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Steam Distribution Excitation between High & Medium Pressure Turbines.

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STEAM DISTRIBUTION EXCITATION BETWEEN HIGH & MEDIUM PRESSURE TURBINES

تأثير توزيع البخار بين تربينات الضغط العالى والمتوسط

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خلاصـــة :

إن التأثير الديناميكى الغازى المتبادل بيـن معـدل سـريان البخـار القـادم مـن تربينـة الضغـط العـالى ومعـدل توزيعه بين الاستنزاف ومعدل السريان الى تربينة الضغط المنخفض قد درس عمليا فى تربينـة صناعيـة ذو قدرة (٢١ ميجاوات).

إن البيانات قد أخذت من قياسات الزمن النسبى مع معدل تدفق البخـار فـى تربينـة الضغـط العـالى وتربينـة الضغـط المنخفـض ذو عضـو دوار واحـد. إن البيانات تحتـوى ايضـا علـى قيـاس السرعة اللحظيـة ومقـدار الاهتزازات ، هـذه البيانـات قـد أخذت بمحـول (تمـاثلى - رقمـى) بمعـدل تجميـع للقياسـات يصـل الـى ٧٠ كيلوهرتز.

وقد وجد أن اضطراب معدل سريان البخار يرفع معدل الاهتزاز بصورة مترنحة الى قيمة خطره. ممـا قـد يؤدى الى مجموعة اهتزازات متصاعدة على العضو الـدوار. هـذه الاهـتزازات فـى تحليلهـا مـع الـتردد تحقق اقصى قيمة لها عند التردد المساوى لسرعة الدوران.

إن افضل توزيع للبخار بين تربينات الضغط العالى والمنخفض قد تم توصيفها ورسمها كـدوال فـى سـرعة التربونة ومعدل الاهتزازات.

Abstract :

The aerodynamic interaction between the steam flow distribution coming from high pressure steam turbine to extraction and medium pressure steam turbine of a large scale axial turbine (21 MW) is experimentally studied. The data is concerned with the measurements of the time average and steam discharge of high pressure turbine and medium pressure turbine on one rotor. It also includes the measurements of instantaneous speed and vibration. These data were acquired with analog-digital converter accompained with acquisition rate of 70 KHz. It was seen that disturbed steam distribution, rise of vibration level with fluctuation range up to dangerous value. This may be due to a series of excitation on the rotor. This vibration peak appears on the vibration frequency spectrum at frequency equal to turbine speed. The optimum steam distribution between high and medium pressure turbines as a function of turbine speed and vibration level was obtained

Introduction :

The non-uniformity distribution of pressure, velocity and temperature along the various sections of the turbine cause a series of excitation on the blades. This generates dynamic stresses which may cause vibration.

The back pressure turbine (refer as type G) make use of the pressure drop available from two steam systems at different pressures. If the steam is available from 80 atm. up to 140 atm. (up to 540 C^o), it is classified as a high pressure turbine (referred type high and medium). So, for this type, the extraction steam (referred type E) is remarkably suitable for operation in chemical synthesis plants. The use of condenser with turbine (type K) uses steam at low pressure and temperature (88 atm, 520 C^o), achieving an expansion down to atmospheric pressure or to the condenser pressure (0.15- 0.25 atm). [1]

The diagnosis of the faults of turbine set by means of the vibration monitoring technique was discussed by Jiang and et al [2]. The frequency spectrum analysis method was used for the vibration analysis. The microcomputer-based vibration diagnostic system for turbine is served for a machine health condition [3]. Also, many functions for industrial compressor - turbine of an on-line expert system was achieved by El-Mitwally [4]. As far as from the available publcations which discuss the aerothermodynamic problem and its excitation on vibration phenomenon at industrial turbine are very limited [5] & [6].

Now, the big problem is how to optimiz the steam flow rate from high pressure steam turbine to medium pressure steam turbine and extraction to acheive the required conditions of chemical industry with smooth operation and minimum vibration. Besides the static forces acting on the rotor and blades, there are another periodical forces resulting from disturbed steam distribution which can possibly cause rise of vibration to undesirable limit. Since, it may result an over stressing. Therefore, it has to analyze, individually, every case according to the load characteristic of the turbine and the supplied steam.

So, it is evident that the aim of this paper is to determine the optimum distribution of the steam flow rate between the high and medium pressure stages on one turbine rotor with speed and vibration level. Also, to specify the nature of the problem for disturbed steam distribution.

