International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

Comparison of Methodologies for Conceptual Design of Mechanisms

Shoumik Pravin Kulkarni[1], Maruti M. Khot[2]

[1]P.G. Research Scholar, Mechanical Engineering Department,
Walchand College of Engineering, Sangli, Vishrambag-416415, Maharashtra, India

[2]Assistant Professor, Mechanical Engineering Department,
Walchand College of Engineering, Sangli, Vishrambag-416415, Maharashtra, India

Abstract: ***In the design phase of mechanisms, which is the most important step, the information with which the designer has to start with is the set of given specifications. These specifications are classified into three different categories viz. structural requirements, functional requirements, and design constraints. In the long course of history, designers and researchers are in pursuit of the systematic approach for the conceptual design of mechanisms, which would enable them to establish direct relationship between these given set of specifications and the candidate mechanism under consideration. This paper reviews and compares four methodologies for the conceptual design of mechanisms.***

Keywords: Conceptual design, Mechanisms, Design specifications.

1. Introduction

In any mechanical design problem, the most crucial stage is of conceptual design. In this stage, one has to initiate the design process by conceptualizing the probable solution for the defined problem or task based on the given set/s of specifications [1]. Similar is the case for mechanism design. It is very important and difficult task to conceptualize the mechanism based on given set/s of specifications. In some cases, only task, that the mechanism has to perform, is mentioned and the designer has to imply the other specifications based on his/her ingenuity. These specifications play key role in deciding whether the designed mechanism addresses the defined task or not and therefore, it becomes necessary part of the process to analyze them thoroughly. At the end of process, the solution mechanism should be such that it addresses each specification mentioned or implied initially.

Under such circumstances, there arises a necessity of a system or tool that enables designer to establish a direct relation between these specifications and the design concept or candidate mechanism under consideration. Thus far, four methodologies have been proposed through which designer can systematically approach from the given set of specifications towards the conceptual design of mechanism.

Freudenstein and Maki gave first breakthrough in this pursuit of systematic approach for conceptual design of mechanisms, followed by Dar-Zen Chen and Wei-Ming Pai, Hong-Sen Yan and H.V. Darbinyan. Brief outline of their methodologies are given later in this paper. These methodologies are compared with each other to state their advantages, disadvantages, effectiveness and their usability in various situations.

2. Design Specifications

As mentioned earlier, design specifications act as initial input to the design process. Therefore it becomes necessary to categorize them on the basis of their nature so that it becomes convenient for designer during embodiment process of them. Design specifications with various natures can be identified and classified into three coherent categories [2]: functional requirements, structural requirements, and design constraints. As shown in Fig. 1, design specifications are classified as functional requirements, structural requirements and design constraints.

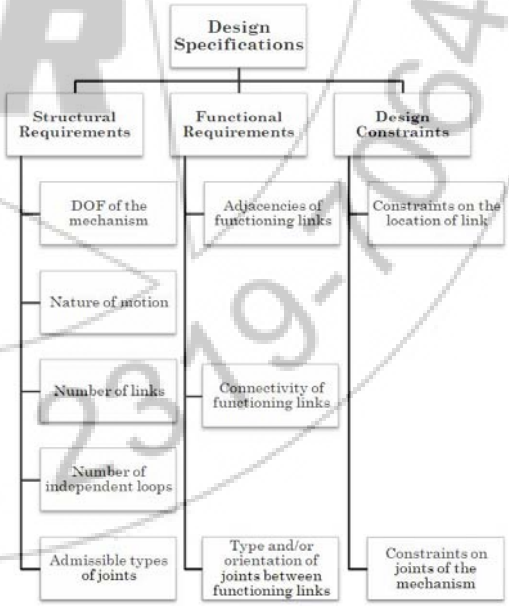

Figure 1: Classification of Design Specifications

Systematic approach for the conceptual design of mechanisms starts with the embodiment process of various design specifications since they are generally established in terms of a descriptive form. Hence, for such descriptive formulations usually depends on the ingenuity, intuition and

experience of a designer, and appears to be the most challenging task in the conceptual design stage.

