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Model Based Design for Effective Design and Development

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Abstract – Model based design is being used as a powerful tool in design and development activity. As compared to conventional design activity, it offers better effectiveness. Parametric variation can be studied and performance can be assessed. Present paper deals with application of such approach in valve spring design.

***Keywords* – Product Development, Mathematical Model, Parametric Design, System Design, Model Simulation.**

I. INTRODUCTION

In design and development process, any component or product, essentially there are certain iterative activities to be performed in analytical design. This is done using fundamental design principles, carrying out iterations manually using such principles and considerations. However, in recent years, with availability of computer based tools, this task has not only been simplified but also new facets have been added to it. Particularly in the system design and product development many distinct activities are involved. This can be represented by Figure 1 as shown below.

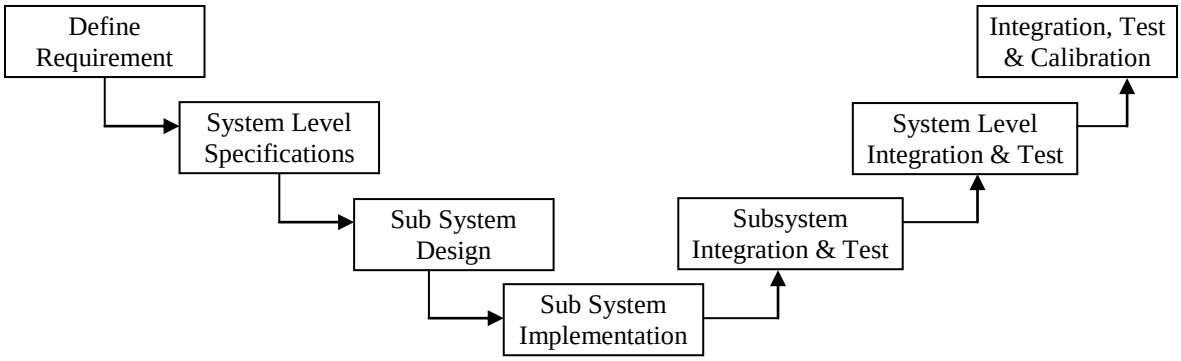

Fig. 1: Distinct Activities in System Design & Product Development

The entire activity can be represented in form of the two branches of V, indicating two distinct activities. The left branch deals with decomposition of initial requirements into subsystems and their components. The right branch represents the realization of these subsystems and component and their integration [1]. Traditionally these activities are executed by teams or groups and information normally in document from is passed back and fourth between the respective teams. This approach has many limitations, like parametric variation is laborious and time consuming. Modification in the design and its result assessment is also slow.

II. CONCEPT OF MODEL BASED DESIGN

In order to overcome the limitation posed by traditional activity, model based design is a preferred alternative to this development process. In this, model is built which is used throughout the design process; Figure 2 indicates different types of models.

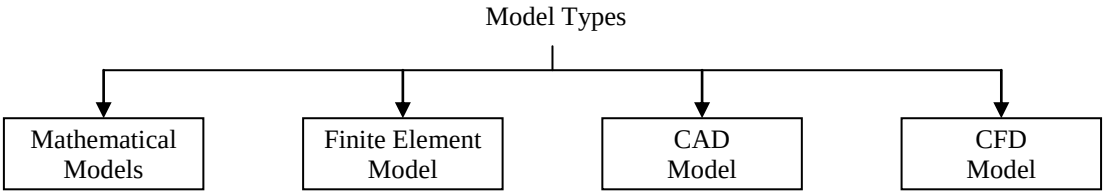

Fig. 2: Model Classification

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Above figure shows various types of models commonly built in model based approach. Regardless of the type of model, certain features of this approach are very much effective [2]. This can be represented by Figure 3 as shown below.

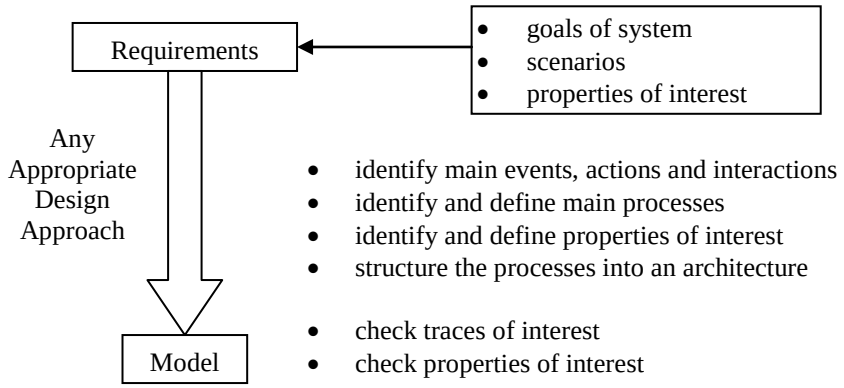
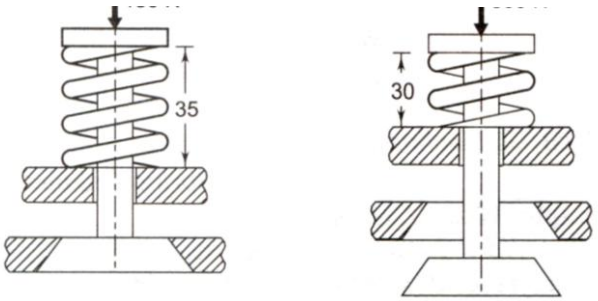


