

BEARING FAULT DETECTION IN INDUCTION MOTORS USING VIBRATION ANALYSIS FOR CONDITION MONITORING

T. G. Habetler And L. Ran

Department of Electrical Engineering, Sanjivani College of Engineering, Kopergaon Maharashtra INDIA

Department of Electrical Engineering, Zeal College of Engineering & Research, Pune INDIA

Abstract: Electric motors are essential machinery used in various industries. However, these motors can fail and breakdown due to various factors, such as oil usage, motor ventilation, layout, and electrical considerations, causing critical levels of temperature and vibrations. Condition-based maintenance (CBM) or predictive maintenance (PdM) is essential to monitor and maintain the motors and, therefore, prevent failures or breakdowns. Vibration analysis techniques can be used in CBM, and this paper focuses on the vibration analysis technique to detect faults in induction motors. The paper examines the sources of vibrations in induction motors and highlights typical faults that can be detected, including imbalance, misalignment, bearings, and electrical issues. The authors propose vibration monitoring as a preventive maintenance solution to improve the performance and reliability of induction motors. The paper concludes with a case study on bearing analysis, where the fault was caused by excessive stress on the bearing. The authors suggest appropriate measures to prevent bearing faults and, therefore, prevent motor breakdowns.

Keywords: Electric Motors, Condition-Based Maintenance, Predictive Maintenance, Vibration Analysis, Induction Motors, Fault Detection, Preventive Maintenance, Bearing Analysis.

1. Introduction

Ventures of this high-level period are overwhelmingly worried about quality and measure of creation throughout some undefined time frame. Essentially every industry has joined the usage of motor to achieve its functional necessities. Acceptance motors are the most well-known AC motors in use today. AC motors are preferred over DC motors because they only require a single force source, whereas DC machines require separate sources for the rotor and stator. Aside from that, there are a number of other aspects that make enlistment motors suitable for modern use in general.

Furthermore, motors are important machinery that can break down at any time. Motor failure can be caused by a variety of factors, including the amount of oil used, electrical considerations, motor ventilation, layouts, and motor load. As a result of these circumstances, motor temperatures and vibrations reach critical levels. The best maintenance practices include condition-based maintenance (CBM) or predictive maintenance (PdM). This is finished by checking the state of the machine consistently or periodically contingent on the requirement for availability of motor or generator. The support is begun when pointers give the sign of issues in the early phases. In fundamental words, the essential premise is to keep up the hardware at the ideal time. The practice of CBM is done by acquiring and inspecting the steady data, with the goal that upkeep activities and assets can be focused on/upgraded accordingly.

A multi-variable brilliant sensor is introduced and ready to assemble, approve, and locally measure information on both temperatures furthermore, tri-hub vibration, as a feature of an instrumentation framework which, coordinating little, brilliant, and profoundly installed 'field' gadgets in enormous numbers, may address the information necessities set by new modern Predictive Maintenance measures applied to modern Induction motors. Machine condition monitoring and fault diagnostics might be characterized as the field of specialized action where chosen actual boundaries, related with hardware activity, are noticed to decide apparatus uprightness. Vibration investigation of electrical machines is included two kinds of data: 1) vibration condition, which is typically assessed concerning extraordinary guidelines or details 2) information examination, which takes into consideration diagnosing of mechanical & electromagnetic issues in apparatus, however, these are not generally connected with extreme machine vibration. During the time spent vibration investigation, the first of these undertakings is called fault detection and the subsequent one is fault conclusion. Fault detection is the point at which an estimation boundary surpasses a typical working reach. Fault conclusion is frequently connected with condition monitoring, and spotlights on explicit changes and side effects to decide a reason, seriousness, and remedial activity. Many strong sign handling procedures can be applied to vibration signals to separate even extremely feeble fault signs from commotion and other concealing signs.

2. Vibrations monitoring technique

The vibrations analysis technique becomes analogous with conditional monitoring & maintenance. This strategy relies upon the instrumentation directly from the start. Vibration investigation is material to all mechanical gear, albeit a typical yet invalid supposition that will be that it is restricted to basic pivoting apparatus with running paces over 600 cycles each moment (rpm)."

