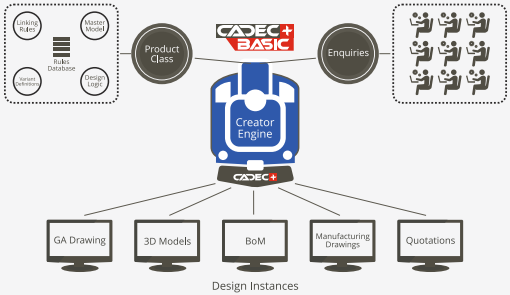

Mark
IMPROVING
DESIGN PRODUCTIVITY

CADEC+
DESIGN AUTOMATION

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Machine Design

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Machine Design

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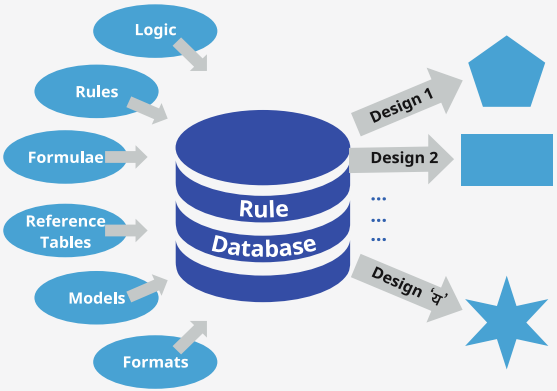
Namaste!

This book briefly conveys background and usage of Machine Design Automation process. We at Mark Design are trying to automate the process of machine design since last 12 years. In this journey, our customers are our inspiration. They are always trying to make more & more sophisticated machines, and also push us to make the machine design process in their companies, more systematic & automatic.



Now let's see what is CADEC+?

Those who know KBE i.e., Knowledge Based Engineering, our KBE is CADEC+. For others, CADEC+ means a software for capturing and leveraging machine design rules, logic calculations, model & drawing formats etc. for design automation.

When you need to design a customized machine, you can give your specifications to CADEC+. CADEC+ does calculations & prepares models / drawings & gives them in the required formats.

What is needed for using CADEC+ – only proper information of your design process – i.e., variations, calculations, validations, output formats etc. These are known to the domain experts. Domain experts are intelligent people who have worked for several years in a company & industry. This software is meant for knowledgeable & experienced people. CADEC+ is also integrated with tools like 3D-CAD (Solid Work,Solid Edge), Excel, etc.

CADEC+ is dedicated to domain experts, who want to automate routine machine design work & get more free time for innovative work. So, let's get on to our CADEC+ journey!!

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2) **Use of CAD for machine design**
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4) **CADEC+ vocabulary**
5) **Defining product family**
6) **Capturing design calculations**
7) **Linking logic with models**
8) **Creator – Fruits of CADEC+**

Machine Design

CADEC+ APPROACH

1

Machine Design Process

What is a machine? It is a facility to do some work with ease, less efforts, good quality. In **CADEC+**, we use the word machine for combination of devices & equipments. Design means preparing a plan. In this plan, there are models, drawings, Bills of Materials (BOMs), process sheets, price sheets etc. But R&D and innovation is not included here. It is presumed that machine design process begins after doing R&D and innovation.

Who has such machine design process? Many manufacturing companies do R&D / innovation to do some work with ease, less efforts, good quality. After R&D, product concept is developed.

When they approach market, different clients want different variations of the machine to suite their needs. So, customized designs are needed. And for creating such customized designs, machine design process is required.

Different companies identify this process by different names – like application engineering, change parts design, design modification, projects etc. It is different than R&D. R&D projects take more time, and are less frequently initiated. Machine design (design modification) projects take less time, and are very frequently initiated.

What is included in this machine design process?

- Information about materials & raw materials
- Application (machine usage) clarity
- Calculations of strength & functionality
- Information of manufacturing processes
- Information of preparing detailed drawings
- Information of preparing BOMs
- General Arrangement (GA) layout preparation, etc.

Naturally, it's difficult for one person to have all this information. Only senior persons may have all or most of the information. But they are involved in many important functions. So, they want to delegate tasks to team members & guide them / approve their work.

