A Review on Application of Multibody Dynamics in the Field of Robotics

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ABSTRACT

With advancements in technology, robots have become very common. As robots consists of multiple connected links and moving parts, their design involves multibody dynamic analysis. This paper reviews how multibody dynamics have been explored as a design tool in the field of robotics.

INTRODUCTION

Most of the machines and systems including automobiles consists of a number of solid bodies that are interconnected to each other and motion of one component results in constrained motion of other. Such systems are called multibody systems[1]. Suspension systems in automobiles, landing gear of an aircraft, robotic manipulators, wind turbines all are examples of multibody systems. As different components are interacting together in a multibody system, for designing the system it becomes important to analyze how motion and forces are transmitted in the body. The study of motion of multibody system under the influence of force is commonly termed as multibody dynamics.

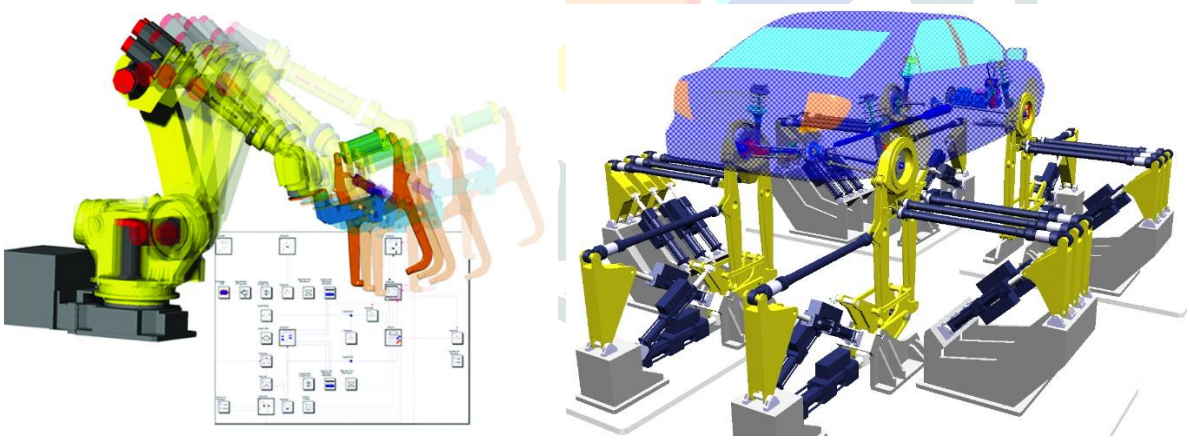

Figure 1 Example of Multi-body Systems [1]

A multibody dynamic analysis involves study of the movement of, impact of multiple bodies. As a robot manipulator consists of multiple links connected together and is used for applications that require control over path and forces involved in movement, multibody dynamics is used in robotics for manipulator design and motion analysis. This paper discusses the research trends in the application areas of multibody dynamics and major applications of MBD in the field of robotics.

LITERATURE REVIEW

Multi-body dynamics (MBD) has grown during the last 20 years to become an important and effective tool in the design, prototyping, optimization and simulation of complex mechanical systems, biomechanical and

multi-physics problems. MBD as one of the most active branches of applied mechanics is based on classical and analytical mechanics. A clear historical development was given by Professor Schiehlen explaining roots, the state-of-the-art and perspectives of MBD [2]. MBD have been for simulating and analyzing motion of mechanism based on cartesian coordinates have been discussed by E Bayo et. al. [3]

In the time period before 2006 multi-body dynamics was primarily acknowledged as an independent branch of theoretical, computational and applied mechanics around the globe and the research trends were discussed with respect to the subjects and countries dealing with multi-body dynamics by Professor Schiehlen [4] In review part at the beginning of present work research trends were analyzed as a brief extension of Professor Schiehlen work, with respect to areas, topics and applications as contributions published in "Multibody System Dynamics" journal in last 10 years. It has been found that theoretical and computational methods, flexible multi-body systems, contact and impact problems, algorithm, integration codes and software along with vehicle dynamics have been areas of prominent application and study of multibody dynamics.