Machine Trains	Centrifugal	Continuous Process
Hobbing Machines	Fans	Hot and cold strip lines
Cylinders	Blowers	Annealing lines
Compressors	Chillers	Printing
Pumps	Turbines	Dyeing and finishing
Metal working machines	Generators	Production lines
Boring machines	Gear boxes	Continuous process lines
Gasoline Engines	Centrifuges	Roofing manufacturing
Diesel Engines	Rotary cranes	Pickle lines
Other Machines	Motors	Paper machines
Temper mills	Pumps	Continuous casters

Fig.1 Applications of Vibrations Analysis

Figure 1 shows various uses of vibration analysis under the grouping of machine trains, centrifugal and continuous process. Vibration examination is a cycle for estimating the vibration levels and frequencies of machinery and afterward utilizing that data to break down how healthy the machines and their parts are. While the internal operations and formulas used to work out different types of vibration can get convoluted, everything begins with utilizing an accelerometer to quantify vibration. Whenever a piece of machinery is running, it is making vibrations. An accelerometer appended to the machine creates a voltage signal that compares to how much vibration and the frequency of vibration the machine is delivering, as a rule how frequently each second or minute the vibration happens. All information gathered from the accelerometer goes straightforwardly into an information authority, which records the sign as either amplitude versus time, amplitude versus frequency (Fourier change), or both. Each of this information is analyzed by PC program.

3. Sources of Vibration in Induction Motors

Every moving piece of mechanical equipment generates a vibration profile, or signature, that reflects its current state of operation. This is true regardless of the action's speed or whether it is executed in a revolution,

a reaction, or a straight line. The vibration of mechanical origin: Rotor unevenness, shaft bowing and misalignment, and deviations in the activity of direction, as well as conditions of couplings, pulleys, belts, and other pivoting mechanical pieces of the framework, are the primary sources of mechanical beginning vibration in turning machines, including acceptance motors. There are two significant sources of electromagnetic vibration in induction motors: radial and tangential electromagnetic forces. In any case, because of inner engine deficiencies or outer issues, for example, low power supply quality and kind of burden, electromagnetic vibration may make significant issues to a typical engine's activity.

A classical theory of electromagnetic vibration mathematically describes radial electromagnetic forces as a force-wave expression $p(\alpha,t) = P(r,\omega) \cos(r\alpha - \omega t - \psi p)$ (1) where $P(r,\omega)$ - The force-wave amplitude; r - The force-wave order (mode); ω - The force-wave angular frequency; ψp - The phase angle; α - An angular coordinate; t - Time.

The amplitude, frequency, and order of a force wave are all factors to consider (mode). The number of full waves circulated along the stator center outline determines the sequence of the force wave. The occasional force part is superimposed on the steady force part and causes force beat. Along these lines, force beat achieves appalling pace heartbeat, commotion, and vibration.

A harmonic (periodic) component of electromagnetic torque is defined as:

$$T(t) = T(\Omega) \cos(\Omega t - \psi \tau) \quad (2)$$

where $T(\Omega)$ - The harmonic torque component amplitude; Ω - The angular frequency; $\psi \tau$ - The phase angle

4. Vibration measurement points

"Where to put the vibration sensor" and "how to place vibration sensor", in an electrical motor, is one of the questions that arise while placing the sensor on the motor. The measurement points for vibrations should compare to the centerline of the shaft, on the bearing housing. Guarantee a steady mounting on a strong part. At whatever point conceivable, taking measurements in the horizontal (H), vertical (V), and axial (A) direction of each bearing has to be done shown in fig 2.

In the final position without transmission, it will generally not be possible to place the sensor on the center line because the defensive front of the fan hinders it, so it is recommended to get as close as possible to the landing. Surveillance points should be checked and information on similar areas is constantly being collected.

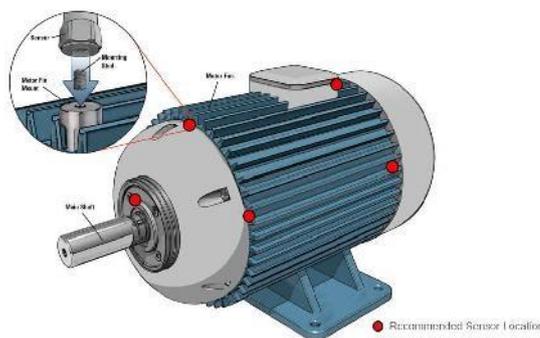
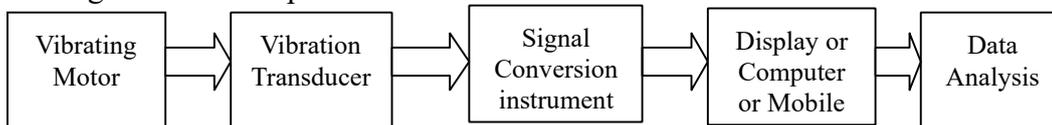


