 1978 through 1981, an average of 40 crane wheel assemblies were replaced annually due to bearing failures. Of these bearing failures, approximately 50% were due to insufficient lubrication. In 1983, when the number of flange failures was radically reduced, bearing failures became the principal cause of wheel assembly replacement.

Early in 1984, a significant rise in the rate of bearing failures occurred (Fig. 5). Initially, it was considered that it was a consequence of not replacing a large number of crane wheel assemblies formerly the result of the flange problem. However, it became evident that lack of adequate lubrication was the major reason for the increased failure rate.
A patented permanent lubrication bearing was considered and tested. This system had been available for bearings for many years but it had not been used in crane wheel assemblies. The first permanent lubricated bearings were installed in mid-1984 and have since been used as a standard replacement unit in reconditioning crane wheel assemblies. A total of 125 wheel assemblies were equipped in 1984 and no bearings of this type failed. In 1985, only five crane wheel assemblies containing the unit were replaced due to bearing failures. In 1986, the total plant crane wheel assembly failures decreased dramatically to 132 together with a slight decrease in the number of bearing failures.

In early 1987, to get another perspective on crane wheel assembly failures, life-cycle charts were developed covering yearly data for 1984, 1985 and 1986. An ideal and actual life-cycle curve for 1986 are shown in Fig. 6 and 7, respectively. The 1986 curve closely resembles the ideal curve. It also shows that there were an excessive number of failures in the infant mortality failure range that corresponds with adoption of the new permanent lubricated bearings.

Bearing failure analysis was intensified with the two-wheel assembly reconditioning companies and bearing manufacturer requested to participate. Bearing failure causes included lack of sufficient lubrication, installation mounting errors, designed dimensional tolerances of mating components, misalignment faulty, passage of electric current through the bearing, vibration when the bearing is not rotating, sealing of the bearings, possible misapplication of bearing and the new feature of permanent lubrication.

Throughout 1987, the search for the cause of failure of the permanent lubricated bearings continued. Mill area, crane environment such as hot areas, bearing position on the crane wheel assembly, driver vs idler, were investigated as potential causes without success. Bearings were removed from the wheel assemblies and sent to the laboratory for further testing. It was found that the problem occurred almost exclusively with bearings in the 24-in. dia crane wheel assembly.

total of 96% of the bearing failures occurred with the 24-in. dia wheel assemblies and represented 50% of the total crane wheel failures. Further analysis showed that the problem occurred in the highest duty cycle crane. By the end of 1987, it was evident that the permanent lubrication pack was deteriorating and the bearing would fail due to loss of lubricant. The probable cause of the deterioration was attributed to the heat generated at the roller/race interface area created by the wheel flanging to rail thrust loads. The bearing manufacturer recommended a change in the synthetic oil viscosity to a heavier E-type medium 2060 SUS/100°F and to pack a compatible grease (Mobilitol SHC 460) around the bearing during installation. The purpose of the grease was to supplement, by osmosis, any oil that might escape from the synthetic pack. In addition, it would also prevent a loss of permanent lubricant oil by filling the bearing capsule completely, thus eliminating a void that could serve as a drain for the permanent lubricant oil. The grease supplement would also provide lubrication on the shaft seal and help prevent contamination.

An analysis of 1987 data showed that the total number of crane wheel assembly failures increased slightly to 142 in comparison with the previous year and that the number of premature bearing failures, based on life-cycle charts, was a serious problem. Other information from bearing failure charts also confirmed the problem was almost entirely associated with the 24-in. dia crane wheel assembly. By the end of 1987 a total of 568 crane wheel assemblies had been reconditioned with the permanent lubricant feature.

Early in 1988, the decision was made to lubricate all permanent lubricant-type bearings in service on a one-time basis. This action took eight to nine months to complete and by the end of 1988, the rate of failure appeared to have decreased.

No permanent lubricated bearings which were greased when installed have failed. During 1988, permanent lubricant bearings were in service on the average of 20 months before failure. 1989 results are promising since a 30% reduction in the number of permanent lubricant bearing failures has been realized.

**Axle breakage**

With the significant reduction in flange failures achieved in 1983, and with bearing failures being brought under control at the end of 1988, axle breakage was selected as the next area for improvement. Although the number of failures from this cause is not large (approximately 7%), there can be substantial costs associated with damage to the bridge truck or end carriage when an axle fracture occurs. Repairs can be time consuming and, on critical cranes, responsible for production delays. For example, the cost of repairing one slab-yard crane was estimated at $10,000. In early 1987, data for the past three years of axle breakage were reviewed and personnel provided with basic knowledge of visual fracture analysis. Every axle break in 1987 was closely examined and, in every case, it was found to have been initiated by a keyway which had a sharp corner in the bottom radius. The standard for machining all shafting was immediately revised and reissued.

