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Dynamic Finite Elements Analysis of Coaxial Dual Rotor System Using MatLab

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Abstract

Dynamic analysis of coaxial dual rotor system was demonstrated in this paper through the use of finite element script files developed using matlab. A coaxial rotor system, generally employed in the aircraft engines to save space and keep the weight to minimum, and for the importance of this application it was considered for this analysis. The system was modeled using eight finite elements only with different shafts and bearings properties. The results obtained in this investigation were closed to other previous studies found in the literature. The developed matlab script files proved to be very essential for designers and analyst of coaxial rotors.

Keywords: Rotor dynamics, Coaxial Rotors, Finite Elements, Matlab.

تحليل ديناميكي باستخدام طريقة العناصر المحددة لمنظومة محور ثنائي متداخل باستخدام الماتلاب

الملخص

تحليل ديناميكي لمنظومة محور ثنائي متداخل وضحت في هذا البحث من خلال استخدام ملفات برامج عناصر محددة طورت لهذا الغرض باستخدام الماتلاب. منظومة المحاور المتداخلة عادة تستخدم في محركات الطائرات لتوفير المكان والابقاء على الوزن اقل ما يمكن، ولاهمية التطبيق تم اعتبارها لهذا التحليل. تم نمذجة المنظومة باستخدام ثمانية عناصر محددة فقط مع خواص محاور واسناد مختلفة. النتائج المستحصله في هذه الدراسة قريبه جدا الى نتائج موجودة

بالمصادر باستخدام طرق تحليل اخرى. برامج الماتلاب المطورة في هذا البحث اثبتت انها مهمة لمصممي ومحللي الاهتزازات في المحاور المتداخلة.

كلمات مرشدة : ديناميكية المحاور، محاور متداخلة، عناصر محددة، ماتلاب.

1-Introduction

Most of the modern day machinery, used for power generation or for industrial applications, employ rotating components called rotors, which are the main elements for the power transmission. To meet the weight and the cost requirements, the present day rotors are made extremely flexible. This makes rotor dynamics as an essential part of the design. It involves the prediction of the critical speeds and the safe operating speed limits for the rotors, based on the evaluation of natural frequencies and plotting them on the Campbell diagram. An alternative option is to decide upon the variables in the design such as bearing specifications in terms of stiffness, bearing span, and coupling specifications, to keep the critical speeds away from the operating region.

However accurately these rotors are balanced, there will be some unbalance still left in the system. The response to make sure that the rotor does not rub against the casing, is an important aspect of the rotor dynamic analysis [1]. A common practice in the rotor dynamics analysis is to use beam models for both torsional and lateral analysis. Such an analysis required special attention to meet the capabilities for the modern day design of high-speed machinery. The beam type models require good modeling technique such as finite elements to approximate the three-dimensional rotor models. The accuracy of the beam modeling analysis is limited to how best the mass and stiffness in the system are captured. For a complex geometry such as the rotor, it is difficult to accurately capture these terms in rotor dynamics model. Finite element rotor dynamics modeling provide an accurate solution for such problems[2]. With the vision of applying different speeds to different elemental components, it is possible to simulate the rotor dynamic analysis of dual coaxial rotors, considering the effect of bearings, unbalance, and external torques. This provides and efficient real-life rotor dynamic simulation of the present day rotors which is more accurate than the conventional modeling approach.

2- Model and Analysis

To demonstrate the capabilities of the finite element model rotor dynamics, a study was carried out considering a coaxial dual rotor system given in Reference [3]. A coaxial dual rotor system is generally employed in the aircraft engines to save space and keep the weight to a minimum by having a hollow outer spool which mounts the high pressure compressor and the turbine running at a relatively higher speed through which an inner spool rotor mounts the low pressure compressor and the turbine rotors. A case study was taken [4], to validate the accuracy of the proposed approach, as shown in Fig.(1). The case study was simulated in MatLab using a developed script files depending on the rotor dynamics toolbox associated with Reference [5] (All the relevant equations for this analysis can be reviewed in this reference). First the rotor was modeled using eight beam elements and nine nodes. The bearing stiffness properties are simulated using two types of bearings. The developed model was shown in Figures (2) and (3) respectively.

3- Results and Discussions

For the above model, a vibration analysis was carried out including the bearing effects, the external torques, and the unbalance at different disk. The Campbell diagram was generated and shown in Fig.(4). It is clearly shows that due to the effect of bearings, both the forward whirl and the backward whirl frequencies decrease with speed. The effect of decrease in frequency with the increase in speed is more for backward whirls than for forward whirls. Similar results and conclusion were demonstrated for the same model, using Ansys solid modeling, in reference [4]. The root locus diagram is shown in Fig.(5). This figure shows clearly the stability of the analysis where the real eigen values and imaginary eigen value are coincide on the same vertical line for all range of the spin speeds. The model first four natural frequencies and mode shapes are shown in Fig.(6). This figure shows the behavior of the two rotors at different natural frequencies. The orbit plots of disk 1 relative other disks for the first six mode shapes are generated and shown in Figures (7-9) respectively. It is clear from these figures that the whirling orbits of the disks relative to each other are different depending on the mode natural frequencies and positions. An investigation on the effect of the unbalance in each disk on the response of the other disks with different spin speeds are carried out. The results were shown in Figures (10-13) respectively. These figures clearly show different response behaviors due to the different unbalance location on the disks.