Fig.2 Basic vibration measurement. (Source: electricaltechnology.org)

Figure 2 shows the essential highlights of a vibration estimation plot. In this figure, the movement (or dynamic power) of the vibrating body is changed over into an electrical sign by the vibration transducer or pickup. As a general rule, a transducer is a gadget that changes in mechanical amounts like dislodging, speed, speed increase, or power into changes in electrical amounts (like voltage or flow). Since the result sign, for example, voltage or current of a transducer is too little to possibly be recorded straightforwardly, a sign change instrument is utilized to intensify the sign to the necessary worth. The result from the sign change instrument

can be introduced on a showcase unit for visual review, or recorded by a recording unit, or put away in a PC for some time in the future. The information can then be dissected to decide the ideal vibration attributes of the machine or design.

Contingent upon the amount estimated, a vibration estimating instrument is known as a vibrometer, a speed meter, an accelerometer, a stage meter, or a recurrence meter. Assuming the instrument is intended to record the deliberate amount, then, at that point, the addition meter is to be supplanted by Fig.2. In some application, we really want to vibrate a machine or design to track down its reverberation qualities. For this, electrodynamic vibrators, electrohydraulic vibrators, and sign generators (oscillators) are utilized. Vibrating machine or design Vibration transducer or pickup Signal transformation instrument Display unit, recorder, or PC Data investigation FIGURE 10.1 Basic vibration estimation conspire **5. Typical failures in induction motor detectable by vibration analysis**

5.1 Imbalance

The nature of rotor imbalances is a fundamental mechanical problem in induction motors. These flaws may also create speed motions that affect the stator current, resulting in additional undesirable symphonious force and force segments at certain frequencies in the spectrum. Below Figure 3 shows three phase induction motor on which actual sensor based portable equipment is fitted to collect the required data.



Fig.3. Sensor installed for condition monitoring on induction motor

In the induction motor, an irregularity is usually due to one of the accompanying causes:

- Incorrect technique changes in the workshop.
- Incorrect warranty to change the quality assessment. □ Use of a keyway except specificity.
- Try to ignore the keyway when adjusting workshop.
- Cooling fan wear or breakage.
- Coupling wear or breakage.
- Breakage or incorrect mounting of the cooling fan.

When diagnosing an awkwardness in an induction motor, the accompanying activities might be suggested:

- Review the activity and support history to see when the issue happened and the working history This will assist with dissecting the reason.
- Audit the techniques and the degree of nature of the asset report of the application.
- Check the coupling and the cooling fan, check the trustworthiness and condition.
- Play out a run-out test to identify any twisting of the rotor.
- Check the balancer alignment.
- Perform exactness adjusting relying upon the application, criticality and properties of the engine.

5.2 Misalignment

Misalignment is the second normal mechanical issue in the acceptance machine in the wake of unbalancing. Misalignment might be either because of two classes specifically: equal, and precise or the presence of a blend of both. It is liable for the determined disappointment more often than not.

For induction motor, misalignment is typically brought about by one of the accompanying causes:

- Incorrect arrangement system.
- Lacking computation of arrangement norms or resilience.
- Warm extension.

- Shortcoming or lacking help base.
- Delicate foot or looped engine base.
- Coupling disappointment, exorbitant runout or harm.

In the event that an induction motor is discovered to be skewed, the accompanying can be suggested:

- Assess methods and faculty preparing.
- Make an exactness arrangement utilizing the proper principles.
- Measure and right the faltering foot.
- Survey the state of the base and docking.
- Assess the impact of warm extension and consider it while adjusting.

5.3 Bearing issues

Direction is the most fundamental component in any sort of turning apparatus. The strength of a machine relies upon the heartiness and unwavering quality of the course. Deficiency in bearing winds up in disappointment and breakdown in a really pivoting machine that isn't efficient.

