Operating Guidelines On Vibration Limits For Large T.G. Sets

INTRODUCTION

The health of large Steam and Gas turbine machinery is usually assessed by measured values of vibration amplitude, relative expansions, operating steam and metal temperatures, pressures and vacuum during startup, transient condition, loading and load changing. These parameters are considered to be the best and true representative of dynamic behavior of turbine machinery. Therefore, it is necessary to monitor their trend and try to keep them within predetermined values which are prescribed by the designers or manufacturers. However, most of the machines are running very close to or slightly higher than the recommended values but within the zone of just satisfactory and tolerable limits. Such behaviour is experienced even after overhauling / recommissioning after certain operation hours in machine life cycle. As it is imperature to run the machine to its optimum capacity under the prevailing environmental condition, it is desirable to formulate operating guidelines for running the machine upto the next overhaul. Determining when the machine vibration is excessive and warrants shutdown for repairs can be one of the most difficult tasks facing the vibration analyst and operation engineers. There is no "magic" or absolute vibration tolerance to signify imminent failure. Trend monitoring is practised to assess the machine health.

Efforts have been made to bring out Operating Guidelines on Vibration Limits for the present "codes and practices" followed by the designer, manufacturers and users for the safe permissible/tolerable limits of bearing and shaft vibration for turbine machinery based on experiences and international standards such as VDI-2056, 2059, BS 4675 and ISO 2372 for evaluating machine health. These guidelines will help in establishing operation and maintenance decisions such as machine shut down or further operation for limited period, under surveillance, without causing damage to the machine or sacrificing its performance.

One of the standard charts used for evaluating the vibration limit tolerances is given in fig (1)

The following plots of the vibration parameters are given in this figure:

i) Displacement in amplitude pk-pk in microns.

ii) Velocity amplitude in mm/sec pk and also in RMS

iii) Acceleration amplitude peak in g.

All of them verses the frequency range of 0 to 3800 revolution per minute. The standard chart was prepared in the assumption that the concend vibration is of the sine form.

The standards charts should be used as follows :

AA. For machinery of rotating speed below 1194 revolution per minute allowable displacement border should be applied (For velocity criteria in this low range will allow such exceeding displacements that low-revolution per minute machines will deteriorate rapidly)- Criteria based on international standards and our experience.

BB. For machinery of rotating speed higher than 1194 and upto 3800 revolution per minute allowable velocity borders should be applied-criteria based on international standard provided by VDI, ISO, BS and our experience.

CC. The following dynamic state definitions were stated and accepted.

VERY GOOD - new machines, just installed.

GOOD - desired to be achieved aftermath overhaul.

FAIR - acceptable after-math overhaul.

USABLE - normal operation.

STILL ACCEPTABLE - Improvement recommended, operational restrictions (rated output, temperature etc.) recommended, operation up to fortnight period for typical machines.

JUST TOLERABLE - Fast improvement recommended, normal operation forbidden up to one day allowance. Any next start-up (for balancing, diagnostic purposes) is only possible provided a proper vibration monitoring is organised.

NOT PERMISSIBLE - Authorises to shutdown immediately. Any start trials are strictly prohibited unless the state of bearings, bearing pedestals, shaft journals, shaft-line and rotors is checked.

USE OF CHART

The example given here illustrates the various uses of standard chart as shown in Fig. 1 (in which X-axis represents machine r.p.m. and Y - axis represents vibration velocity in Peak or rms.) The diagonal lines show vibration displacement in Pk-Pk. while accerlation values are shown by dotted lines.

