THE INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERS

INCORPORATED

29TH CEMENT INDUSTRY TECHNICAL CONFERENCE

SAN FRANCISCO, CALIFORNIA

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FOREWORD

THE TWENTY-NINTH IEEE CEMENT INDUSTRY TECHNICAL CONFERENCE

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SAN FRANCISCO HILTON & TOWER
SAN FRANCISCO, CALIFORNIA, U.S.A.

Sponsored by
The Industry Applications Society's
Cement Industry Committee
of the
Institute of Electrical and Electronics Engineers, Inc.

The 1987 IEEE Cement Industry Technical Conference completes 29 years of this activity. Only the dedication and perseverance of Cement Industry Committee Members and of the Annual Program Committee Members enable us to continue to present these annual affairs with the professionalism that exists. To those people who participated in these various activities, we give our thanks and gratitude.

The Technical Papers contained in this Conference Record have been prepared using guidelines from the *"Authors Guide"* of the Industry Applications Society (IAS) modified by the Cement Industry Committee. We feel confident that these papers will add to your knowledge concerning the various subject matters and, in turn, this knowledge will enable you to discharge the job responsibilities assigned to you with increased efficiency and confidence.

Thanks to all of you for attending our conference. We hope that the papers and activities will enhance your knowledge while entertaining you in our lovely San Francisco.

RONALD F. PALMER
National Committee Chairman

C. "DAVID" MAARS
Conference Chairman

1987 IEEE CEMENT INDUSTRY TECHNICAL CONFERENCE

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GENERAL PRACTICES

DUAL DRIVE PROBLEMS
Kilns and Mills

Richard A. Thompson, VP - Chief Electrical Engineer
Penta Engineering Corp, St. Louis, Missouri

ABSTRACT

Oscillations exist between any drive and its load. Dual drives sometimes severely aggravate these conditions. This will increase wear rates of the gearing and sometimes destroys some part of the drive system in a short time. Gear tooth distress and some cases of broken jack shafts and coupling bolts have been reported. Sometimes, these oscillations are of such low magnitude that they are not recognized for several years. It is believed that some are never recognized. They are viewed as ordinary maintenance problems because there is no noticeable vibration.

This paper discusses application, lists reports on several dual drive gear problems and discusses solutions.

INTRODUCTION

"In the beginning" there were wooden gears with oxen or water wheels as the motive force.

When man got around to rotary kilns and mills, the speeds and horsepower were much lower than those used today. Therefore, the exciting forces, which can bring about oscillations, were of small magnitude.

As horsepower and speed requirements increased, gear tooth stress became a limiting factor as did lubrication. Dual drives were an answer because stresses were halved.

Any time two masses are connected through shafts and gears there are several "critical" speeds where these masses oscillate and some parts of the drive system take a beating. There are 3 situations.

1. No problems. The drive runs well from day one.
2. Early problems indicated by abnormal tooth wear and/or vibrations.
3. Troubles as in 2 but occuring several years after start-up.

BIAS vs OBJECTIVITY

The driving force behind this paper was the impression that dual drives were much more prone to troubles then were single drives. The thrust was to see if that was true without being biased to the degree that precluded objectivity.

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STATISTICAL BASIS

Inquires were made of the Cement Industry. Over 200 inquires were mailed to corporate and plant personnel. This encompassed 114 domestic plants. Plants having a total of 33 dual drives responded. Of these, 16 drives have reported problems. That is 45% of the total drives reported. It seems doubtful that 45% of all dual drives in our industry have experienced difficulties.

There are cases where past troubles are not known to the plant personnel because those that lived with the problems are no longer there and the current people have no knowledge of past happenings.

It is believed that this sample is not representative. The plants that had troubles certainly reported while many without problems likely did not.

The only conclusion reached, based upon the statistics, is that the true picture is not known at this time. Without additional investigation, including single drives, no reasonable conclusion can be drawn concerning the relative merits of single vs dual drives.

DISCUSSION

Present day designs can handle over 6000 HP on a single pinion or trunion. Therefore, dual mill drives are needed only for very large mill drives or some special situation. Pinion sizes are more limited for kilns because speeds are lower. Therefore, horsepower per shaft is likewise limited by virtue of tooth stress. This results is many more duals for kilns than mills.