In this process, we have to think from high level (GA layout, application knowledge) to low level (raw material availability, detailed dimensions). There are many calculations involved in this. Also, many references / standard handbooks have to be referred. Sometimes, some application R&D, analysis is required to be done.

We mainly think of mechanical design in CADEC+ - i.e. strength, material, dimensions, process sheets, fabrication / machining / assembly drawings, BOM etc. Functionality design for mechanical products is also included. For electrical, electronic, chemical, thermal products, functional design calculations and design of mechanical hardware are included.

Thus, machine design includes creating new concepts, modifying old ones, getting design approved from customers, releasing detailed design, etc. This was a general overview of machine design process. We will consider use of CAD in the next section.

Machine Design

CADEC+ APPROACH

2

Use of CAD for design

When we say CAD, we first think of AUTOCAD. But here, we consider 3D CAD because :

1) 3D Visualisation becomes easy & error-free.
2) It's parametric. So, when numerical values change, graphics (geometry) changes automatically.
3) When 3D models are created, drawing views & BOMs are available without extra efforts.

3D CAD requires more investment of money, time & efforts than AUTOCAD. So, those designs which are complex, frequently changing and need precise geometry details, are considered here. Machines which need 3D CAD for design are material handling systems, fabrication, fixtures, hydraulics, process equipments, testing / packaging machines, control panels, heat & mass transfer equipments, filtration units etc.

In 3D CAD, Solid modelling is more popular, because in Solid model, product can be seen as it is, and there is no need of validating geometry. Parts and features of model match with physical product. So only product knowledge & common sense is needed to create model. For example, to create model of table, legs & top are required. To model top, you need to extrude a rectangle, and to model leg, you need to revolve a rectangle. Then they need to be placed with respect to each other, or the assembly.

Once, the model is created as per requirement, the drawings & BOM are bye-products. So, if the model changes, the drawings & BOM also change automatically. These drawings, models, BOM can be viewed easily in PDF & Excel formats.

In the next section, we will understand similarity between modelling and programming.

Machine Design

CADEC+ APPROACH

3

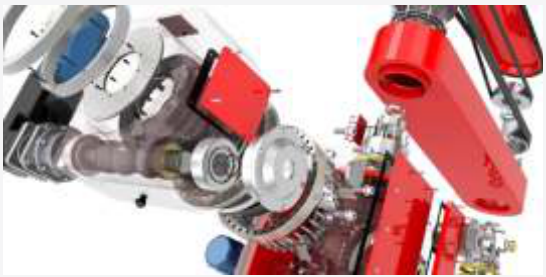
Mechanical Objects

As we have seen in previous chapter, components of 3D models & actual machines are similar. Models, drawings & BOMs are associated with each other. CAD model components are like programming components. Because of parametric technology, when numerical values change, graphical shapes / sizes also change.

You can re-use components in modeling. If the component is linked, the same file can be used in many assemblies. If you change it, automatically changes are seen in all assemblies using the components. If you don't want that, then you can embed the component. So, if template changes, components created from that template don't change. A lot of combination designs can be made from few generalized components.

In **CADEC+**, we have used the concept of OOPS (Object Oriented Programming Systems). OOPS & modelling are similar in many ways. Those who know OOPS will realise this. **CADEC+** uses mechanical objects.

What are these mechanical objects? Generalised parts or assemblies are components. Components have features like extrude, revolve, pattern etc. Dimensions of these features are properties of these components. Further, whether a component requires a feature or not, is also the component's property.



We can capture components, features, their properties from master model of a product concept in **CADEC+**. Various design outputs can be created by modifying quantity, dimensions, arrangement of components and features based on design requirement.

We can define variables and calculations in **CADEC+** to find numerical values of quantity, dimensions & arrangement. For calculations, formulae / reference tables can be given. Even these variables, formulae & tables can be changed as required. When these variables are linked to model properties, the entire process from specifications to formation of model becomes completely automated, without any programming.

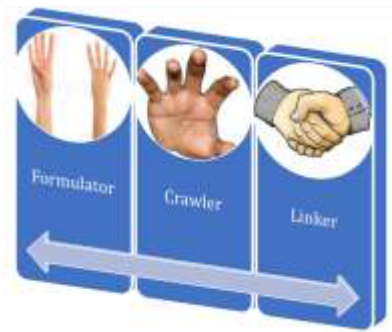
This is **CADEC+** approach. In the next section, we will understand it's vocabulary.