4-Conclusions

From the above analysis, the following conclusions can be drawn:

1- The finite element analysis and matlab are good tools for dynamic analysis of rotors and easiest in implementation than using packages such as Ansys or Nastran.

2- The developed matlab script files can produced all the graphics needed for the illustration of the analysis.

3- The developed matlab script files proved to be very essential for designers of coaxial dual rotor systems.

5- References

[1] Santos I.F.,"Vibrations in Rotating Machinery", Lecture Notes, Department of Mechanical Engg., Technical University of Denmark, Denmark.

[2] Rajan, M., Nelson H.D., and Chen W.J., "Parameters Sensitivity in the Dynamics of Rotor-Bearing Systems", J. Vib. Acouust. Strss and Rel. Des., Trans. ASME, Vol. 108, 1986.

[3] Rao, J.S., Sreenivas, R., and Veeresh C.V., "Solid Model Rotor Dynamics", Paper presented at the Fourteenth U.S. National Congress of Theoretical and Applied Mechanics, BlacksBurg, VA, 23-28 June 2002.

[4] Rao, J.S., Sreenivas, R., "Dynamics of Asymmetric Rotors using Solid Models", Proceedings of the International Gas Turbine Congress 2003, Tokyo, November 2-7, 2003.

[5] Friswell M.I., Penny J.E., Garvey S.D., Lees A.W., "Dynamics of Rotating Machines", Cambridge University Press, 2010.

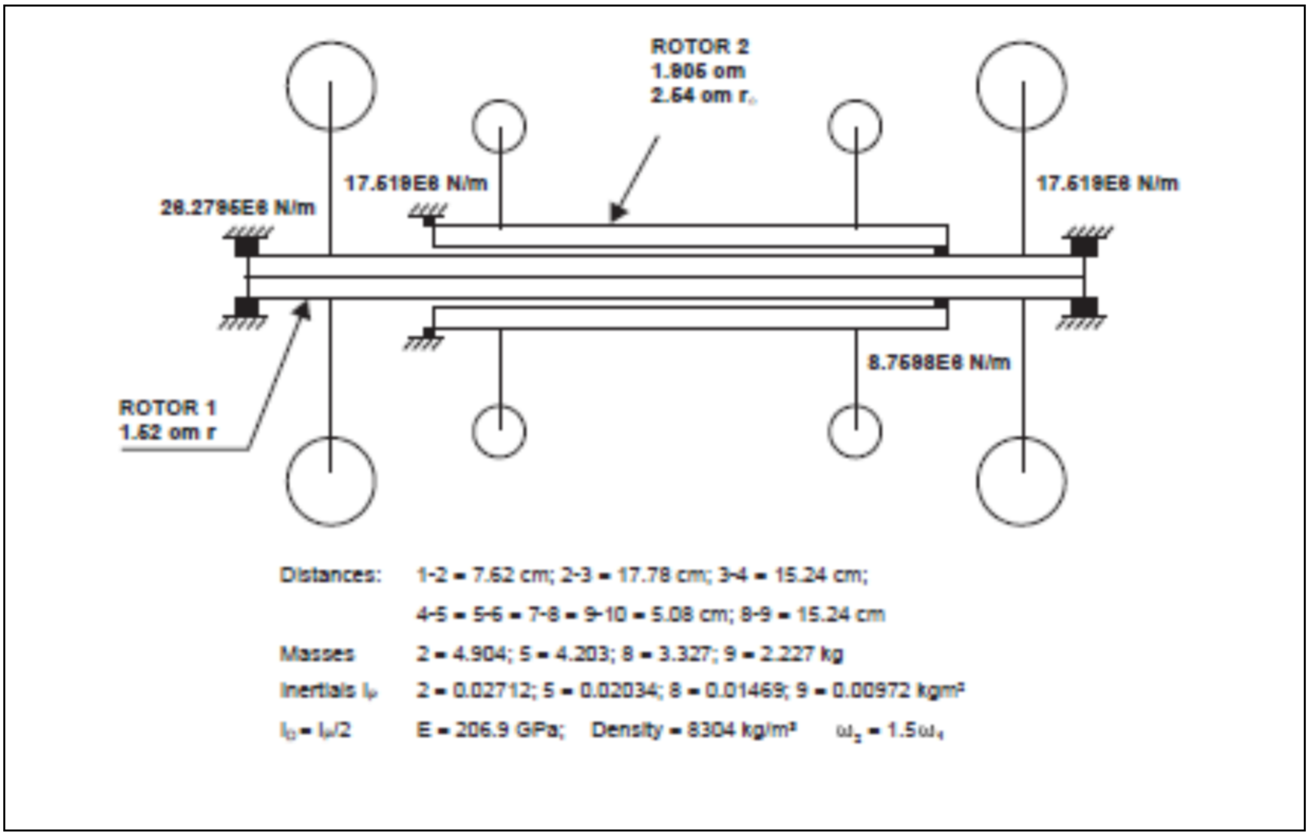

Fig.(1) Coaxial dual rotor system.