In general, functional requirements mandate the motion relations of a set of specific functioning links, such as the input, output, and ground, etc. Functional requirements can be mapped into the required motion of functioning links and the required motion of functioning links can be embodied as (1) adjacencies of functioning links, (2) connectivity of functioning links, and (3) type and/or orientation of joints between functioning links.

Design specifications with a set of parameters used to determine the kinematic structure of the mechanism are referred to structural requirements. This set of parameters include the DOF of the mechanism, the nature of motion, the number of links, the number of independent loops and admissible types of joints, etc.

Design specifications based on particular engineering reasoning and imposing restrictions on the mechanism are considered as design constraints. Two kinds of constraints are often involved: (1) constraints on the location of link such as the input, output, and ground, etc. and (2) constraints on joints of the mechanism.

3. Overview of Methodologies

3.1 The Creation of Mechanisms According to Kinematic Structure and Function by Freudenstein and Maki [1], [2]

Based strictly on structural requirements, Freudenstein and Maki developed a systematic approach for the conceptual design of mechanisms, where admissible mechanisms are enumerated. Atlases of admissible kinematic structures, such as those of kinematic structures with up to six links, eight links, ten links, and eleven links have been established during the past three decades.

Following the enumeration of admissible kinematic structures, ground link is assigned and joint types are labeled in as many non isomorphic ways as possible in search of candidate mechanisms. Since only structural requirements are used to enumerate candidate mechanisms in this approach, the needs for human ingenuity and experience involved can be substantially alleviated. Functional requirements together with design constraints are then used for further viability evaluation. As a result, feasible mechanisms that fulfill design specifications are obtained by the way of rejecting those candidate mechanisms failed in the evaluation process. However, numerous infeasible mechanisms are subsumed since only structural requirements are considered in the enumeration of candidate mechanisms. Thus, in turn, it leads to circumstances, where infeasible mechanisms need to be carefully screened out from enumerated candidate mechanisms, resulting in a tedious and inefficient process.

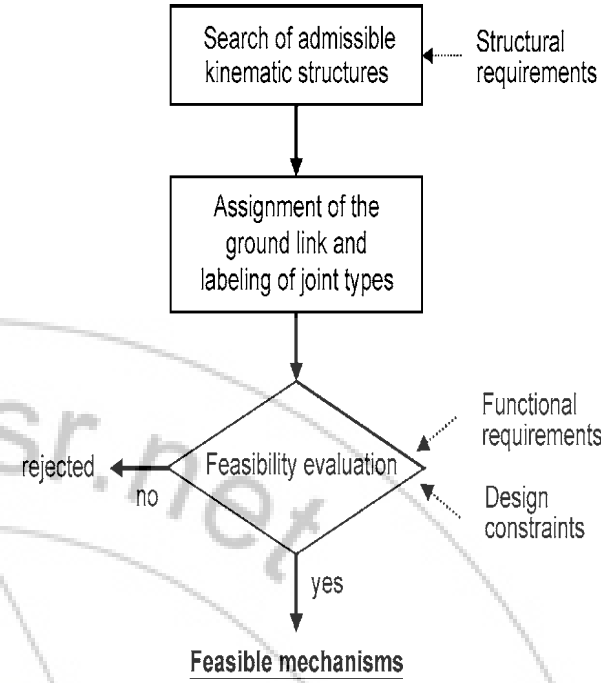

Figure 2: Conceptual design approach by Freudenstein and Maki [2]

3.2 A Methodology for Conceptual Design of Mechanism by Parsing Design Specifications by Dar-Zen Chen and Wei-Ming Pai [2]

As shown in Fig. 3, design specifications are classified as functional requirements, structural requirements and design constraints.