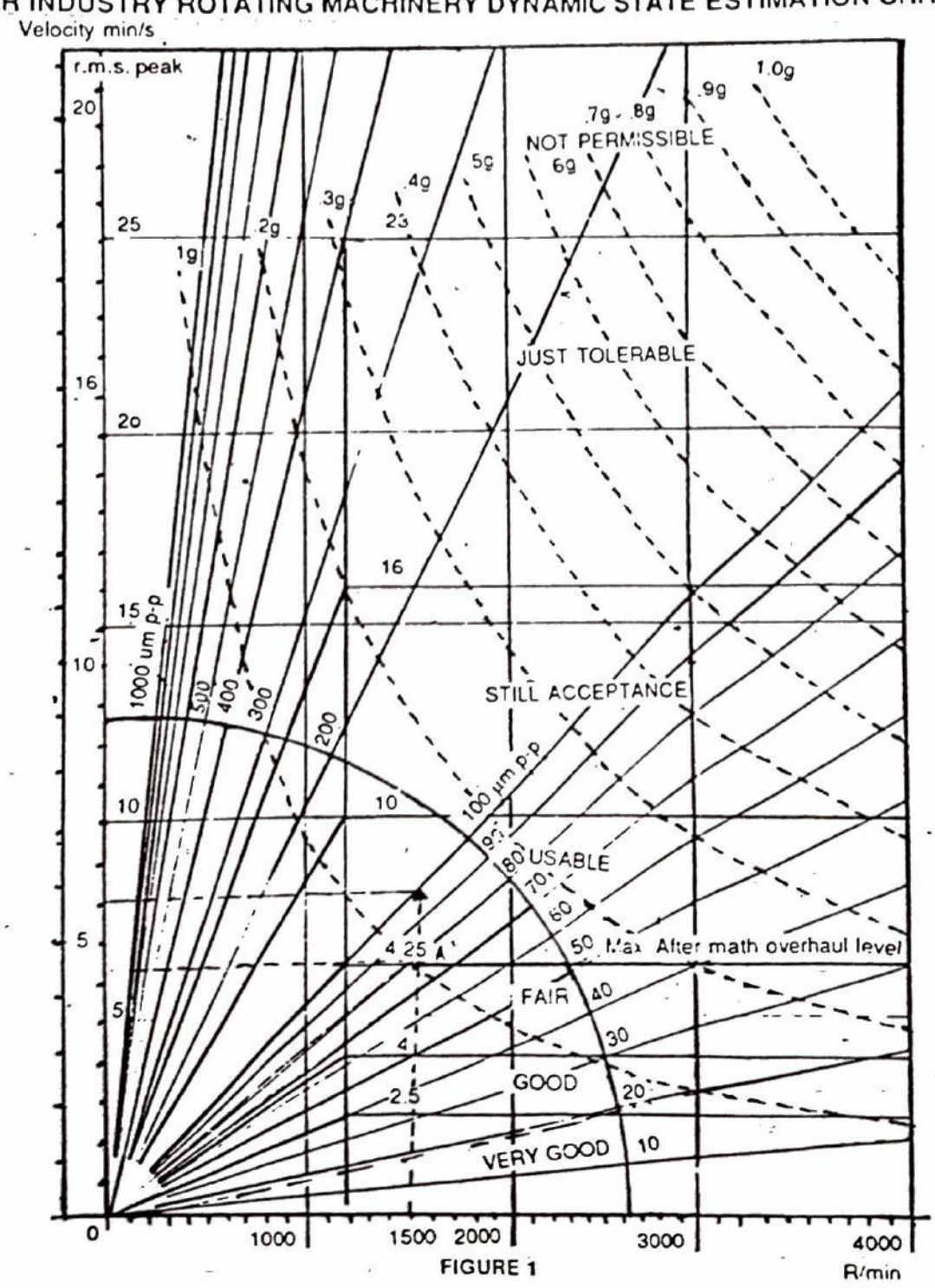

FIGURE 1

Suppose a machine which is running at 1500 rpm and its vibration levels recorded as 80 microns Pk-Pk and 8mm/sec Pk. Now to know whether the machine is in acceptable vibration limits or not, draw a vertical line at 1500 rpm which intersects diagnonal diaplacement line at point "A" of 80 microns. In this case inter-section point "A" is found to fall in usable zone which indicate that machine vibration is within the acceptable limits.