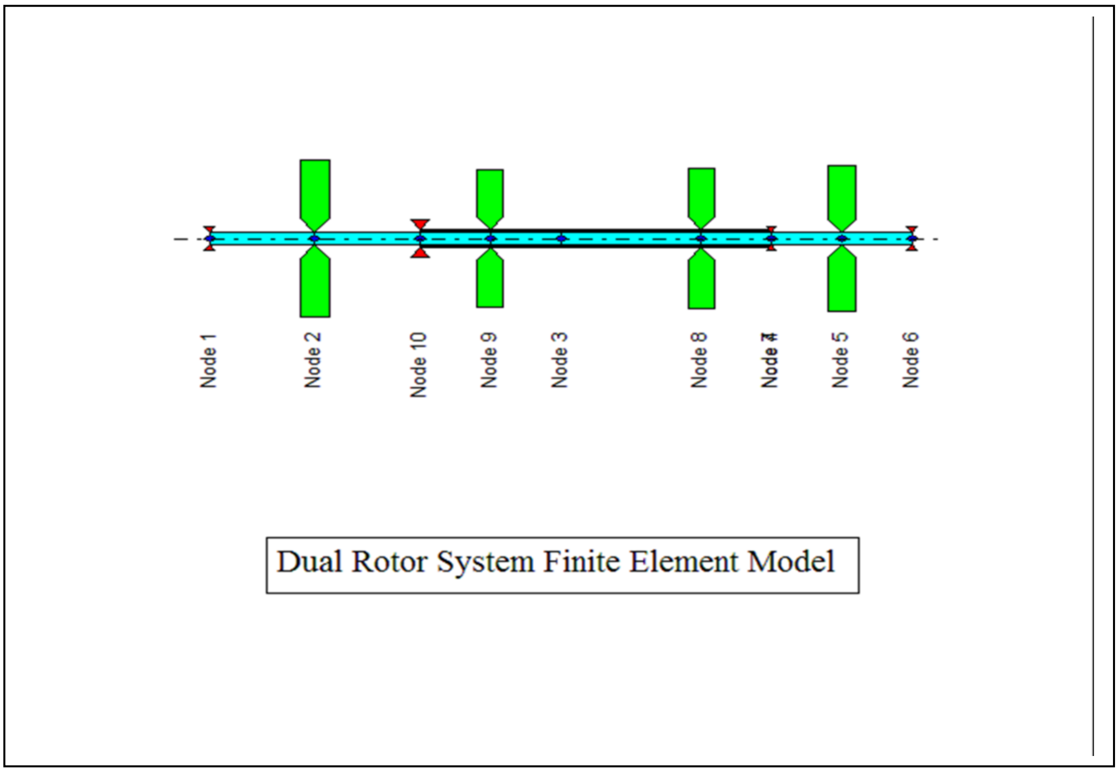

Fig.(2) Dual rotor system finite element model.

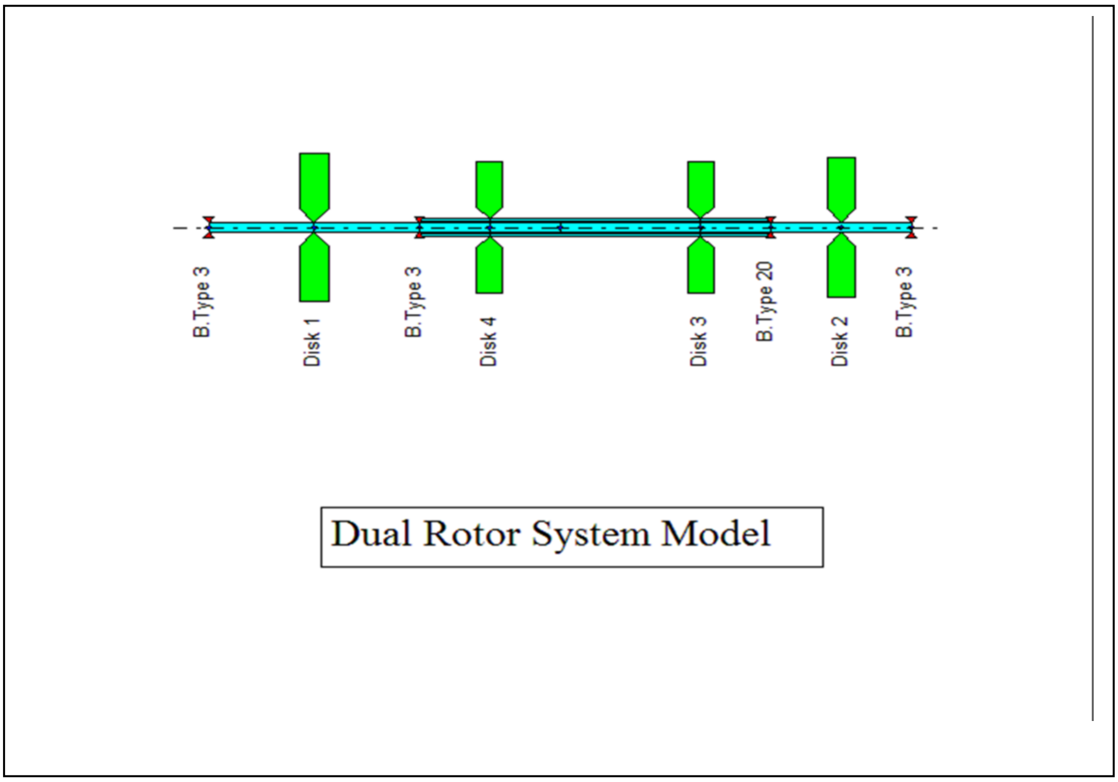

Fig.(3) Dual rotor system disks and bearings locations.