Fig. 3: Requirement Model Corelationship

As shown in Figure 3, the requirements guided by the goals of the system, properties of interest and circumstances are transformed into a model of any form as classified in Figure 2. A suitable approach is followed to build the model. In model based design, the mode is at the centre of the design process and various tasks surround the model. The model is the specification of the design. By using model based approach, dependence on physical prototype is significantly reduced [3]. Model based design pushes the executable model downstream throughout the design flow all the way down to test and verify, by elaborating that same model through the phases. Through this process model based design enables a circular closed loop of productivity, efficiency and innovation. Also the failure can be predicted by applying various theories of failures by building on finite element model using suitable finite element analysis software. Using special software's for simulation, it is possible to gain information about all the parameters that influence design, which may also include force, coefficient of friction, and position of forces, along with tolerances. There are software's like Sigmound, M IT Calc [4], TASysWorks which even support tolerance analysis of the element or mechanism after it is designed. After final design analysis like stability analysis can be carried out by using DOF software. Also the CAD model data can be used for activity like reverse engineering, which consist of creating full CAD model from 3D point cloud data. By making CAD model [5] fully parameterized component can be redesigned by changing attribute parameters. This paper deals with a typical case study of IC engine valve spring design using MATLAB 7.3 software. The problem is solved using analytical solutions with given input data. The outcome of above approach is verified using MATLAB 7.3 as mentioned below.

Analytical Approach:

Design inputs – K – (wahl's constant) = 1, P (Axial Load) = 300 N,
D (Mean Coil dia.) = 24 mm, N (No. of turns) = 7.



(a) Closed position with force 300 N (b) Open position with force 300 N

Fig. 4: IC Engine Valve Spring

For selected spring material permissible Shear Stress (ζ) is 411 N/mm^2.

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$$\zeta = k.\frac{8\,P.D}{\pi d^3}$$

$$\therefore \quad d^3 = k.\frac{8\,P.D}{\pi\zeta}$$

$$d^3 = \frac{(k \times 8)}{\pi} \times \frac{P.D}{\zeta} = \frac{(1 \times 8)}{\pi} \times \frac{P.D}{\zeta}$$

$$d = \sqrt[3]{\frac{(8)}{\pi} x \frac{P.D}{\zeta}}$$

$$d = 1.36 \sqrt[3]{\frac{P.D}{\zeta}}$$

Substituting above values,

$$d = 1.36 \sqrt[3]{(300) \times 24 / 411}$$
$$= 3.53 \text{ mm.}$$

$$\text{Deflection } (\delta) = \frac{8\,P.D^3\,N}{G\,d^4} \qquad \ldots\ldots\ldots \quad (a)$$

Since the modulus of rigidity (G) for the spring material is 81370 N/mm^2 equation (a) can be written with appropriate substitution as –

$$\delta = \frac{8\,(300)\,x\,(24)^3\,x\,7}{(81370)\,(3.53)^4}$$

$$= \frac{(2400)\,(13824)\,(7)}{(81370)\,(155.27)}$$

$$= \underline{18.38 \text{ mm.}}$$

With spring diameter corrected to integer 4 mm deflection (δ) = 11.15 mm

Axial gap = 15% of deflection
= 0.15 x 11.15
= 1.67 mm

Above analytical designed can be verified by using model based design approach as indicated. The analytical approach is, converted into MATLAB Simulink toolbox [6]. Accordingly, a model is built using appropriate, symbols as shown in Figure 5. Model [7] parameters are assigned parametric values and blocks are connected. The model is simulated and the results are verified. The spring diameter derived using analytical [8] approach is 3.53 mm where as the output of simulated model indicate output as 3.55 mm as displayed in Figure 6. Thus, the analytical approach is validated.