The test loop construction :

Many chemical processes need giant amounts of extraction steam. The UREA fertilizer plant is a good example for that. The axial selected steam turbine is about 21 MW of three stages. In this type of plant the turbine operates between two pressure systems and is subjected to an intermediate stage to steam extraction. The high and medium pressure stages are fitted on one rotor and contained in the same casing (EMG). This axial steam turbines are coupled directly with four stages centrifugal compressor and recycle. Fig. (1) shows the layout of the axial steam turbine. As can be seen the main condenser services the third stage (WK). The folowing table gives the turbine specifications :

Type	Axial three stages (High, medium & low)		
	EMG		WK
Power	21 MW	Rated speed	12500 rpm
Stages Cond.	High	Medium	Low
Pressure (bar)	101	43	30/0.03
Temperature	520	410	380/70
No. of impeller	2	3	2 x 6

It is known that the aim of the hydraulic control system of the steam turbine is primarily to match the quantity of steam delivered in accordance with the variable operation conditions of the machine. This system consists of governor valve, emergency trip, cylinder, governor, starting equipment and safety equipment. [7]

Some effective parameters such as rotor speed, steam discharge,steam pressure and steam temperature are measured as demonstrated in Fig. (2). Signals from the fitted non-contact probes on the rotor and vibration meter (sensing unit) are connected to a 12 bit analog to digital converter (conditioning unit) which is interfaced with a 80386 microcomputer system (processing unit). This system (UCDAS 16-G) can trigger vibration signals at a speed up to 75000 sample/second using direct memory access (DMA),[8]. This system can be used by internal trigger routine or external trigger. External trigger can be done by the operator throughout the interface board. The internal trigger is very useful in case of transient event in order to synchronize intervals during an abrupt increase of signals. Other parameters; e.g. temperature and pressure (mv & mA) are measured through the data acquisition Helious and recorder.

Statistical analysis for evaluation :

The relationship between both vibration level and rotor speed at the normal operation of turbine and steam discharge to high pressure turbine and medium pressure turbine is going to find out. The turbine vibration is measured in the range of rotor speed (1000-12500 rpm), and steam discharge as well.

Multiple non-linear regression have been used to fit an equation usig the measured data of parameters, in the form of :

$$Y = b_o \sum_{i=1}^{i=k} b_i X_i + \sum_{i=1}^{i=k} \sum_{j=1}^{j=k} b_{ij} X_{ij} X_{ij} \qquad (1)$$

Where X_i : variable

K : number of variables.

b_0, b_i, b_{ij} : regression coefficient associated with the variables.

The least square method was applied to find the variables coefficient[9]. It has to be sure that the predicted equation and the individual coefficients are significant (significant level ≤ 0.05). This provided F-test for each coefficient. The backwise regression, in this form, is applied to remove the insignificant coefficients.

Results and Discussion :

A typical long period of turbine looking are represented in Fig. (3). It shows the steam discharge at high pressure stage and medium pressure stage, rotor speed and vibration level as a function of time. Vibration are presented in both sides of the high and medium pressure turbines. It is clear that vibration level on the rotor near the entrance of high steam turbine has the higher value. thus, it will be as maximum turbine vibration.

Fig.(4) represents the turbine speed as a function of steam discharge for high pressure and medium pressure stages. However, the same data is analyzed statistically (multiple non-linear regression). It is found that steam turbine speed and vibration level are function of steam discharge at high pressure and medium pressure stages. These significant relation has the following form :

$$\begin{aligned} N = {} & 5.842379*10^{-2}*m_m + 7.143585*10^{-2}*m_h \\ & -4.135038*10^{-4}*m_m^2 -1.220354*10^{-4}*m_h^2 \end{aligned} \tag{2}$$

This relation has correlation coefficient =0.9999 and F-test =3626, which means that the relationship is highly significant level. This is a second order equation of (m_h,m_m) which make it easy to present its values is the 3-dimension response surface. Fig. (5) illustrates this responce surface.

$$\begin{aligned} V_t = {} & -.05505628* m_m + .03742 * m_h + \\ & +8.351524 *10^4 *m_m^2 -1.080514*10^4 m_h^2 \end{aligned} \tag{3}$$

where :

V_t : vibration on axial steam turbine (mils)

m_h : steam mass flow rate at high pressure stage

m_m : steam mass flow rate at medium pressure stage.