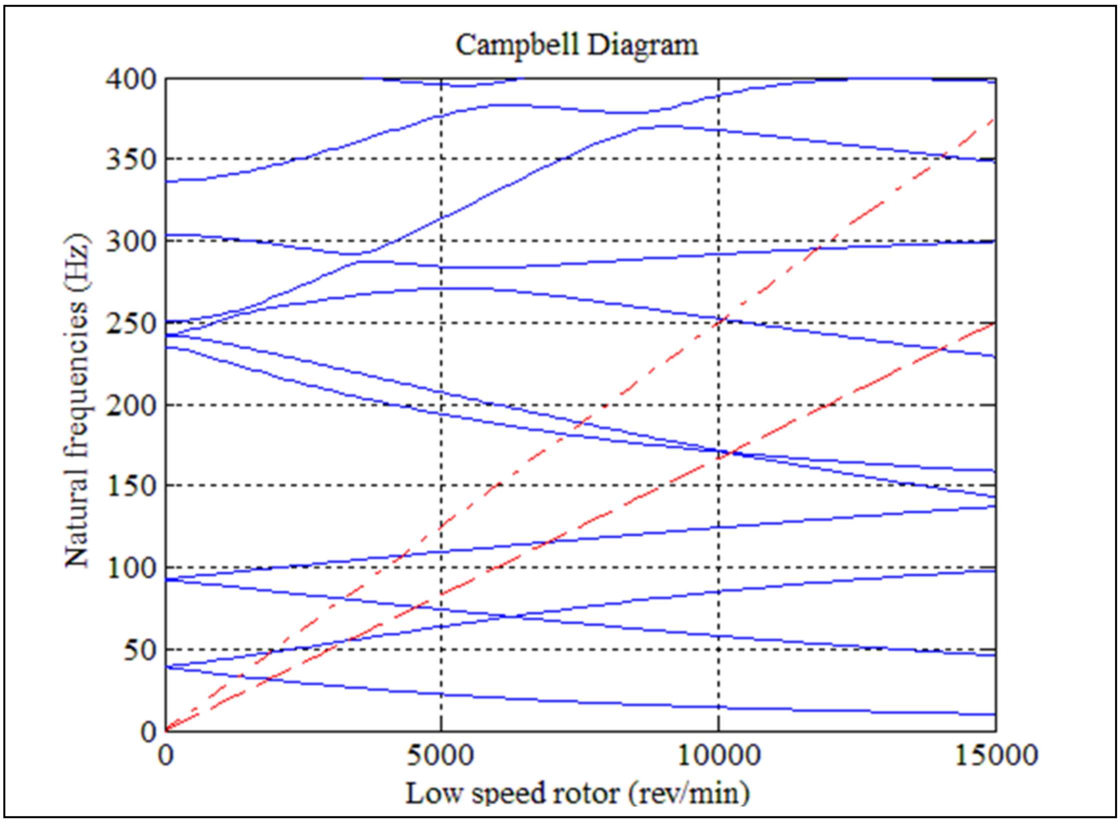

Fig.(4) Campbell Diagram for the model with bearing effects.