The applications of MBD in the field of robotics are presented in following table:

Table 1 Literature Review

Authors	**Year**	**Area**	**Findings**
W. Schiehlen [2], [4]	1997, 2007	Multibody system dynamics	Author reviewed multibody dynamics as modeling and simulation tool and found it to be promising research subject.
Pinhas Ben-Tzvi, Andrew A. Goldenberg, and Jean W. Zu [5]	2008	Hybridization of the mobile platform and manipulator arm	Authors used computer software Adams to perform multibody dynamic modeling and simulation of robotic system that led to decrease in the time used in modeling and designing and development of prototype.
Junzhi Yu, Lizhong Liu and Min Tan [6]	2008	Modeling of robotic fish	Authors used Schiehlen method with kinematics to design propulsion mechanism for the robotic fish and then integrated it with hydrodynamic analysis to determine dynamic equations required for modeling of equations in computer and controller.
E. Abele1, J. Bauer, C. Bertsch, R. Laurischkat, H. Meier, S. Reese,	2011	Modeling of elastic joints of industrial robot	Authors compared the flexible joint multibody dynamics system model of an industrial robotic arm consisting of 5 links using computer software Adams

M. Stelzer4, and O. von Stryk [7]			and SimMechanics. The simulated path agreed with actual robot path in y-direction. However, the effect of gravity resulted in differences in the path generated in z-direction.
Houman Dallali, Mohamad Mosadeghzad, Gustavo A. Medrano-Cerda, Nicolas Docquier, Petar Kormushev, Nikos Tsagarakis, Zhibin Li, and Darwin Caldwell [8]	2013	Dynamic simulation of humanoid robot	Authors developed a simulator for dynamic analysis of compliant humanoid using symbolic multibody approach. The simulator provides dynamic simulation of complete robot and works in C and MATLAB language.
A Purushotham and J. Anjeneyulu [9]	2013	Robot arm dynamics	Authors used Kane's method to perform multibody dynamic analysis of a 2R robotic arm using computer software MATLAB.
Stefano Baglioni, Filippo Cianetti, Claudio Braccesi and Denis Mattia De Micheli [10]	2016	Error evaluation and modeling of n-dof robotic arm	Authors modelled multibody model of robotic arm with n degrees of freedom to perform dynamic analysis and calculate errors when used in milling manufacturing. The model was based on Denavit-Hartenberg convention. Simulink was used to perform dynamic analysis.
Anand Nagarajan, S. K. Rajesh Kanna, and V. Manoj Kumar [11]	2017	Simulation of hyper-redundant robotic manipulator	Authors performed dynamic analysis of hyper redundant manipulator, which contain multiple degrees of freedom in same direction, using computer software ADAMS and coupled the results in ANSYS to complete the interaction.

Alexandra A. Zobova, Timothée Habra, Nicolas Van der Noot, Houman Dallali, Nikolaos G. Tsagarakis, Paul Fisette, and Renaud Ronsse[12]	2017	Modeling of compliant humanoid robot	Authors studied COMAN humanoid robot using a multibody dynamic simulator. The simulator developed was tested by comparing with actual robot
Kazuma Komoda and Hiroaki Wagatsuma [13]	2017	Analysis of legged robots with different closed loop mechanism	Authors applied multibody dynamic analysis to compare different legged walking mechanisms. Energy consumption and motion parameters of Chebyshev linkage, Klann and Theo Jansen mechanisms were compared.

SUMMARY

Multibody system analysis finds its application in robotics for variety of applications. Energy consumption for movement of a link or energy losses due to friction during movement can be calculated using this method. Implementation of multibody dynamic analysis using various computer software has become common and helps in saving time and resources. Today, multibody dynamic analysis combined with finite element analysis is a prominent area of research.

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