OPERATING GUIDELINES AND THEIR INTERPRETATION BASED ON EXPERIENCE AND STANDARDS VDI 2056/59. BS 4675, ISO 2372 FOR ASSESSING TURBINE & MACHINERY VIBRATION

Status	Point of Measure-ment	Direc-tion	Vibration Limits	GUIDELINES FOR		
				Operation Engineers	Predictive Maint. Engineers	Management HOD
VERY GOOD	Bearing pedestal Vibration	H V	Upto 18/2.5	New machine just installed is allowed to run to its max. capacity.	Record baseine vibration data and signatures for future refe-rence. Vibration monitoring to to be carried on monthly basis and also record steam temp. press, expansion at various loads and frequencies. Exception report should be submitted to HOD.	Exception report may be seen to assess the health of critical machine.
	Shaft Vibration	H V	30	Normal operation is to be done.	Transient changes in shaft vibra-tion have to be considered during analysis as these changes may be caused by deviated operational parameters.	Trend of shaft vibration may be seen to assess the health of machine.
GOOD	Bearing Vibration	H V	18/2.5 to 25/4	Machine is allowed to run at full capacity	Trend monitoring on monthly basis is to be carried out to establish the probable causes of rise in vibration level from reference status. Exception report to be submitted to HOD.	Exception report may be seen to know the probable causes of rise in vib. level from previous status.

Status	Point of Measurement	Direction	Vibration Limits	GUIDELINES FOR		
				Operation Engineers	Predictive Maint. Engineers	Management HOD
	Shaft Vibration	H V	40	Normal operation is to be done.	Transient changes in shaft vibration have to be considered during analysis as these changes may be caused by deviated operational parameters.	Trend of shaft vibration may be seen to assess the health of machine.
FAIR	Bearing Vibration	H V	25/4 to 40/6.3	Machine is allowed to run at its optimum capacity.	Machine is to be monitored at fortnightly interval to know vibration behavior and its predominant frequencies and prepare its trend report for understanding how fast it is rising and also establish whether they are load or speed dependent. Exception report to be submitted to HOD.	Exception report may be seen to know critical machines and its trend. "This levels of vibration can be acceptable aftermath overhaul. Effort has been made during overhauling that 'GOOD' limits can be achieved for increasing the lead time for next repairs."

Status	Point of Measure-ment	Direc-tion	Vibration Limits	GUIDELINES FOR		
				Operation Engineers	Predictive Maint. Engineers	Management HOD
	Shaft vibration	H V	50	Normal operation is to be done.	Transient changes in shaft vibration have to be considered during analysis as these changes may be caused by deviated operational parameters.	Trend of shaft vibration may be seen to assess the health of machine.
USA-BLE	Bearing pedestal	H V	40/6.3 to 65/10	Machine is allowed to run at full capacity	Establish the cause of rise in vibration level by signature analysis and highlight in the exception and trend reports. Monitoring is recommended at fortnightly interval. Efforts have to be made to identify whether these vibrations are periodic or transient in nature.	Exception report may be seen to know the probable causes. If suspected cause is oil whirl then bearing should be inspected immediately.
	Shaft Vibration	H V	60-70	Normal operation is allowed in case of Steam Turbine but in case of gas turbine shutdown may be planned. Any star-up trial is strictly prohibited unless the state of bearings, its pedestals, shaft line and journal is checked.	Transient changes in shaft vibration have to be considered during analysis as these changes may be caused by deviated operational parameters.	Trend of shaft vibration may be seen to assess the health of machine.

Status	Point of Measure-ment	Direc-tion	Vibration Limits	GUIDELINES FOR		
				Operation Engineers	Predictive Maint. Engineers	Management HOD
STILL ACCEP-TABLE	Bearing pedestal vibration	H V	65/10 & above	Machine is allowed to run at partial load	Rigorous monitoring is to be done closely at the interval of 8 hours to establish the probable causes and highlight in the exception report. Effects have to be mode to Confirm the cause of high vibration when M/c is running at Partial Load	Based on exception report refer matter to specialist and prepare plan for taking remedial actions. (operational restriction must be imposed till desired improvement is achieved. Reduced operation upto fortnightly period is allowed).
	Shaft Vibration	H V	Above 70	Reduced operation is allowed in case of stream turbine but in case of gas turbine shutdown may be planned immediately. Any start-up trials are strictly prohibited unless the state of bearings, its pedestals shaft line and journal is checked.	Transient changes in shaft vibration have to be considered during analysis as these change may be caused by deviated operational parameters.	Trend of shaft vibration may be seen to assess the health of machine.