When drive troubles occur a vibrational analysis is often performed at great cost. These analyses typically show several problem frequencies with some one frequency being especially damaging. The end recommendation is usually to install energy absorbing couplings. This is done and the problem usually disappears.

QUESTION! Since there will always be some portion of dual drives which experience difficulties, why not install those couplings initially? Certainly some installations do not need them but the cost of retrofit, including all the grief with worn gearing, broken shafts, replacement and down time, may be much too high to gamble on.

A 4000hp, 200rpm coupling for a mill will cost about $20,000 per shaft. Couplings for 400 hp kiln pinion shafts will cost about $10,000 each. If located on the higher speed kiln drive motor shaft, the cost is about $5,000.

Consider only the cost of lost production. At a rate of 125 tons/hr, the lost profit from a 1 day loss of production is at least $60,000. Assuming a minimum of 2 days down time to retrofit couplings for a mill, an investment of $40,000 additional to the mill cost saves $120,000 lost profit. This is a 3 to 1 return - if troubles had occured.

Because the kiln drive application of energy absorbing couplings costs only $10,000, a return of 12 to 1 is possible - once again, if trouble occurs.

Energy absorbing couplings are certainly not an answer for incorrectly designed piers, foundations or improperly installed drive systems.

TYPES OF MOTORS

Any two interconnected rotating masses will oscillate at some frequency. Oscillations can occur during both starting and running. The type of drive systems can have a great effect upon those exciting forces and resulting oscillations.

Starting:

Any induction motor - squirrel cage or wound rotor - produces an essentially non-pulsating torque during acceleration. The same is true of dc motors. When the dc motor is being driven by an SCR package, the starting voltage wave form is anything but smooth. However, the frequency of these pulses is 6 times line frequency for a typical six pulse converter. The rotating system typically does not resonate at these higher frequencies.

During starting, synchronous motors produce a pulsating torque at a frequency equal to twice slip frequency. Thus at the start, a 120 hz. sine wave shaped torque is impressed on the system. The frequency decreases as the system accelerates and reaches zero when the motor is synchronized. There is no slip when synchronized and therefore no pulsations at operating speed.

It is well established that this varying torque can and does become negative at times during acceleration. This means the gearing is actually unloaded momentarilly at some varying frequency. The results of this are much higher torques during the rest of the cycle. This can produce severe stress in the drive train. This type of gear overloading may take years to become apparent.

It is recommended to have a dry clutch rather than a direct connected synchronous motor mill drive. The clutch permits starting the motor without equipment rotation. After the motor is synchronized, the clutch is engaged and mill acceleration is accomplished against pull-out torque of the motor. CAUTION: The gearing can be damaged by establishing too rapid an acceleration. The greater the rate of acceleration, the greater the stress on the gear teeth.

A clutch becomes a necessity where the power system is not sufficiently stiff to permit across-the-line starting of the motor. An improvement of about 1/2% in efficiency is an added feature of the clutch. The clutch doesn't create this efficiency windfall but permits it to happen by change in design of the motor.

A clutch eliminates torque pulsations generated during starting of a synchronous motor.

The problems of load sharing between dual drives is treated later.

Running:

Under running conditions, the induction and dc motors produce no significant oscillatory forces due to their own torque characteristics. They respond to any change in torque requirements by a slight change in speed. No oscillating excitation is generated by this action. The motor assumes the needed speed after slowing or speeding slightly to arrive at the point where torque required equals torque produced.

The synchronous motor, however, can create an oscillating excitation of the drive system when the load changes. The synchronous motor responds to load changes by a change in rotor position relative to the rotating magnetic field produced by the stator. This shift in relative rotor position results in pole restoring torques being created. These torques accelerate or decelerate the rotor until it settles in a position yielding a torque equal to the load.

These pole restoring torques can be visuallized as rubber bands connecting the rotating magnetic field and the rotor. Each time torque needs change, the rotor position changes and always over-shoots the proper location. The "rubber bands" will slow or accelerate the rotor in response to the degree of overshoot. Therefore, each change in torque generates oscillating forces which the gears, shafts and other components must withstand. Considering that the instantaneous torque requirements are constantly changing in a mill, the synchronous motor is always generating some oscillatory torques of various magnitudes.

When dual drives are involved, there is an additional rotating mass system consisting of the second motor, shafts and gearing. This can and does interact with the other drive. Thus, the twin synchronous motor drive adds its own nasty characteristic oscillation forces to the system.

