

# A Review paper on Application of Bond Graph Technique on Bearings

**Omkar Dhamangi<sup>1</sup>, Omkar Vajjaramatti<sup>2</sup>, Prajwal Kalloli<sup>3</sup>, Prabhugoud Biradar<sup>4</sup>,  
Prof Yogita N Potdar<sup>5</sup>**

Students, Department of Mechanical Engineering, KLS Gogte Institute of Technology,  
Belagavi, Karnataka<sup>1-4</sup>

Assistant Professor, Department of Mechanical Engineering, KLS Gogte Institute of Technology,  
Belagavi, Karnataka<sup>5</sup>

**Abstract:** Bearings play a crucial role in various mechanical systems, including engines, turbines, and rotating machinery, where their proper functioning is essential for reliable and efficient operation.

Traditional methods for analysing bearing system often focus on individual components and technique, a graphical modelling approach based on energy flow and power transfer, provides a holistic framework for capturing the dynamic interactions within a bearing system.

The fundamental principles of bond graph modelling and highlight its advantages in capturing the multi-domain nature of bearing, including mechanical, thermal, and fluid dynamic aspects.

By representing bearings are interconnected power domains, the bond graph technique enables the integration of various physical phenomena occurring within the system, leading to a more accurate and comprehensive analysis.

**Keywords :** Bearing, Magnetic bearing, Bond graph

## INTRODUCTION

Bearings are element of machine which supports another moving machine element known as journal. It helps to create relative motion and reduce friction between the moving parts, while carrying load. Bearings are classified according to the requirement of the element in which they are going to be used, they are basically designed to match the expectation of the machine for example, in the type of operation, and motions, direction of forces and calculated loads. These are some important parameters to be taken care while designing a bearing.

There are various types of bearings, each of them operate on different principle.

**Magnetic Bearing :** It is an oil or lubrication free bearing system that uses electromagnetic forces to maintain relative position of rotating element called Rotor and a stationary element called Stator. Magnetic bearings are used in machine such as pumps, compressors, turbines, and generators etc. They are generally more efficient compared to other bearing there is comparatively less wear and tear due to its lubrication free property.

## BOND GRAPH

A connection graph or a bond graph technique is a graphical modelling technique used in engineering to depict and analyse the dynamic behaviour of complex systems. It provides a visual representation of the interaction and energy flows in the system. The concept of bond graph was introduced by Henry Painter in 1960s as a unified approach to modelling different types of physical systems, including mechanical, electrical, hydraulic, and thermal systems. The main idea of bond graph is to depict the components and their interactions in a system using their connections.

In a bond graph, Bonds which link together as “single port”, “double port”, and “multi port” each bond represents the flow of energy or power between different components, and connections represent the interaction and exchange of energy between connections. Bonds are denoted by variables such as force, current, or pressure that corresponds to physical quantities in the system. The main elements used in bond graph are namely Resistive, Capacitive and Inertia elements. These are all single port elements. They consist of junctions and nodes. This graphical representation allows us to visualize and understand how energy is transferred and transformed in a system. One of the key advantages of bond graph is their ability to analyse the dynamics of complex systems and study their behaviour under different conditions.

Bond graphs are widely used in various engineering disciplines, including mechanical engineering, electrical engineering, control systems, and mechatronics and not just in engineering field but also in management studies. They are particularly useful for modelling and analysing systems with multi-domain interactions where different physical domains are coupled together, Bond plots allow engineers to study interactions between different components and evaluate system behaviour and performance.

### **Applications of Magnetic Bearing**

- Electric circuits
- Gyroscope Flywheels
- Plane engines
- Turbo pumps
- Generators
- X-ray tubes
- Inertia wheels

Software used for simulation of magnetic bearing

- ANSYS
- ADAMS
- MATLAB
- COMSOL

Why is Bond Graph Technique better than other softwares

- Bond graph is used to generate complex models based on law of physics and thermodynamics.
- In vector form, they give proper description of complex systems.
- It gives us the information quickly compared to all other softwares
- Same elements can be used in different field such as hydraulics and electrical which makes bond graph as multi-domain system.
- Bond graphs give a proper graphical representation which is better than block diagrams, and can be understood easily.
- It even generates vibrational analysis in graphical form which makes it easier to understand the defect or fault in the designing element.

### **METHODS**

Investigation of demonstrating and recreation of moving component [1] orientation centers around the utilization of bond diagram displaying in the reproduction of moving component course. The creators propose a thorough bond chart model that thinks about the mechanical, warm, and grease parts of bearing activity. The model is approved through trial information and exhibits its adequacy in catching the powerful way of behaving of moving component heading.