This relation has a correlation coefficient =0.9721 and F-test = 227, which means that the relationship is highly significant level. The above relation is represented as a responce surface in fig.(6)

Turbine speed and vibration level are computed from equations (2) & (3) respectively,and plotted in the contour line form as showin in Fig. (7). This figure shows the steam mass flow rate of high pressure stage and medium pressure stage on the resultant vibration level with the rotor speed. Also, maximum extraction performance are plotted. It is clear from the contour lines that the vibration level decreases as the high pressure steam discharge increases. While, turbine speed increases with the increase of medium pressure steam discharge.

Fig. (8) shows the vibration level fluctuation associated with the oscillation of steam discharge at the high and medium pressure turbines,and the fluctuation of speed. The vibration level reachs a higher value more than safe limit. It is fluctuated with constant period. This unstable vibration events required a very high speed acquisition rate when it reaches the upper value. Fig. (9) show the wave form of vibration which created at peak point of position (1.7) with a sample rate of 31.25 KHz. Fig. (10) shows the frequency response analysis of a vibration signal compared with normal condition. It is clear that the difference appears at frequance equal to rotor rotating speed.

Conclusion :

It is obvious that, the steam flow distribution from high pressure steam turbine to extraction and medium pressure turbine was investigated in a large scale axial turbine. The vibration signature associated with steam distribution has been characterized from in accordance with turbine charactresticis and the operation conditions.

Based on the vibration signature and the analysis of the turbine performance, the nature of vibration generation has been explained. The generated vibration in the steam turbine by the interaction of the steam flow distribution between high pressure turbine and medium pressure turbine and the corresponding turbine speed have a second order relation-ship. This relation are demonstrated with the maximum extraction operation of the system as shown in figure (7).

It is remarked that, when the turbine is operated at disturbed steam discharge the performance curves are oscillated. These oscillation causes a drop in performance and become a source of oscillating rotor vibration. The fundamental vibration frequency due to disturbed steam flow, at the peak value, is located at one turbine rotor speed in the radiated vibration spectra.

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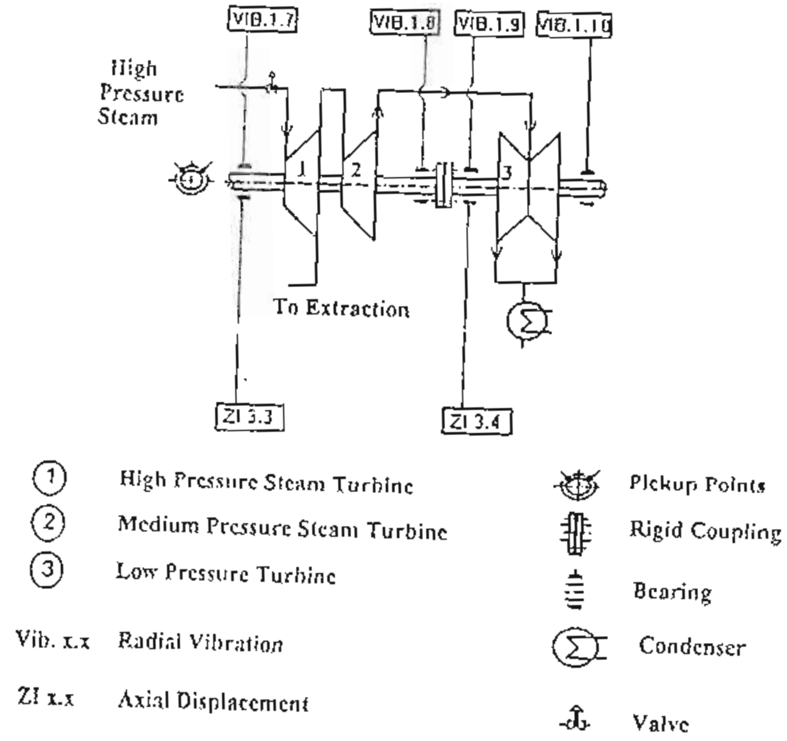

Fig. (1) Schematic Diagram of the Axial Steam Turbine
"Vibration Measurement with Bearing's Arrangements"