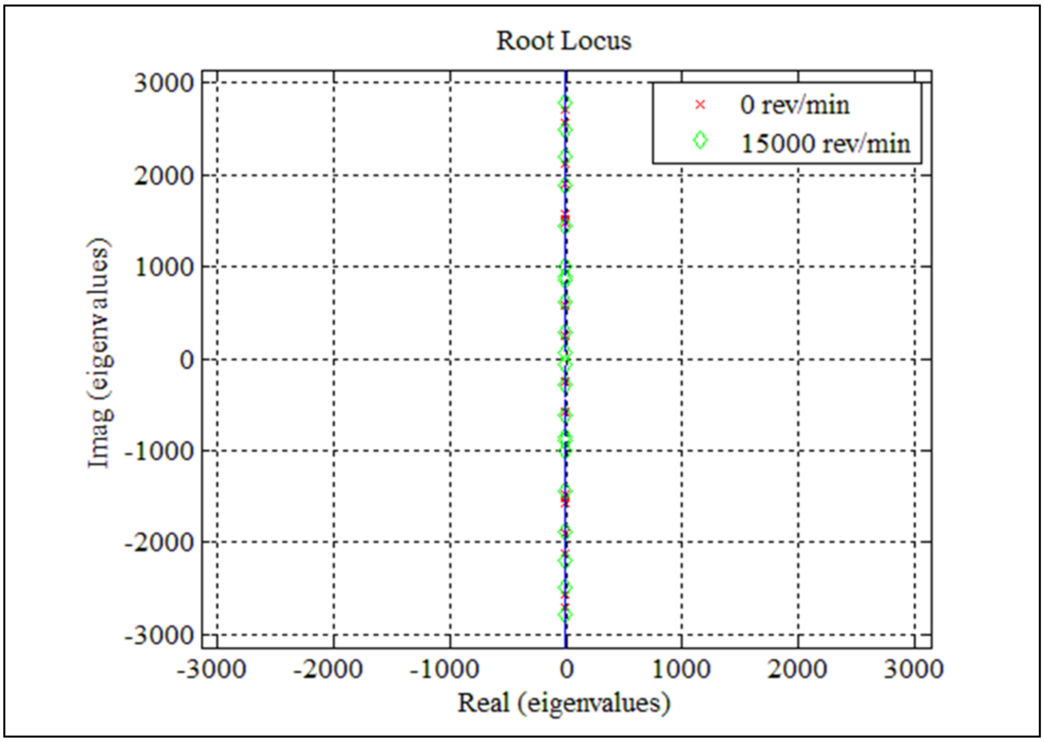

Fig.(5) Root locus diagram of the model.

Fig.(6) The first four natural frequencies and mode shapes for the model.

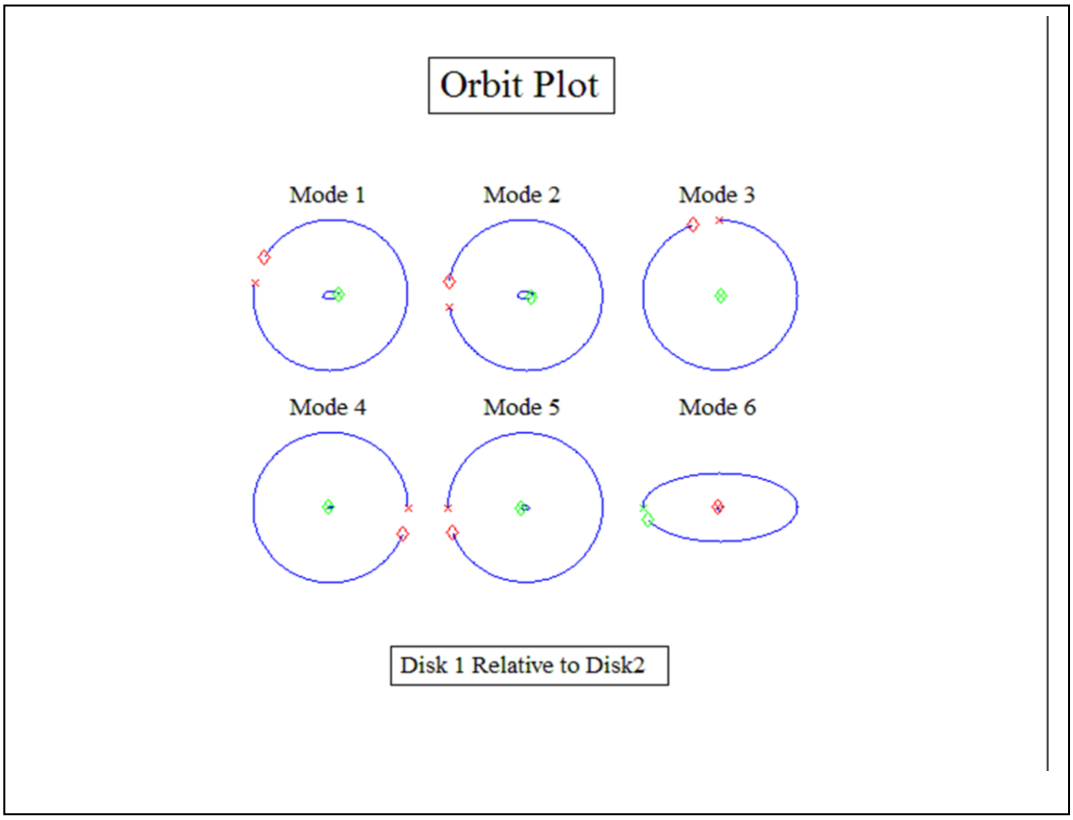

Fig.(7) Orbit plot of disk 1 relative to disk 2.