With induction motors, bearing issues are ordinarily because of one of the accompanying causes:

- Bad assembly, extreme preload or bearing lodging wear.
- Mistakes in the grease cycle, overabundance or inadequate oil.
- The grease is of low quality or contrary with the application.
- Sullied grease.
- Inordinate vibration during activity. □ Ground wiring flaw.

In the event that bearing issues are identified in an induction motor, the accompanying measures can be suggested: □ Analyze the harm attributes: consumption, disintegration, wear.

- Assess the bearing get together interaction.
- Check equilibrium and arrangement.
- Check the right bearing choice.
- Check the measurements and resilience for mounting on the lodging and rotor. □ Upgrade the oil interaction.

5.4 Electrical issues

Turn to turn faults, phase to phase short circuit faults, coil to coil short circuit faults, an open circuit of stator windings, and a lack of insulation are all common electrical issues found in induction motors.

With induction motor, electrical issues are typically brought about by the accompanying causes: □ Non uniform air hole among rotor and stator.

- Free or broken rotor stem.
- Low quality of the force supply: voltage lopsidedness, music.
- Issues of the recurrence converter.
- Over-burden.
- Over the top beginning and halting of the motor. □ Seclusion issues.

At the point when electrical issues are identified in an induction motor, the accompanying activities might be suggested dependent on the indications:

- Perform a force quality investigation.
- Do an air hole consider and assess the beginning (rotor/stator) □ Perform electrical tests on the engine (nature of protection).
- Assess the honesty of the associations in the rotor bars.

6. Case History

This was a 400kW, 50Hz variable speed control Induction Motor having a power factor of 0.78, rated. speed 992.0 rpm, rated current 728.00 A and rated voltage 415 V. On that motor, a smart sensor was mounted for conditional monitoring. This sensor was fitted on a mechanical mounting which was in between the fins of the motor. Graph measured with the help of a sensor during a standardized weekly survey (Figure 3).

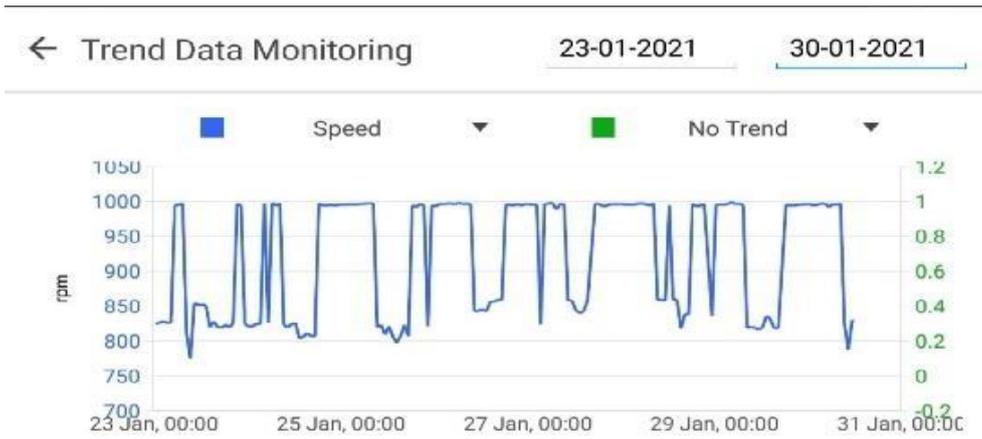


Fig.4 Graph representing Time Vs. Speed

Fig.4 is the graph which showing the speed and the trend of the motor. The graph measured does not contain any distortion or fluctuations so that there are no drastic changes in vibrations implies there are no faults with the motor.

The values we got are:

- Radial vibration: 1.035mm/s RMS
- Tangential Vibration: 1.073mm/s RMS
- Axial Vibration: 0.766mm/s RMS
- Motor supply frequency: 41 Hz
- Output power: 100.00 kW