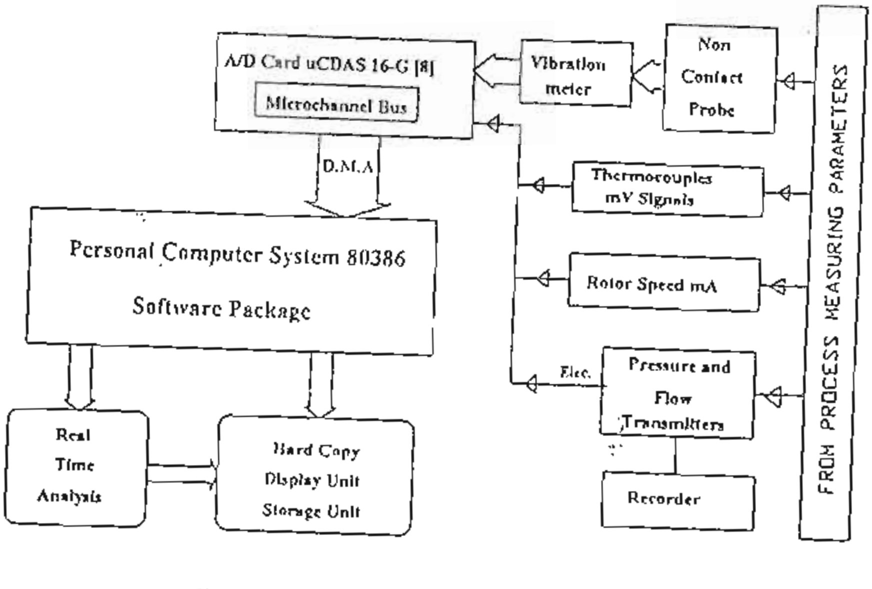

Fig. (2) Computer System Configuration For
Signal Acquisition and Analysis

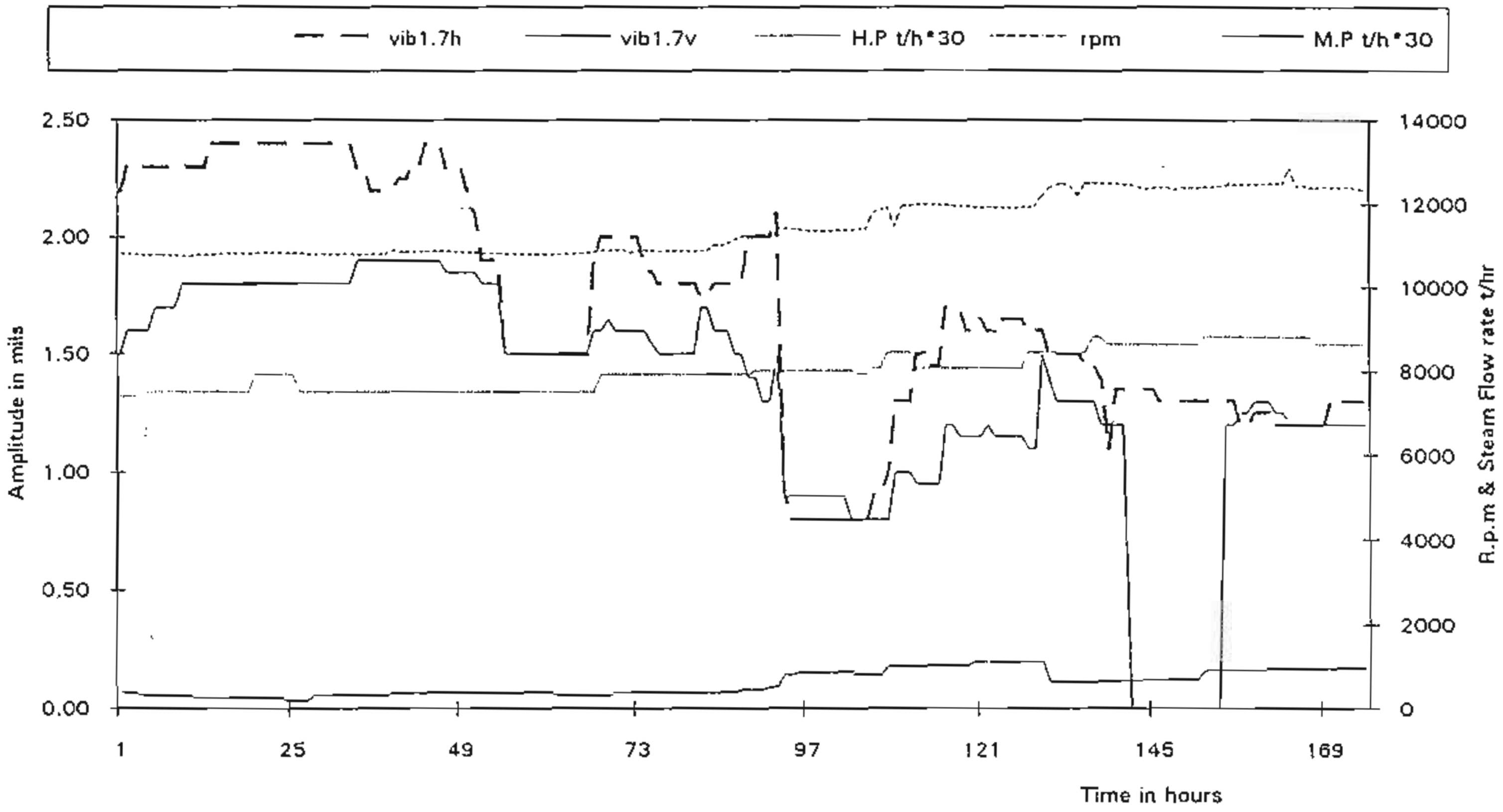

Fig. (3) The interaction between the Steam Discharge of High Pressure Stage and Medium Pressure Stage with Vibration Level and Rotor Speed.