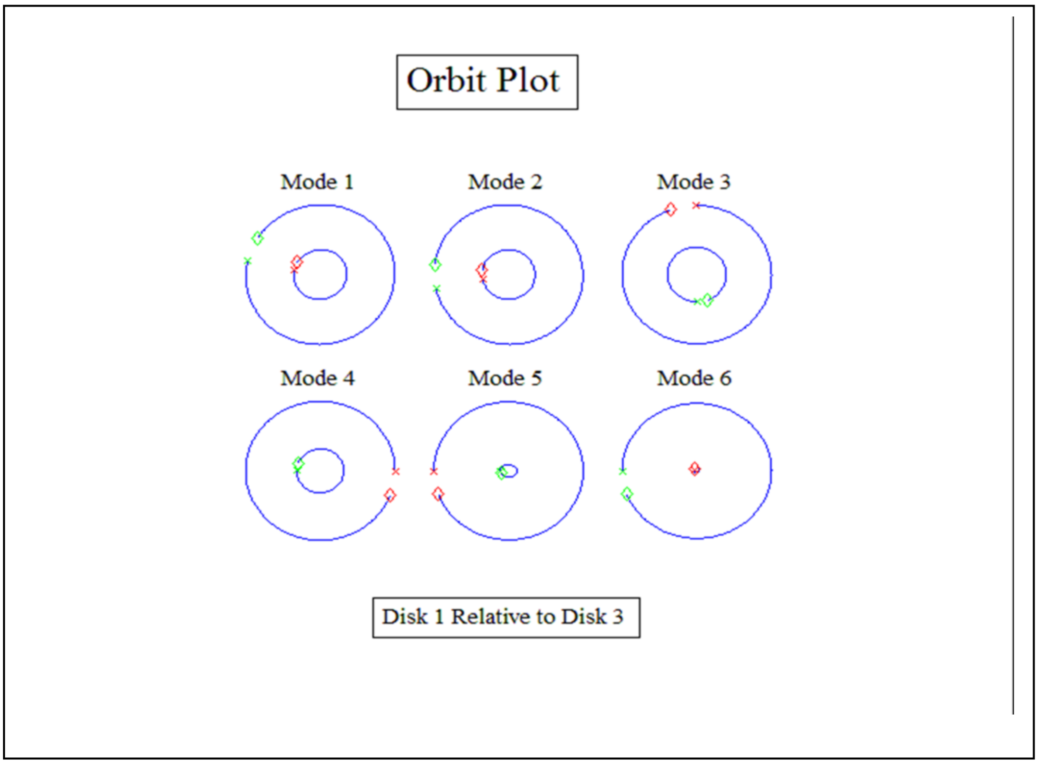

Fig.(8) Orbit plot of disk 1 relative to disk 3.

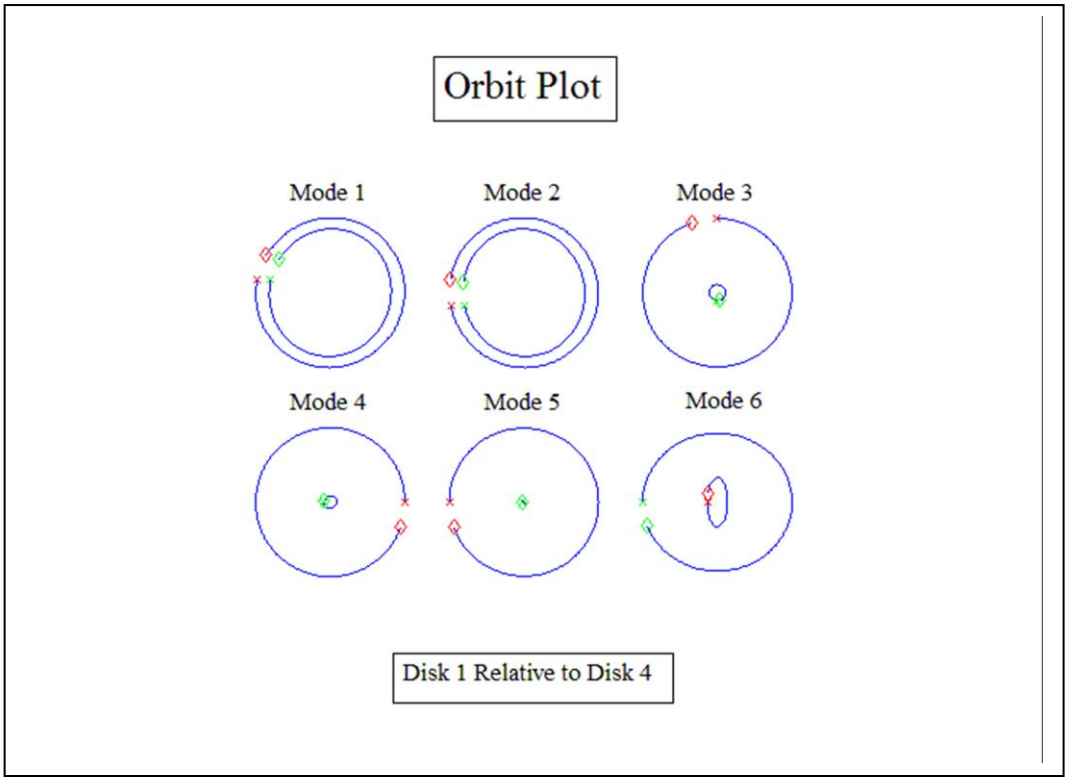

Fig.(9) Orbit plot of disk 1 relative to disk 4.