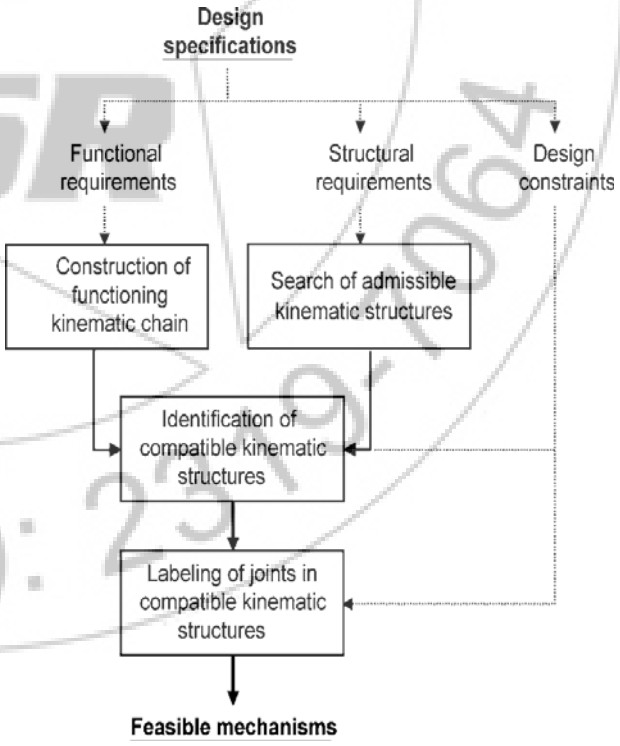

Figure 3: Conceptual design approach by Dar-Zen Chen and Wei-Ming Pai [2]

Motion requirements of a set of functioning links, such as the ground, input and output links, are specified as functional requirements. Mapping functional requirements to

the connections of functioning links, the functioning kinematic chain of a mechanism can be constructed. On the other hand, based on structural requirements, admissible kinematic structures of the mechanism are searched from the existing atlases of kinematic structures. By assigning the functioning kinematic chain into admissible kinematic structures subject to design constraints on locations of functioning links, compatible kinematic structures can be identified. According to design constraints on joints of the mechanism, joints in those compatible kinematic structures are labeled to yield feasible mechanisms. With this procedure, conceptual design of mechanisms can be performed in an efficient manner.

3.3 A Methodology for Creative Mechanism Design by Hong-Sen Yan [3], [4]

Hong-Sen Yan suggests design methodology that starts by investigating the existing designs to determine their topological characteristics and choosing one of the existing designs to serve as original mechanism. Next step is to transform the original design into its corresponding generalized kinematic chain. Third step is to synthesize the atlas of kinematic chains with required numbers of links and joints. The forth step is to obtain specialized kinematic chains by assigning types of members and joints into elements of kinematic chains subject to design requirements. The fifth step is to identify acceptable specialized kinematic chain subject to design constraints. The sixth step is to particularize each acceptable specialized kinematic chain into its corresponding mechanism. And the last step is to remove all the existing designs from generated atlas to obtain new designs.

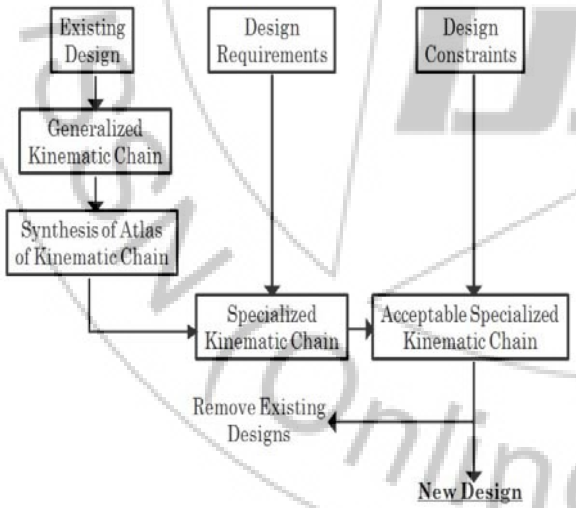

Figure 4: Methodology Proposed by Hong-Sen Yan

3.4 Task Based Conceptual Design Method by H.V. Darbinyan [4]

In general the Task Based Conceptual Design Method consists of the following steps [4]:

1. Consider the function.
2. Modify the prototype to develop the model or develop the model or develop the model from the scratch implementing the required function. Use the standard set of tools for all modifications.
3. Apply standard set of tools to satisfy more functions.
4. Generate the function entity (function tree).
5. Pick up set of functions for next step of conceptual design.
6. Repeat p.5 until no more functions are generated.
7. Reject a mechanism and restart from parent function or model if some function or the requirements of minimum link number are violated.

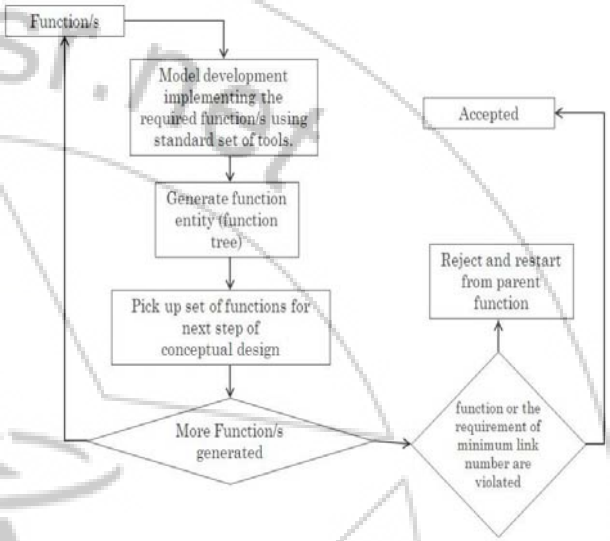

Figure 5: Task Based Conceptual Design Method by H. V. Darbinyan

4. Comparison of Methodologies

First three approaches, viz. Creation of Mechanisms According to Kinematic Structure and Function, A Methodology for Conceptual Design of Mechanism by Parsing Design Specifications and A Methodology for Creative Mechanism Design, are taking the topological characteristics of the future mechanism, generating possible options on the same topological base, considering structural requirements and design constraints, filtering the not acceptable options and confirming the novel mechanism.

Whereas, Task based Conceptual Design Method goes by approach of addressing each function to be performed by future mechanism one by one according to hierarchy established earlier. While doing so it treats all the requirements. It operates on the standard systematic tool set which can be used in iterative manner over and over again, at the any stage of design, until all the aims of the designer are finally achieved.

So, here while comparing (Table 1) these methodologies of conceptual design, it would be better to compare this task based conceptual design method with other three as they (first three) follow similar pattern and share same advantages and disadvantages.

Table 1: Comparison of Methodologies

No.	*Particulars*	*Task Based Conceptual Design Method*	*Others*
1.	Components of Design Specifications (functional requirements, structural requirements and design constraints)	Considered as equal	Not Considered as equal
2.	Methods of Implementation for components of design specification	Are involved consecutively in same method	Different methods are used
3.	Dependence between function and mean of implementation	Direct dependence	Isolates the direct involvement
4.	Standard methodical tool	Available	Not available
5.	Task decomposition	Arrange hierarchically and manage the function entity generated as a result of application the synthesis tool. Decomposing the large task into smaller manageable tasks and trying to find solution for each function applying the same set of intuitive design methods. Concentrate on local manageable task instead of large difficult to manage task.	Not using decomposition of task because all the design specifications are not considered as equal functions.
6.	Functions addressed	Key Function as well as requirements for implementation of the Key Function. They may be sub subjected to the Key Function but the Key Function cannot be provided without them, so they are as important as the Key Function.	Existing methods are not addressing the requirements of involvement of numerous functions and have not universal (standard) method for mechanism generation.
7.	Stage of Application	Iterative process which can be applied at any stage of design such as synthesis, analyzes, simulation and modeling of the mechanical object.	Can be applied at initial stage only.