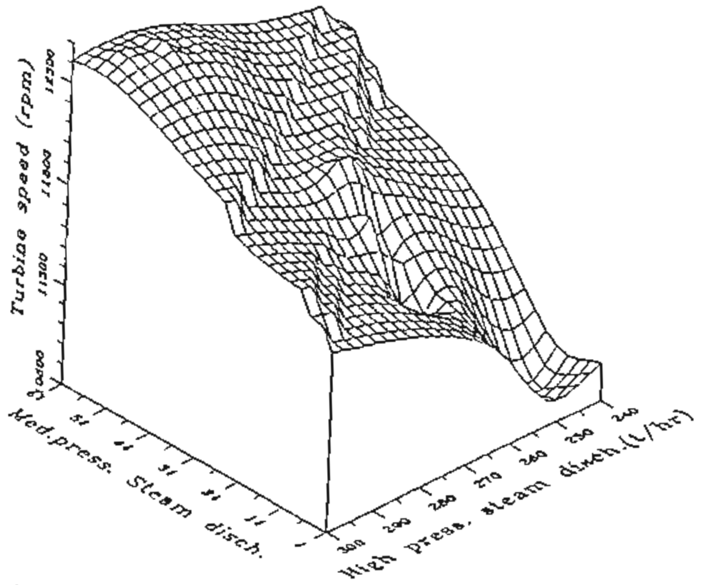

Fig.(4) Turbine speed with steam disch. distribution

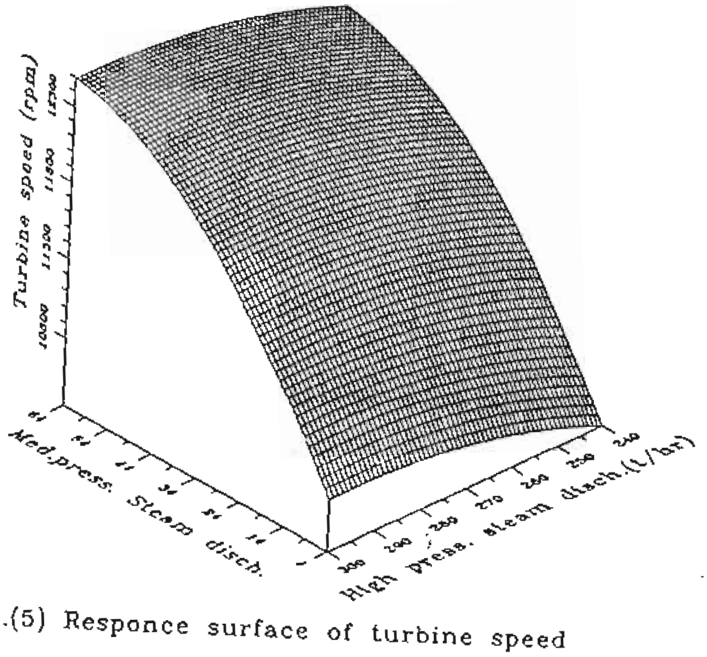

Fig.(5) Responce surface of turbine speed