Machine Design

CADEC+ APPROACH

4

CADEC+ Vocabulary



When using any technology, we need to know the meaning of important words / concepts to leverage the technology effectively. In this section, we will see the CADEC+ vocabulary.

1 Product class: Generic master model, drawing formats and calculation database of a product family.

2 Classifications: A product is used for different applications & requirements. There can be hundreds / thousands of variations. A master model is required to encompass all these. Classifications are useful to create such a master model. If we classify these variations on the basis of different functionalities, we can make sets of each functionality along with their components & features. These are classifications.

3 Options: Combinations of each classification's components, features are known as options. So, total functionality combinations = multiplication of each classifications' options.

4 Shape variables: Same as Classifications.

5 Shape values: Same as Options.

6 Size variables: These are variables which are required for calculations. These are related to dimensions, quantity, etc. So, they are numeric. These may be input or dependant.

7 Size values: Calculation formula or logic.

8 Size validation: Additional information needed to calculate variable value. For example Range, Series, Driven Shape, etc.

9 Rules: Facility to define Lookup (reference tables), optional drawings, quotation formats, etc.

10 Lookup table: Facility to refer to values from table instead of using formula.

11 Crawling: Updating database by capturing components, features from master model.

12 Shape linking: Linking options with components & features.

13 Model parameters: Parameters from sketch, feature, pattern, mates. For example, D1@Sketch1

14 Size linking: Linking calculation variables with model parameters.

15 Creator: Facility to auto-generate new design (design instance) using product class.

16 Layout ID: Unique ID of each new design instance.

In the next section, we will see the method of defining product family.

Machine Design

CADEC+ APPROACH

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Defining Product Family

In this section, we will start using CADEC+. Let's take an example for better understanding. We will consider bicycle product class. Older bicycles like Hercules, BSA, etc. did not have much variety. However, latest bicycles have many variations. Let's define product class of a bicycle. Select folder & name the class to define the new product class.

Now the first and important step is to classify the bicycles. How to do it?

1. Type of frame: Steel, Aluminium, Carbon
2. Handle: Normal. Lowered
3. Brake: Disk, V
4. Gear set: 2x9, 3x8, 3x7

CADEC+ has facility of defining shape variations i.e., defining classifications and options. Add these classifications and options to the product class.

The next step is to decide which components are required in a bicycle: frame, wheel, crank, peddles, gearset, seat, brakes, etc. Then decide the important parameters of those components: frame height, frame length, wheel diameter, Center distance between two wheels, crank length, etc. You need to prepare a master model which will have different frames, handles, brakes. It would be an abstract (generalized) model.

Next step is deciding input specifications which would include measurements of hands & feet of customer, type of frame, handle, brakes, gearset etc. Output needs to be defined. You can use this application to get quotation (for customer), or drawings (for fabrication / assembly). Formats for quote and drawings need to be prepared.

In the next section, we will capture design calculations.

Machine Design

CADEC+ APPROACH

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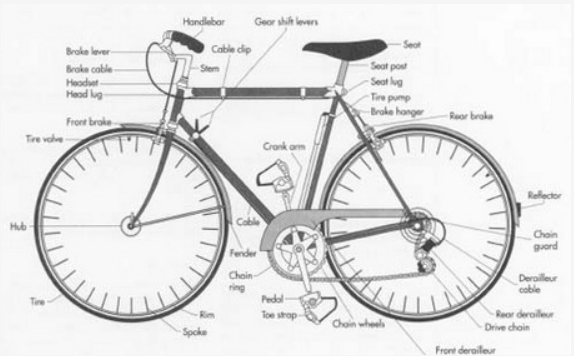
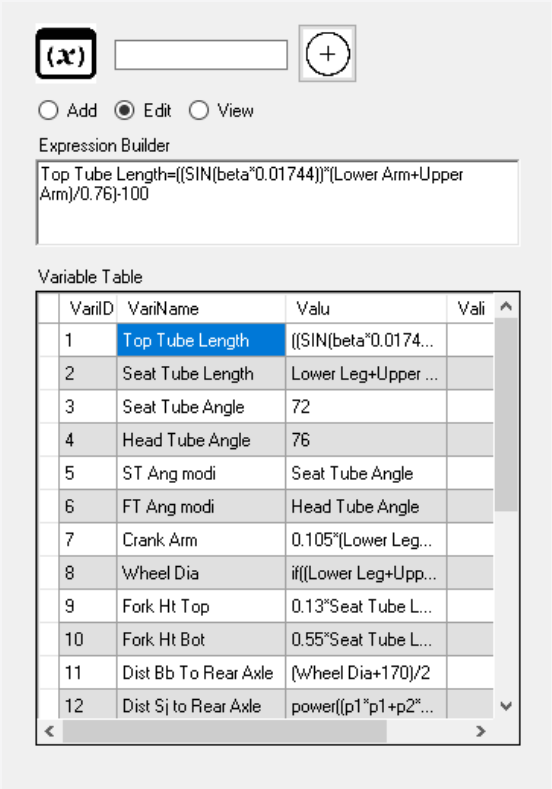
Capturing Design Calculations