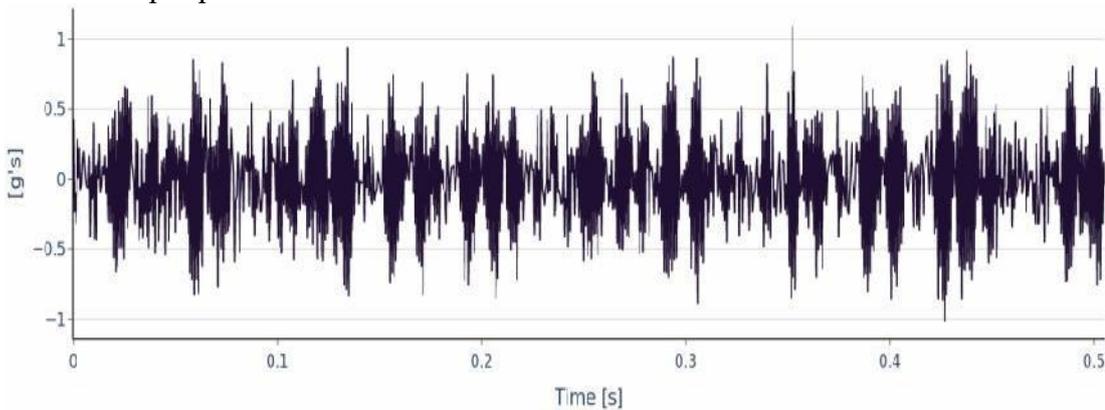


Fig.5 Vibration Acceleration Axial

The boundary limit for axial vibration rms value is set 0.766mm/s, but in the figure 5, it shows that at some point between 0.3 sec to 0.4 sec, there is large variation and it crosses boundary limit value is more than 1mm/s which indicates us that there is fault. The maximum values observed are marked in the table 1 below.

Table 1: Data for maximum values of vibration acceleration axial for operating motor

Statistical measure	Value
Kurtosis	2.393
Peak to peak	2.117 g's
Crest factor	2.821
Velocity RMS	1.035mm/s

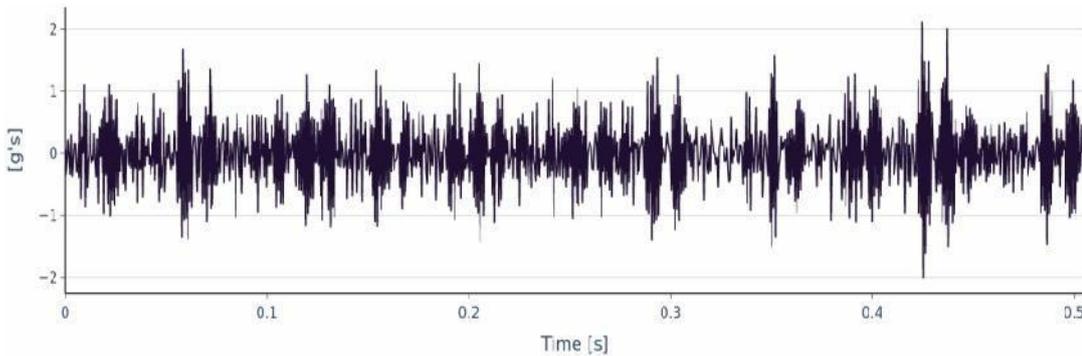


Fig.6 Vibration Acceleration Tangential

As far as possible for tangential vibration rms value is set 1.073mm/s, however in the figure 6, it shows that eventually between 0.05 sec to 0.45 sec, there is enormous variety and it crosses limit value which demonstrates us that there is shortcoming. The most extreme values noticed are set apart in the table 2 underneath.

Table 2: Data for maximum values of vibration acceleration Tangential for operating motor

Statistical measure	Value
Kurtosis	3.016
Peak to peak	4.133 g's
Crest factor	3.638
Velocity RMS	1.073mm/s