Load sharing between induction motors is inherent in their design. Dc motors of proper design inherently share loads but usually not as well as induction motors. Control system proportional band and reset adjustments usually solve any unbalance problems for dc drives.

Load sharing is an additional problem, or at least complication, for synchronous motors. Load sharing can be accomplished by shifting the rotor of one machine with respect to the other. A vernier coupling permits slight shifting of the rotor shaft with respect to the pinion shaft. The balance of load between the drive motors will change as gears and bearings wear. A vernier coupling can only be shifted after the drive has been stopped.

Another method is to shift or rotate the stator of the motor. This can be done manually or automatically while the drives are operating.

Load sharing can also be effected by interconnecting stator windings or electronically controlling field excitation of the synchronous motors. This method does not require stopping the drives.

Another automatic system uses clutches for both motors. When the control system detects loading differences between motors of about 7-10%, air is vented from both clutches and quickly reapplied. The controls stagger reapplication of the air so that one clutch fully engages slightly after the other. This yields a different relative position for the rotors and therefore a different share of the load.

Kiln drives have traditionally been dc. First with motor-generator sets and then SCR's. The SCR systems can be made to oscillate by virtue of the gain of the control system. These problems are usually easily solved by tranquillizing the drive controls. Increasing proportional band(reducing gain) and/or reducing reset(integration) rates of the speed controller will usually solve this. As with mill drives, the kiln drive problems require analysis if speed controller adjustments do not stop oscillations.. A common solution is an energy absorbing coupling.

COMMENTS

It seems that every couple of years, there is another Cement Conference Paper concerning vibration, torsional analysis, abnormal gear wear or broken parts. It appears that the industry is gradually becoming aware of a problem that has existed for years but seldom been correctly diagnosed.

It is relatively common for a cement producer to supply the electrics for a major project. When the owner specs a mill without drive motor, a mill vendor will sometimes quote a dual drive because it is less expensive from the mechanical standpoint. However, when motor and controller costs are added, the single drive usually costs less and will be less expensive to operate and maintain. Energy usage as well as maintenance costs are reduced. A comment from two plants was "double drive - double trouble." It is suggested that anytime a dual drive is proposed by a vendor, the customer question that selection by getting an alternative quote for a single drive. Add motor and controller costs. Then compare. Also look at guaranteed efficiencies. A 1/2% increase of efficiency at 4000hp and $.05/kWH(which is below national average), operating 7000 hrs. will save $5300/ year.

SPECIFIC REPORTS

Plant	Application	No of Units	Type of Motor	Problem
A	Kiln	1	Dc	5 years of vibration, broken coupling bolts 2 times
B	Kiln	3	Dc	High rate of reducer failure, broken gear spring mounting plates, still have problems even with larger reducers
C	Kiln	1	Dc	Severe oscillation beginning at start-up. Energy absorbing coupling solved the problem
D	Kiln	1	Sq. Cg.	Broken jack shafts, annual overhaul of motor and eddy current coupling. Fine tuned speed controllers. No more trouble.
E	Kiln	1	Dc	Double maintenance - double trouble.
F	Mills	4	Syn	Gear wear and apparent shift of motor stator on 1 mill. Gears strengthened - problem solved.
G	Kiln	1	Dc	After 3-4 years, oscillations cause gear wear. Pier stiffened. Trouble apparently cured.
H	Mills	3	Syn	Gear and pinion failures. Hardened gears installed, problem appears solved.
I	Kilns	2		Gearpitting, spalling & craking. Energy absorbing couplings solved problem

RETROSPECT

This survey was begun from the bias that dual drives are significantly more trouble than singles. During preparation of this paper, information gained indicates a number of single drive problems of the same type. It is believed our industry would be well served by a similar review of ALL drives. The information gained and presented herein does not truly answer the question "Is a single or a dual drive a significantly better choice?"

SUMMARY

There are certainly places where dual drives must be used. Where horsepower is high and speed is low, the low torque capabilities of small pinions requires dual drives. The most common is kiln drives because of small pinion size. This means relatively low torque limits so duals become a must in many cases.

With the evidence mounting of drive oscillation troubles - whether single and dual drives - it behooves the owner to insist upon either:

1. Energy absorbing couplings from the start, or
2. An analysis during initial running whether vibration is obvious or not. Then act appropriately.

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