These are rules to calculate values of derived variables from the input specifications. CADEC+ has a facility to capture calculation logic. You can specify variable name, formula, validation in a table. Any number of variables can be defined in any sequence.

Here are variables and calculation logic for bicycle:

1. Crank length: calculated from person's height
2. Distance of seat from lower peddle: calculated from leg height
3. Frame height (seat tube length): calculated from distance of seat from lower peddle
4. Distance of seat from handle (top tube length): calculated using Pythagoras Theorem & measurements of hand & body
5. Front fork height: calculated from seat tube length
6. Chain stay length: calculated from wheel diameter
7. Seat stay length: calculated using Pythagoras Theorem & chain stay length and seat tube length





Making these formulae could be a little tedious initially since design engineers mostly use existing formulae and rarely define them. However, once we you start developing logic, you can make formulae for any calculations easily.

CADEC+ has some more methods of calculations – e.g. lookup table, user defined functions, which we will see later.

In the next section, we will see methods of linking logic with model.

Machine Design

CADEC+ APPROACH

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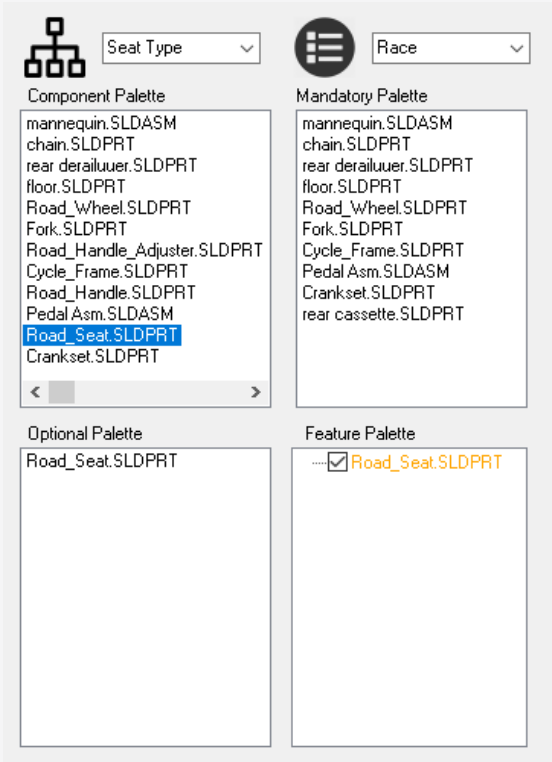
Linking logic with model

In this section, we will see how to link design calculations with model. Then, the model will get modified according to the user's requirements. We will also see how to link variables with excel sheet so that even quotation can be prepared. When model is crawled (captured), its entire information goes into database. The parameters in model can be shape parameters or size parameters.

Initially, we will see how shape linking is done. Shape parameters are properties that define whether component / feature is required or not. Component / features can be suppressed or unsuppressed as required. Those Components / features which are linked to options selected by user would get unsuppressed



CADEC+ has shape-link functionality. All top-level components can be seen in component palette. You can right-click on any component and add it to mandatory or optional palette. Mandatory means those components / features which are unsuppressed. Optional means those components / features which are required for the selected options. For adding component to optional palette, you need to choose the option in the Shape Value (Option) dropdown above.