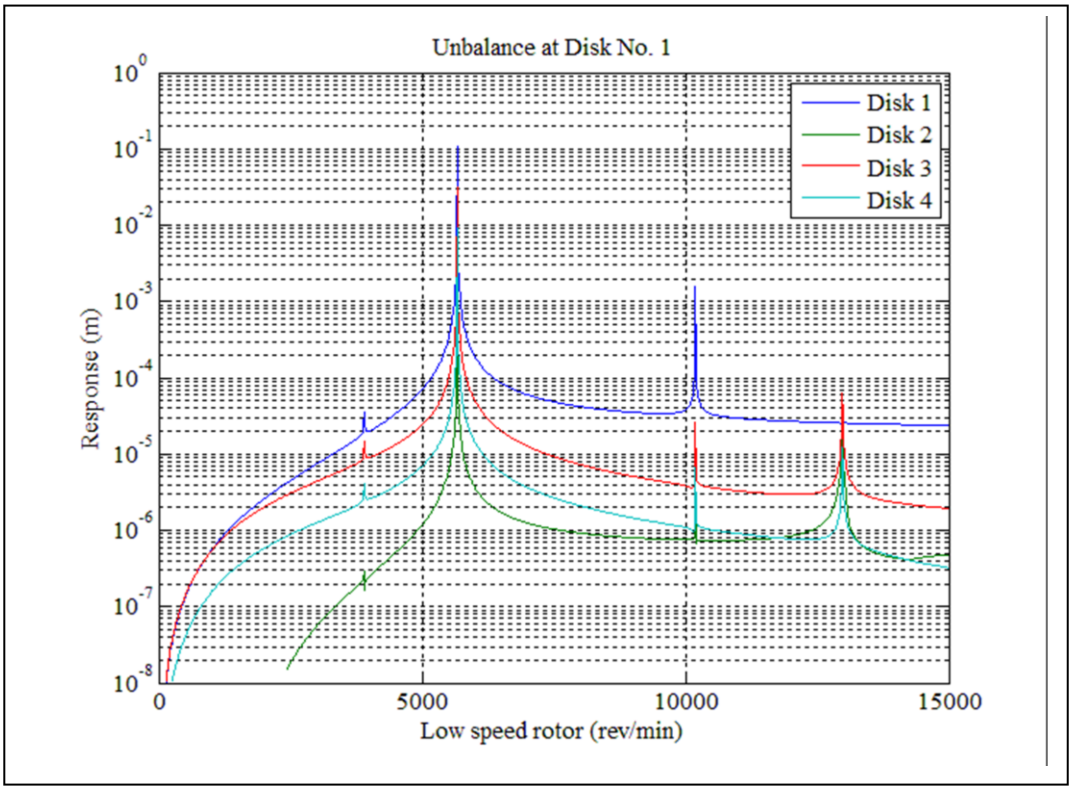

Fig.(10) Response of the model disks due to an unbalance at disk 1.

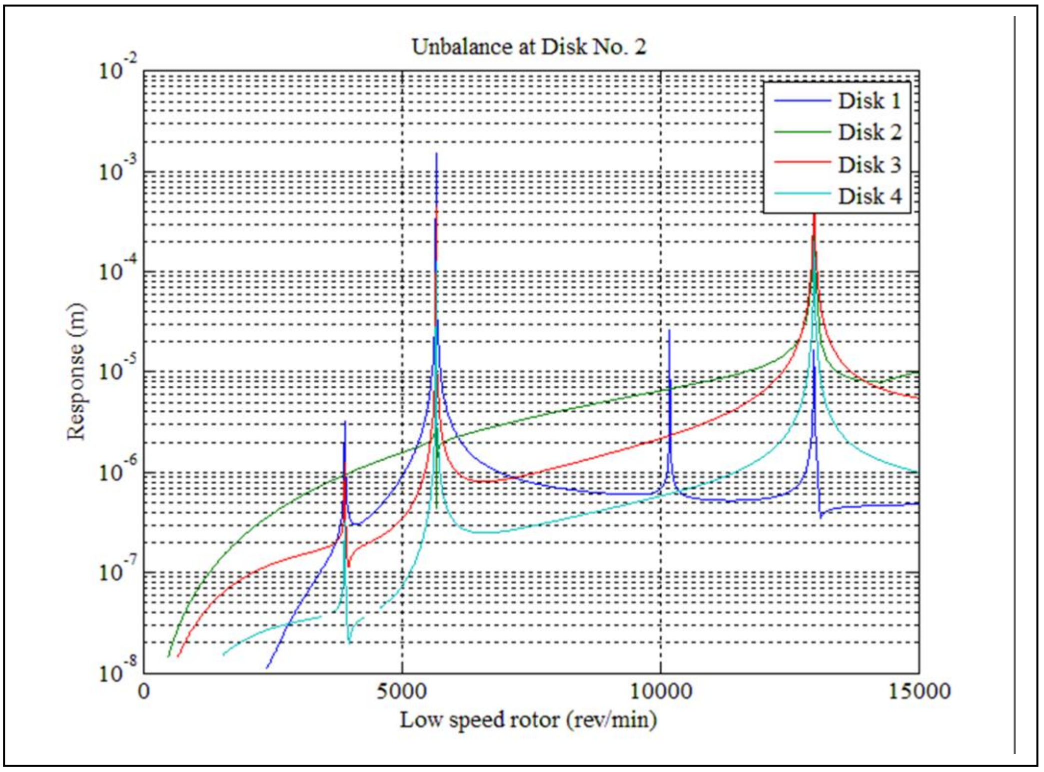

Fig.(11) Response of the model disks due to an unbalance at disk 2.