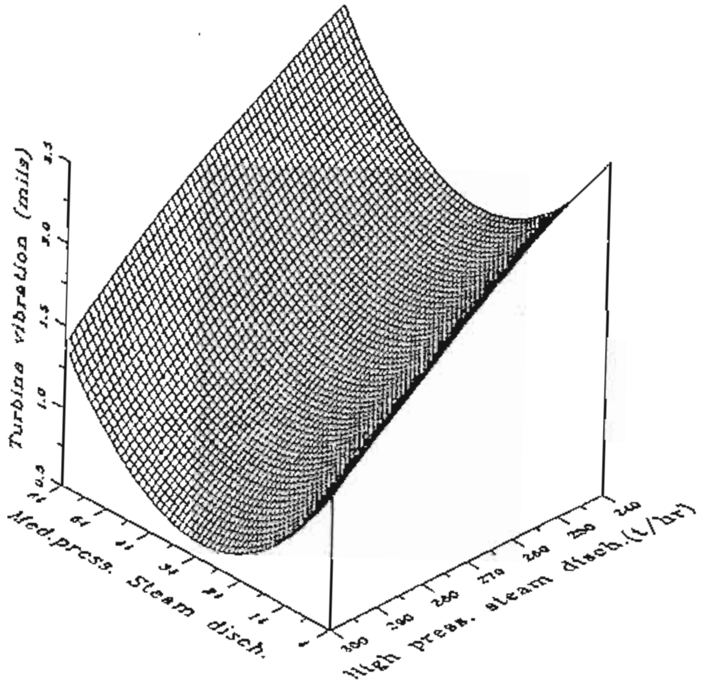

Fig.(6) Responce surface of turbine vibration

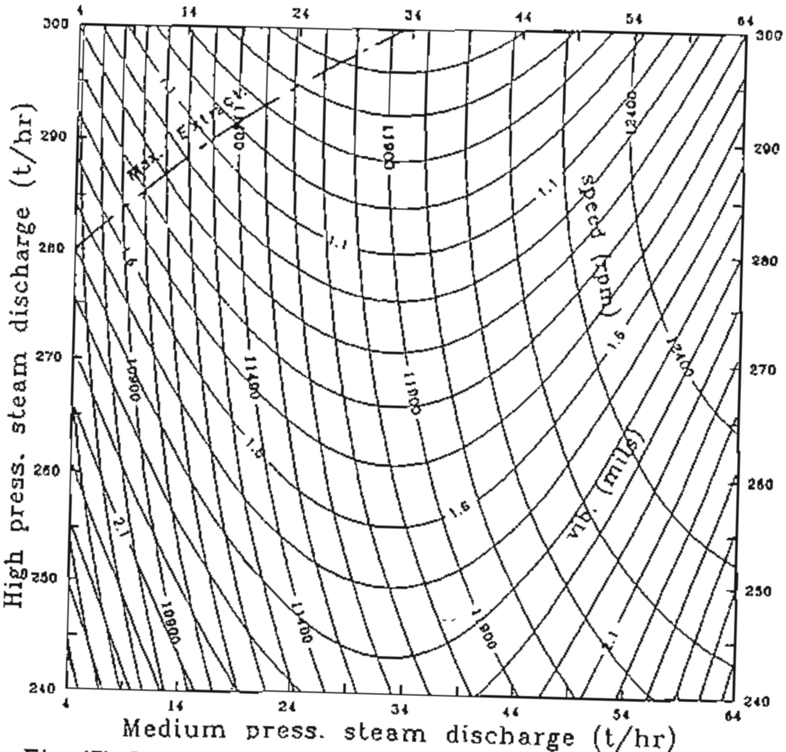

Fig. (7) Contour lines of turbine spead and vibration level.