Demonstrating of Moving Component Heading with Surface Contact Deformities Utilizing Bond Graphs[2], the model of moving component bearing which is created in a vector security diagram consolidated multibody elements of components, diffusive impacts, elements of contacts, and surface imperfections. Newton's Euler conditions for every component were encoded into bond diagrams, with elements of contacts, foothold powers, and rotational gratings planned

as constitutive laws of components. A kinematics based shortcoming model was presented. Tribological (communicating surface in relative movement) flaws were demonstrated as surface profile changes, which produce motivations through powerful collaborations of deficiencies and bearing components. Shortcoming boundaries characterize type, size, shape, and areas of flaws. A review explored the impacts of type, size, and state of flaws on vibration reactions. The secluded and nonexclusive moving component bearing bond chart model address complex elements of both ordinary and blemished course, for moving component heading with various math and details.

The exploration with respect to vibrational analysis[3] of diary bearing researches the utilization of bond diagram displaying in the vibration examination of diary course. The creators foster a bond diagram model that thinks about the rotor elements, bearing calculation, and diary misalignment. The model is utilized to foresee the vibration reaction and strength of diary course. The review exhibits the viability of bond diagram demonstrating in recognizing potential vibration issues and advancing the plan of diary bearing frameworks.

In proposition of conclusion of moving component of bearing[4], the creators research the utilization of bond diagram displaying for issue finding of moving component heading. They foster a security chart model that consolidates different issue conditions, like limited imperfections and wear. By breaking down the energy stream and power conveyance inside the framework, the security chart based approach empowers exact and solid recognition of bearing issues.

In this paper, there is outline of the bond-chart demonstrating strategy, which gives a graphical portrayal model of mechanical-electrical physical system[5]. With the assistance of programming apparatuses which help the designer in creating bond diagrams. CAMP-G and Images are such instruments that interfaces straightforwardly with MATLAB/SIMULINK, which moreover gives a reproduction capacity and the representative controller which is expected to foster the nonlinear transformers that are expected for pragmatic execution of mind boggling frameworks. The airplane arrival model introduced clarifies the entire cycle from origination for reenactment to graphical outcomes investigation. The bond chart model offers a novel multi energy approach that has been checked utilizing consequences of similar model by different strategies. Which is a long cycle on the off chance that one infers the conditions physically with the aim to program them into MATLAB. The PC mechanized approach introduced here helps us acquiring the model from reality to reproduction rapidly and definitively.

A bond diagram model consolidating sensors, actuators, and vehicle elements for creating regulators for vehicle safety[6], In this paper, Bond chart is utilized to foster a four-wheel nonlinear vehicle dynamic model valuable for regulator improvement. The model incorporates six levels of-opportunity for the body, controlling at the front, suspension, and street input. Bond charts and causality were utilized to foster the model in pieces which were collected into a general model by associating those pieces.

## CONCLUSION

The use of the bond diagram strategy in the examination of orientation has shown to be an important device for understanding and streamlining the unique way of behaving of bearing frameworks. It gives us bring about extremely less time contrasted with different programming projects. By addressing heading, the bond chart approach catches the multi-space nature of direction, taking into account mechanical, warm, and liquid elements perspectives at the same time. the utilization of the bond diagram method in bearing examination holds extraordinary commitment for propelling the comprehension and advancement of bearing frameworks, adding to improved execution and unwavering quality across different mechanical applications.

## REFERENCES

- [1] Bond Graph Modeling and Simulation of Rolling Element Bearings by L. Chen et al. (2014).
- [2] Bond Graph-Based Fault Diagnosis of Rolling Element Bearings" by M. Yu et al. (2016)
- [3] <https://ui.adsabs.harvard.edu/abs/2020JSV...47315205T/abstract> <https://ntrs.nasa.gov/api/citations/20040085773/downloads/200https://dspace.mit.edu/handle/1721.1/6260940085773.pdf> <https://www.sciencedirect.com/science/article/abs/pii/S0016003200000685#:~:text=The%20advantage%20of%20the%20bond,a%20compact%20and0%>
- [4] Thomas, Jean Ulrich (1975). Bondgraphs: introduction and applications. Oxford: Pergamon Press. ISBN 0-08-018882-6. Gawthrop, Peter J.; Smith, ISBN0-13-489824-9 ISBN0-8493-9648-4



[5] Modelling and simulation of engineering systems through bondgraphs. Boca Raton: CRC Press. ISBN 978-0-84930982-3. (12)

[6] Gawthrop, P.J.; Ballance, D.J. (1999). "Chapter 2: Symbolic computation for manipulation of hierarchical bond graphs". In Munro, N. (ed.). Symbolic Methods in Control System Analysis and Design. London: Institution of Electrical Engineers. pp. 23-52. ISBN 0-85296-943-0.