When a component is selected in mandatory or optional palette, all its features can be seen from the feature palette. You can tick required features and Save. When the entire shape linking is done, press “Make mandatory” button, Then the mandatory components / features in model will get unsuppressed and the model will be saved.

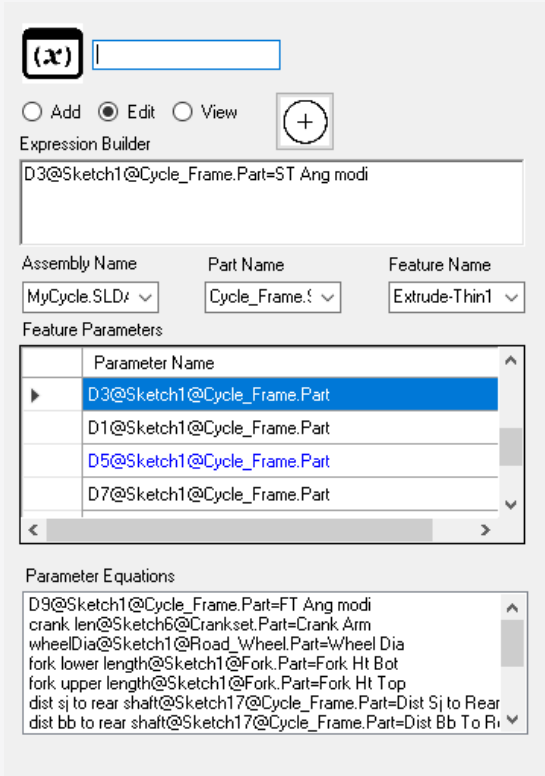
Size parameters are the parameters defining feature sizes. CADEC+ has size-link functionality. You can select assemblies, parts, features in a model from dropdowns. Parameters of selected feature are seen in parameter list. Linked parameters are seen in blue colour, others in black. To link, we have to select “Add” radio button & click on parameter so that it goes in equation editor.

In variable text box, you can search required variable and on selection, it gets added to Right Hand Side of the parameter equation. On clicking “+” button, the parameter equation gets added to equation list. On saving, this information goes to database.

If you want to get output without CAD, you can link excel sheet with variables. You can define master excel sheet (10 columns x 50 rows). Wherever you need calculated value to be updated, add a dollar sign prefix before variable name. Please give “quote.xlsx” name to the master excel file and save it in master folder.

Now we have completed all settings of bicycle family.

In the next section, we will see how customized designs of bicycles can be created using Creator.



Machine Design

CADEC+ APPROACH

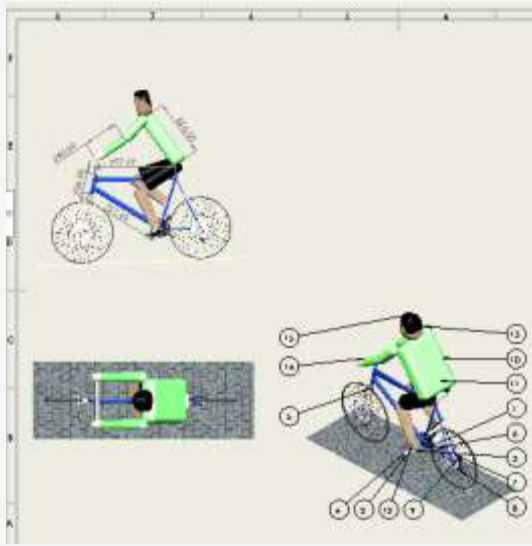
8

Creator : fruits of CADEC+

We have gone through all the previous steps so as to enable generation of customized designs of bicycle automatically. Now our application is configured. So, let's taste the fruits of CADEC+ .

All the configured applications can be seen in Creator. Choose bicycle application. Specify unique design number (layout ID) and specifications. Press “Calculate” button to see dependant values. Click “Modify” button to update the model. Click “Drawing” to generate drawings. (We will see how to configure drawings later). Click “Quote” to generate quotation.

All the specifications of each design created by us are stored in the database and previous specifications can be used / modified to create new designs. “Fetch layout data” functionality is provided for this.



This is CADEC+ approach. In the last 8 sections, we learnt how to configure KBE / product configurator. We will be happy to address your queries / comments. You can reach us at **info@markengg.com** or **9881742536.**