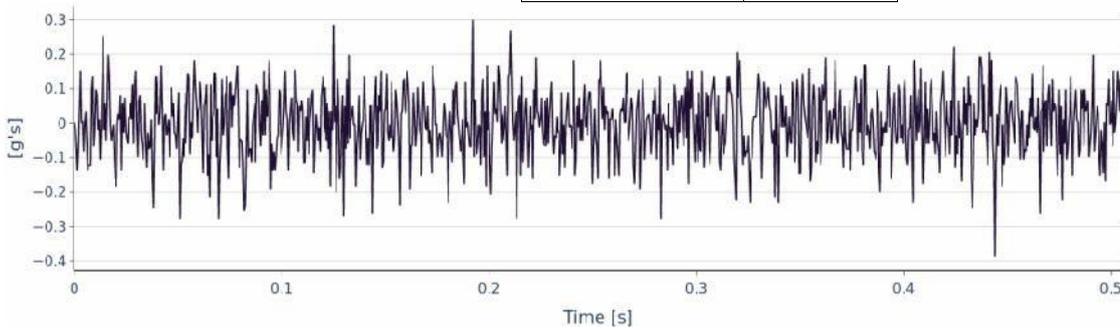


Fig.7 Vibration Acceleration Radial

Quite far for radial vibration rms value is set 1.035mm/s, but in the figure 7, it shows that overall, there is gigantic assortment and it within the prescribed limit which exhibits us that there is adequacy. The most outrageous values saw are separate in the table 3 under.

Table 3: Data for maximum values of vibration acceleration radial for operating motor

Statistical measure	Value
Kurtosis	3.164
Peak to peak	0.688 g's
Crest factor	4.098
Velocity RMS	0.766 mm/s

Figure 5 shows vibration acceleration axial, Figure 6 shows vibration acceleration tangential and Figure 7 shows vibration acceleration radial which is axial vibration, a kind of longitudinal shafting vibration which

occurs in the machine because of the radial as well as tangential forces. For counter acting on the longitudinal vibration of the ship, engine bracings are used. One end of the bracing is attached to the top part of the engine and the other to the ship's structure. This stiff connection dampens and transmits the engine's rocking vibration to the ship's hull.

6.1 Bearing analysis

After monitoring the condition of the motor by vibration technique and sensor, we notice that there is a bearing fault in the motor. As shown in Fig.8 we got a notification from the application we used to detect. So, to solve this issue we analyzed the bearing condition. With the help of the vibration analysis technique, this fault was detected. The display or dashboard we can observed bearing condition and every events logs can be monitor, as like shown in fig 8. The type of bearing used in this motor shown in figure 3 was ball bearing.

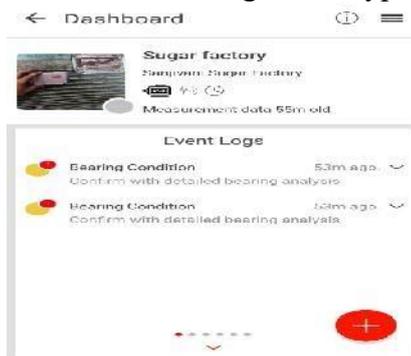


Fig.8 Fault Detection

By and large, under moving contact stacking conditions, the accompanying types of weakness breaks can be recognized:

- Surface breaks (pitting)— set off by surface imperfections or unpleasantness and the presence of miniature scores, through which further break development can be sped up by oil infiltration.
- Subsurface breaks (spalling)— brought about by the other shear focuses on, the presence of incorporations, and so on, which start breaks close the outer layer of rolling.
- Cracks began at profound deformities additionally showing up in the low-stress zone.

This motor is used in the sugar factory, during the time of peak periods the load on the motor is more than the rated load. This results in failure of bearing due to excessive stress on bearing and this fault is called Operational stress. Assuming less or more burden is applied then it will prompt be bearing weakness or slip). The proliferation of subsurface spalling is the fundamental type of weakness disappointment. Miniature breaks start beneath the surface (i.e., around incorporation, in high-stress volume, and so forth) and develop into the surface. In such a system, the break commencement and proliferation are brought about by shear impacts. High burdens and the helpless completing of contact surfaces lead to disappointment in a system of low-cycle exhaustion.

On account of metal balls, the connection between the span of the ball and the range of the raceway impacts the anxiety.

To prevent such bearing fault, we have to take appropriate precautions such as:

- To apply sufficient load on the motor (not excessive).
- To provide time to time lubrications to the bearing.
- Use electrical insulated bearing at non drive end.
- In case of prolonged period of standstill, turn the shaft time to time.
- To apply bearable load only.
- Time to time checking of lubrications.

7. Conclusion

The movement of this paper is the improvement of the engine's certifiable restrictive observing. With the help of a keen sensor, information recuperation and access have been made simple to utilize. Any issue with engine

disillusionment because of vibration can successfully be instructed to an unequivocal customer through the sensor. This paper adequately arranged and executed an adaptable engine condition checking framework using remote detecting which could diminish vacation for some businesses and assembling organizations. The remote restrictive observing framework is tried under different working conditions and it is found to work acceptably.

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