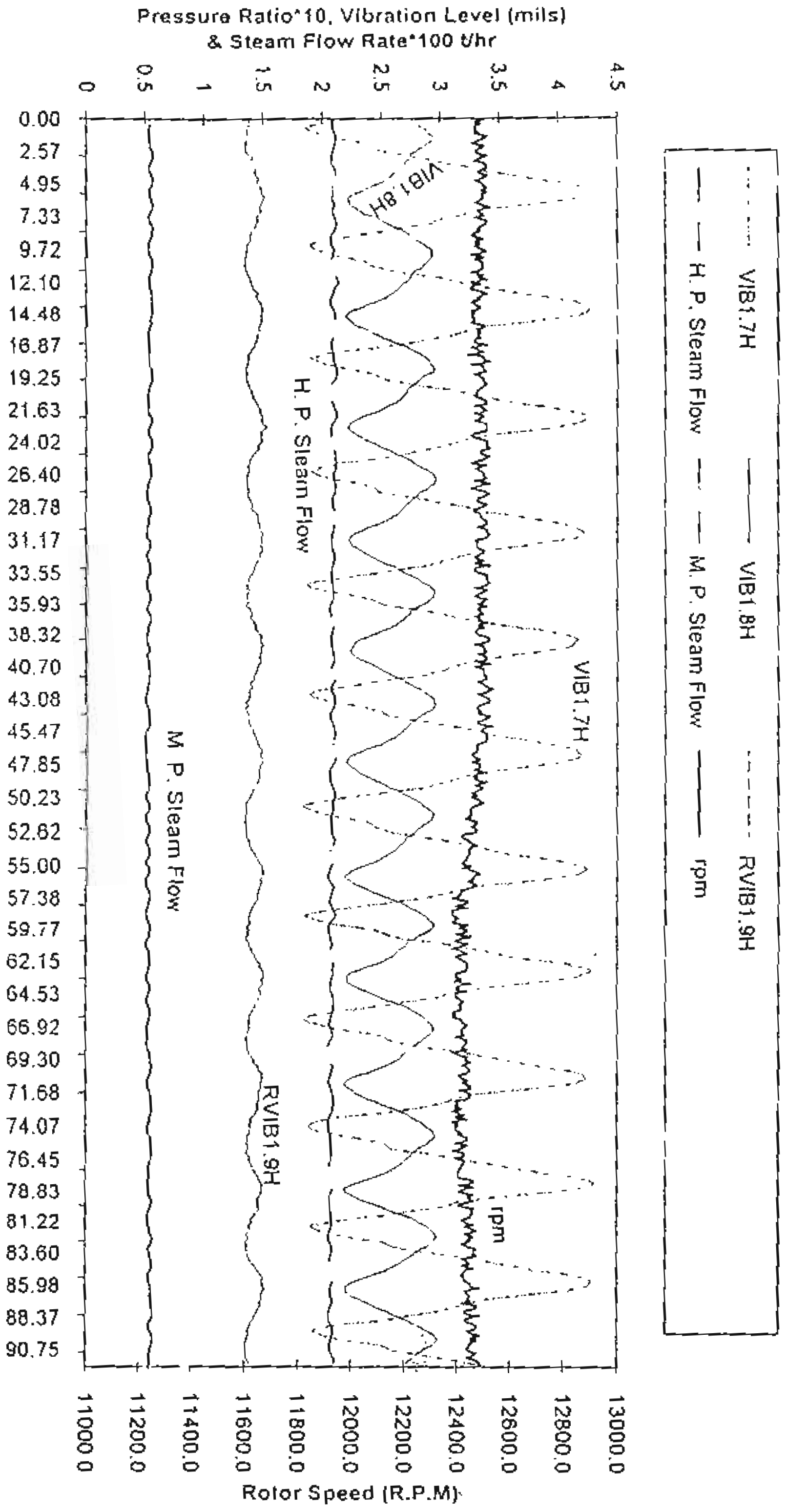

Fig. (8) Distributed Steam Discharge with Vibration Level

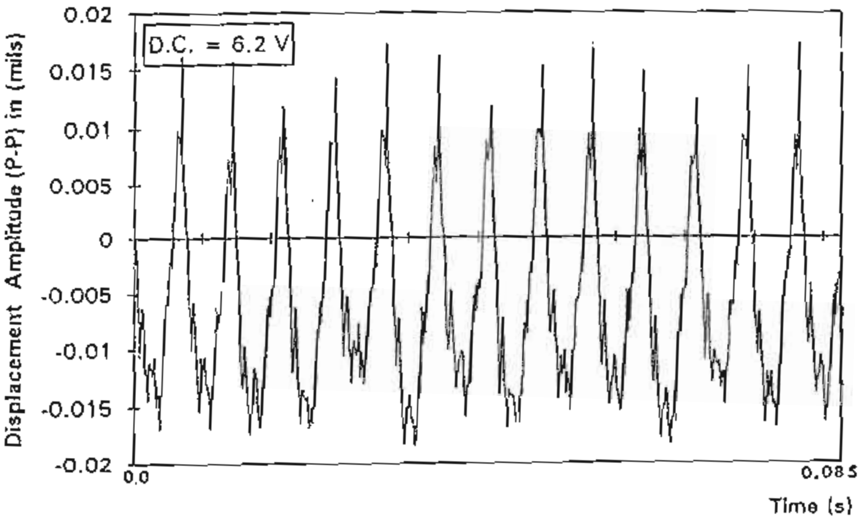

Fig.(9.a) Vibration Signal (Peak to Peak) of Bearing VIB1.7H during Normal Operation