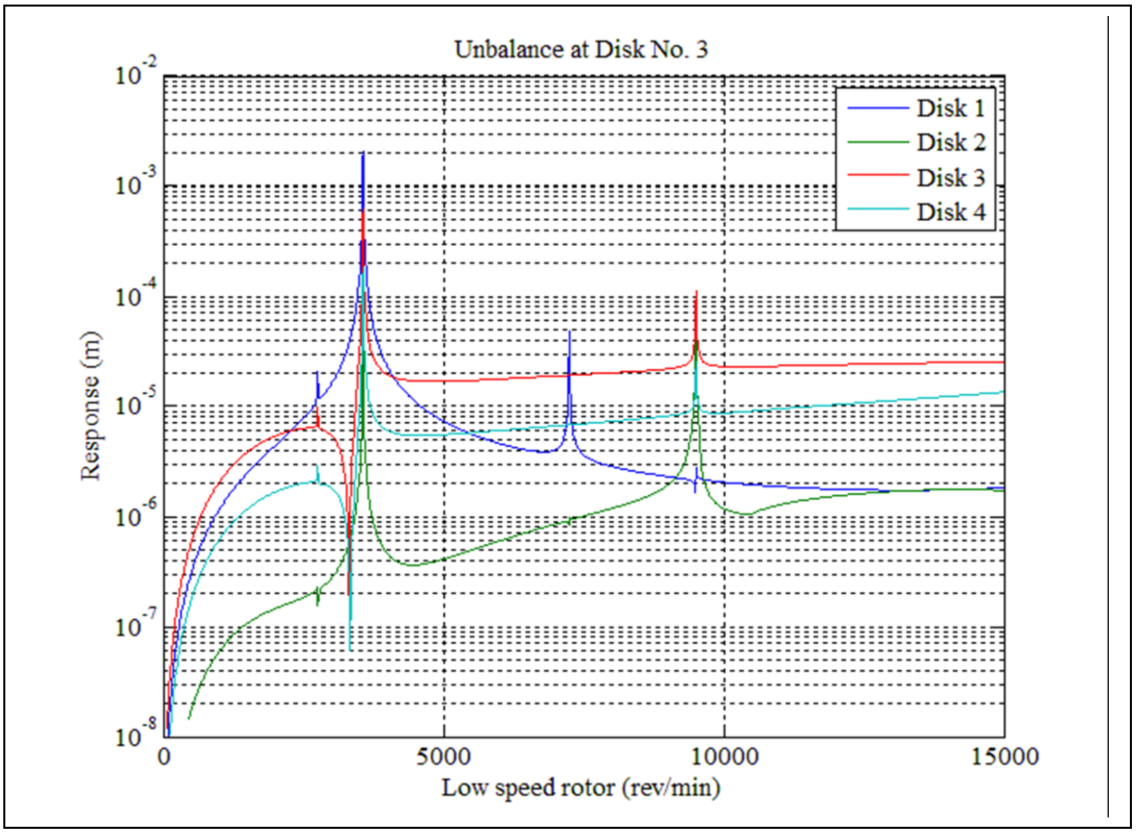

Fig.(12) Response of the model disks due to an unbalance at disk 3.

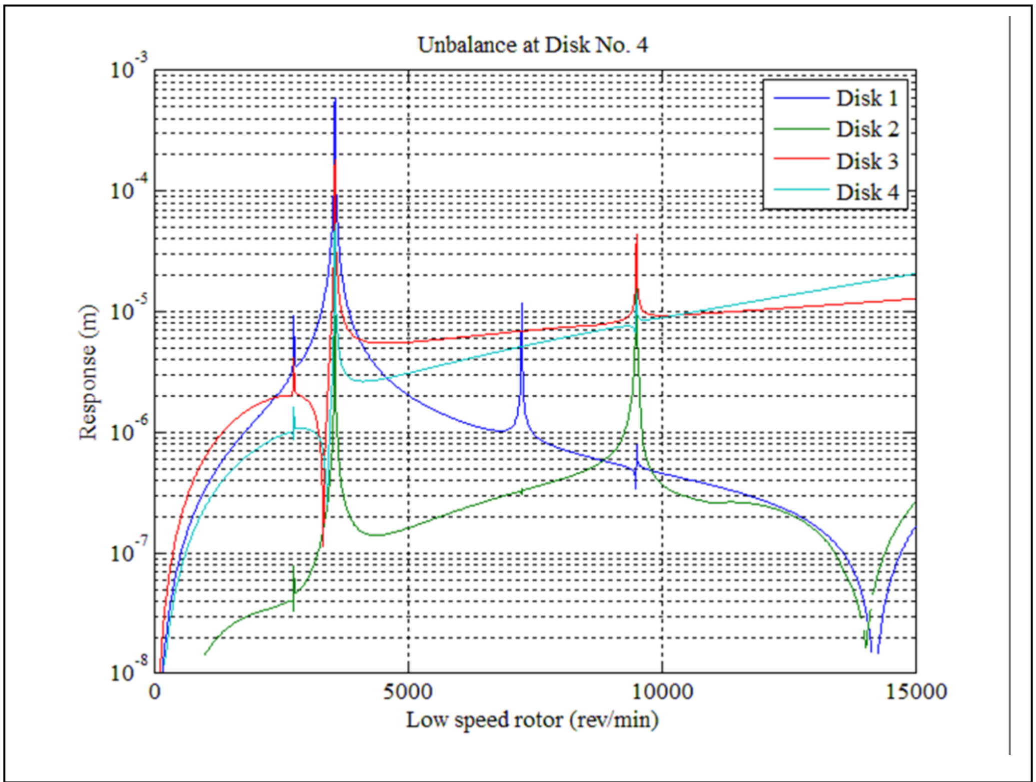

Fig.(13) Response of the model disks due to an unbalance at disk 4.