Status	Point of Measurement	Direction	Vibration Limits	GUIDELINES FOR		
				Operation Engineers	Predictive Maint. Engineers	Management HOD
NOT PERMISSIBLE	Bearing pedestal vibration	H V	Above 100/15	Trip the machine Operational engineer should not allow to run the m/c after achieving this vibration level. No allowance is given for planning the shut down.	If operated under this condition should continuously be kept under strict surveillance by doing continuous monitoring for any untoward happening.	Shutdown the machine for inspection based on exception reports and also consult supplier or specialist
	Shaft vibration	H	Above 120	In case of steam and gas turbine shutdown should be taken immediately. Any start-up trials are strictly prohibited unless the state of bearings, its pedestals shaft journals, shaft-line and rotors is checked.		-do- -do-

Status	Point of Measure-ment	Direc-tion	Vibration Limits	GUIDELINES FOR		
				Operation Engineers	Predictive Maint. Engineers	Management HOD
JUST TOLE-RABLE	Bearing Vibration	H V	Below 100/15	Machine may not be allowed to run after achieving this level. Upto one day allowance may be given for for planning.	If operated under this alarming condition must be kept under strict surveillance by continuous monitoring for observing sudden changes in vibration levels.	Fast decision is to be taken based on exception report after consulting specialist or site. Immediate im-provement is required. (Upto one hour may be allowed to run at low/partial load to confirm and establish the cause of high vibration (diagnostic pur-pose).
	Shaft Vibration	H V	Equal & below 120	Reduced operation is allowed in case of steam turbine but in case of gas turbine shutdown may be planned immediately. Any start-up trails are strictly prohibited unless the state of bearings, its pedestals, shaft line and journal is checked.	Transient changes in shaft vibration have to be considered during analysis as these changes may be caused by deviated operational parameters.	Trend of shaft vibration may be seen to assess the health of machine.

DATUM MEASUREMENTS DURING RETURN-TO-SERVICE FROM MAJOR OUTAGES

Under certain circumstances it may be considered necessary to take datum measurements on plant during return-to-service, while the plant is still reaching its working temperatures. The existence of this data will enable detailed comparisons to be made between the new vibration response and that from a previous return-to-service. A detailed knowledge of any changes in response will often enable a precise diagnosis to be made swiftly on the basis of changes to the build state and known defects.

i) Vibration measurements should be taken during the run-up to speed, during an overspeed test and when unit is synchronized.

ii) Vibration should be logged during the loading pattern. This may be carried out continuously or intermittently, depending on the anticipated progress in loading.

It is extremely useful to have readings of overall levels (1/rev, 2/rev magnitude and phase) at 'no load', approximately 75 per cent and 100 per cent stabilized full load. If there is clear evidence of a generator 'thermal' effect, then additional interim load measurements should be advised.

iii) In addition, it may be considered beneficial to arrange for a hot run-down from full speed to approximately 300 rev/min and measure the vibration signatures throughout this range, at the earliest opportunity following a return-to-service and prior to the first natural 'hot-run-down'. The analysis of this reading then forms the as-built 'hot run-down' datum. Alternatively a warm (or cold) run-down could be obtained for base load plant, during the return-to-service.

In considering such datum measurements it is worth recognising the complex nature of the vibration response of rigidly coupled multi-rotor machines. The vibrations depend not only on residual defects in the mechanical build of the machine, but also on factors controlling its operation, e.g. steam conditions, electrical generation, and bearing oil supply conditions. In all cases, the vibration response is determined both by the dynamic exciting forces present and by the machine's response to these forces. The excitation forces that can arise from defects in the mechanical build including those due to residual unbalance and lack of straightness of individual rotors, together with any bends which result when the rotors are

coupled. The response to these excitation forces is considerably influenced by the dynamics of the journal bearings and depends on the bearing loadings which are a function of bearing alignment. The process of electrically loading the machine induces 'thermal' changes which modify both the dynamic excitation forces and the machine's response to these forces. The excitation forces are modified because of thermally induced bending of rotors (in particular the generator rotor). Relative movements of bearings during operation result in bearing load changes which, in turn, modify the response to a given unbalance.