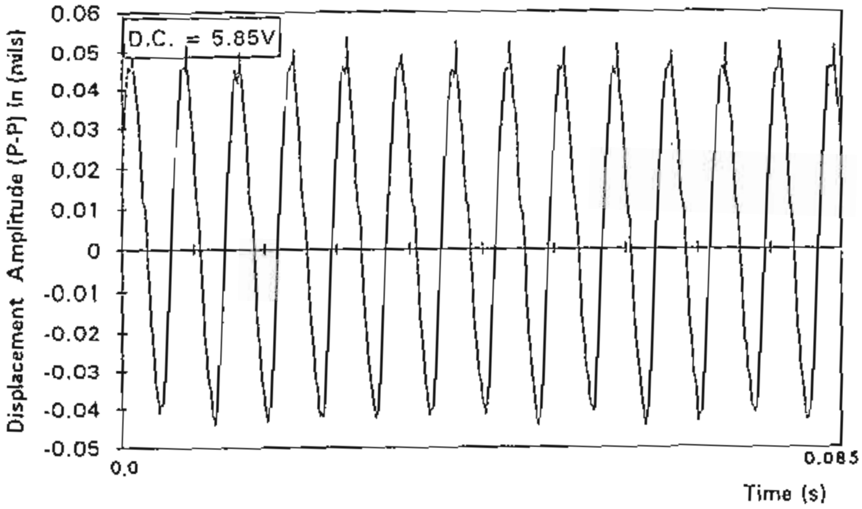

Fig. (9.b) Vibration Signal (peak to Peak) During the Steam Disturbance

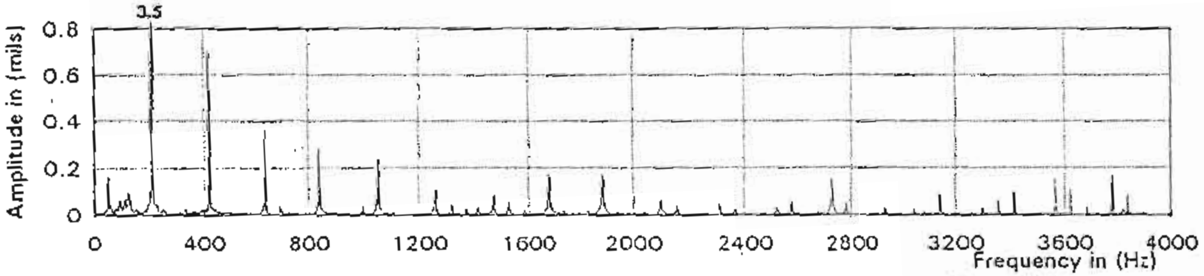

Fig.(10.a) Vibration Amplitude Frequency Analysis for Position(1.7) During Normal Operation

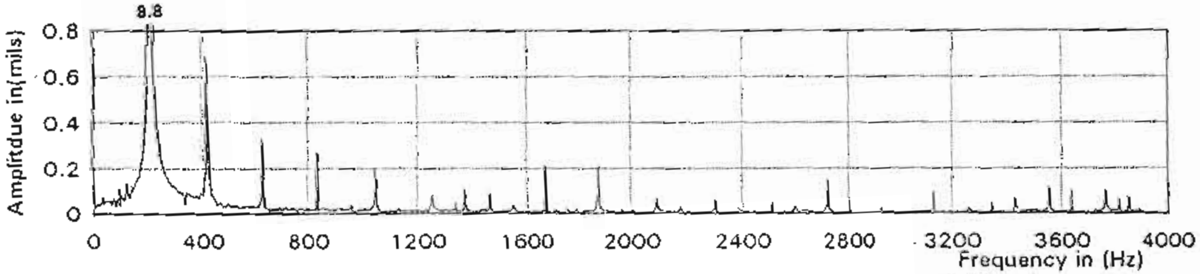

Fig.(10.b) Vibration Amplitude Frequency Analysis for Position(1.7) During Steam Disturbance