As a long-term corrective action, it was decided to eliminate the key for the crane wheel. An FN3 interference fit with a shrink-on procedure for the wheel was adopted.

Currently, the axle keyway radius in each reconditioned wheel assembly is examined and the axle replaced if a radius is absent from the keyway. In 1988, the second year of the focus on axle features, only seven failures occurred (a record low).

**Spalled wheels**

The single most important factor in the life of overhead crane wheels is reported to be their ability to withstand pit-
ting and spalling that often results from extremely high contact stresses. Test results, confirmed at Burns Harbor, have demonstrated that case hardened wheels with a hardness of 60 to 63 Rc are superior to lower hardness crane wheels.

At Burns Harbor, more than 3700 replacement crane wheels have been purchased in the 25-year history of the plant. The majority were carburized, usually to 50 to 53 Rc. In the past seven years, of the 947 crane wheel assemblies replaced nearly 10% were due to spalled treads. There were also many other assemblies replaced for other problems which showed spalled tread. It is suspected that spalled tread is a major contributing factor to bearing failures, a relationship has been substantiated by studies in the railroad industry.

In Feb. 1980, two adjacent shipping cranes in the 160-in. plate mill were each equipped with eight new crane wheels. Both sets were specified to a new hardness value of 60 to 63 Rc on the tread which, subsequently, became the plant standard.

To facilitate evaluation of crane wheels, a color coding system was placed in operation which involved painting the entire wheel. The color identified the manufacturer, case hardening method and other characteristics of the particular wheel assembly. The results of a plant evaluation program, conducted from in-service running tests, do not rank a carburized wheel as the most durable wheel available. Several brands of carburized wheels have been tested with similar results. Wheels and rails form conjugate surfaces that should be viewed as a system. For example, many tests were performed during times when crane runway rail joints have been in a deteriorated condition which is not unusual in the steel industry. This condition represents the severest duty a crane wheel (and crane) can experience and represents one of the factors that must be considered in measuring performance of carburized wheels.

Crane wheels with proven spall resistance are commercially available and are being evaluated at the Burns Harbor plant.

**Out of round tread wear**

Wheels with out of round tread wear (flat spots) have usually been found during investigations into the cause of severe crane cab vibrations. An out of round wheel creates abnormal external dynamic loading which has the same harmonic resonance frequency as the crane cab and can contribute to exceptionally high vibrations in the cab.

These flat spots develop slowly over a long period of time and are not the result of skids. Often, these problem wheels have been in service for four to six years before the problem develops. A casual visual inspection will not usually reveal the problem. The tread surface generally has the same texture and finish in the flat spot as the rest of the tread. Tell-tale signs of the condition are recognizable with experience. The wearing edge of the tread does not remain parallel with the flange, and has a noticeable wave profile. Sometimes the flat spots can be felt by hand.

Heat treating of the wheel is considered to be a possible cause of out of round tread wear. This problem has led to the use of initial wheel acceptance/testing criteria. Hardness checks at five positions across the tread at each of the four quadrants of the wheel (20 test positions total) are normally made as a standard procedure at the Burns Harbor plant with consistency expected in the 60 to 63 Rc range. This problem has been found only on carburized wheels.

**Summary**

Implementing controlled changes and measuring the success through a continuous failure analysis program have resulted in an improved crane wheel assembly and crane maintenance program at the Burns Harbor plant.

Solutions to the following problems have resulted in significant reductions in crane wheel assembly replacement:

- Worn flanges.
- Bearing failures.
- Lubrication.
- Axle breakage.
- Spalled wheels.
- Out of round wheel tread wear.

Substantial savings in maintenance costs have been achieved.

**REFERENCES**


**UE&C Units receive contracts from I/N Kote**

United Engineers & Constructors International, a Raytheon Co., announced that two of its subsidiaries have finalized contracts for the engineering and construction of a $500 million galvanized steel coating facility near South Bend, Ind.

The subsidiaries, United Engineers & Constructors Inc. and UE&C Catalytic Inc., are providing engineering and construction, respectively, to I/N Kote — a joint venture of Inland Steel Co. and Nippon Steel Corp. — for the new coating facility, which will produce corrosion resistant sheet steel for the automotive and appliance industries.

The facility, due to be completed at the end of 1991, is adjacent to the continuous cold rolling mill where UE&C provided engineering and construction management for the I/N TEK joint venture owned by the same partners.

Engineering and construction already are well underway on the facility's 500,000 ton/year hot-dip galvanizing line and the 400,000 ton/year electrogalvanizing line that complement the adjacent cold rolling mill, which began commercial operation in March 1990.