5. Discussions

For first three procedures, design specifications are classified as functional requirements, structural requirements, and design constraints. These different categories of design specifications are used to guide the construction of functioning kinematic chain, identification of compatible kinematic structures, and labeling of the joints in compatible kinematic structures. With this methodology, design specifications are well classified and systematically taken into account during the conceptual design process. As a result, the enumeration of feasible mechanisms is performed in a much more efficient manner. It is believed that this methodology can be beneficial for the design of mechanisms in the conceptual design stage.

For Task Based Conceptual Design Method direct dependence between structure and function allows managing the synthesis process. Developed set of synthesis tools provides development of original model per predefined functions. Function generation engine provides systemized arrangement of functions and pick up for new function development. Mechanism expansion possibility (with the help of synthesis tool set) allows examining not visible (hidden) functions of the mechanical object. Mechanism contraction possibility allows changing the key function of design and defining different models per task. Function arrangement possibility allows organizing function pick up of necessary function for its resolution. Different visualization means facilitate management of design process. Decomposition of tasks based on function arrangement method localizes the task to only one solution. The development method is flexible giving the chance to restart development at any phase and still use the same standard set of tools.

6. Conclusion

In this paper four methodologies proposed for Conceptual Design of Mechanism are compared. Three of the methodologies are same in nature where components of design specifications i.e. structural requirement, functional requirement and design constraints, are considered separately while designing the mechanism. Based on these requirements kinematic admissible functional chains are enumerated and further subjected to design constraints for rejection.

Whereas in Task Based Conceptual Design Method every function or requirement is considered one by one and subsequently it is achieved in the design in iterative manner.

So it can be concluded that, however efficiently the kinematic chains are enumerated it is very tedious process and the first three processes fails to control all the functions generated by mechanisms during design process. In contrast, Task Based method offers flexibility to designer and ensures that each and every aspect of mechanism design can be covered.

7. Future Scope

Though the first three methods fail to provide detail control over entire design process of mechanism, they can be used in

simpler designs where only key function is the point of focus. Whereas, task based method provides better control over each and every possible function. In future, combination of the steps involved in all of these approaches to optimize the design process can be done. It will result in new more efficient process. Also, computer algorithms of these processes may also be developed to aid the designer throughout the process in the cases where data to be handled is large.

References

[1] Freudenstein F. and Maki E.R., "The Creation of Mechanisms According Kinematic Structure and Function," Environment and Planning B, Vol.6, No.4, pp. 375-391, 1979.
[2] Dar-Zen Chen and Wei-Ming Pai, "A Methodology for Conceptual Design of Mechanisms by Parsing Design Specifications," Journal of Mechanical Design, Vol.127, No.6, pp. 1039-1044, November, 2005.
[3] Hong-Sen Yan, "A Methodology For Creative Mechanism Design," Mechanism and Machine Theory 27(3), pp. 235-242, March 1991.
[4] H.V. Darbinyan, "Task Based Conceptual Design Method," In Proceedings of 13th World Congress in Mechanism and Machine Science, Guanajuato, México, 19-25 June, 2011.

Author Profile

Shoumik Pravin Kulkarni received B.E. in Mechanical Engineering degree in 2011 from Pune Vidyarthi Griha's College of Engineering and Technology, Pune and Pursuing Master of Technology in Mechanical Design Engineering degree for year 2014 from Walchand college of Engineering, Sangli.

Maruti M. Khot completed Diploma in Mechanical Engg. in 1997, Graduated in Mechanical Engg. in 2001, completed Post graduation in Mechanical Engg. in 2007. Submitted Ph. D. thesis on 30th Dec. 2013 at Shivaji University Kolhapur India. Working as a Assistant Professor in Mechanical Engineering Department Walchand College of Engineering, Sangli, India, since 2006. Two research papers papers published in Indian Journals, One paper presented in International conference