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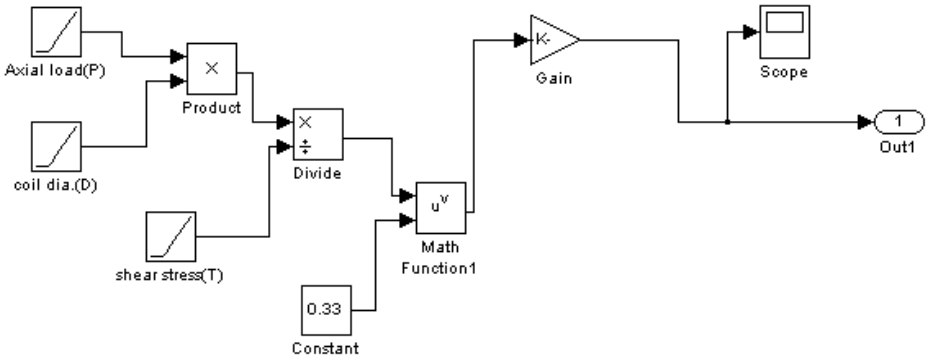

Fig. 5: Simulink Model

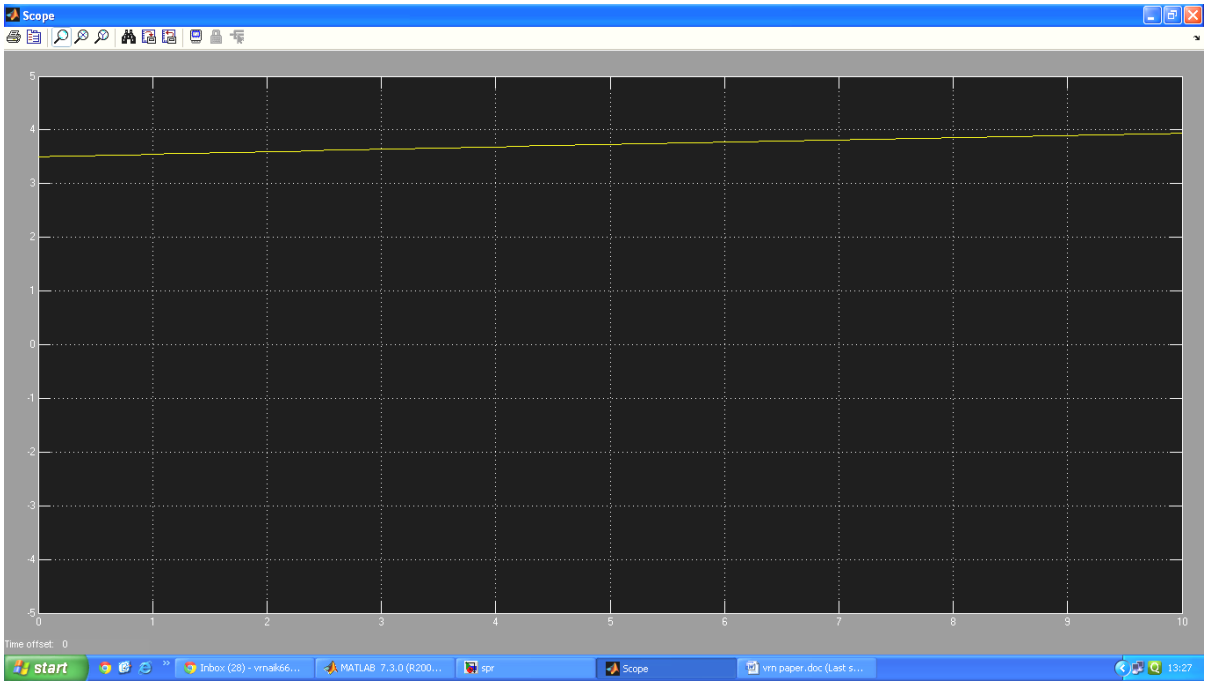

Fig. 6: Simulink Model Output

III. CONCLUSION

- Model based approach is a very powerful tool, to design the component, equipments and subsystems.
- This approach facilitates parametric experimentation and enable designer to study the results.
- This approach has a predictive feature whereby the designer can predict the outcome of the design before prototype development.
- Parameters experimentation is possible for crucial decision making.

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EDUCATION DETAILS:

College/university	Degree	Year	Field of Specialization
Shivaji University, Kolhapur	Ph. D. (Mechanical)	2011	Mfg. & ANN
Shivaji University, Kolhapur.	M.E. (Production)	1989	Production.
Shivaji University, Kolhapur.	B.E. (Mechanical)	1987	Design and Development.

PUBLICATIONS:

In Journals – 7 Nos.
International/National Conferences – 21 Nos.

RESEARCH WORK:

1) Nov 1998 – Developed Carpet Winding Equipment for Ministry of Heritage/Culture, Sultanate of Oman.
   Carpet winding and unwinding machine was designed and developed along with successful commissioning for woolen carpet of 5 kms. Long, 1.5 m wide and 2 mm thick. The machine was interfaced with sophisticated electronic devices and plc based controls, to control the linear speed of carpet, linear speed of lab and its synchronization.
2) Nov 1998 – Development of Cam development for Narendra Industries, Mumbai.
3) June-2005 - Vendorbase development & Manpower sourcing for Dogetech Industrial Corp. Taiwan
4) January 2011 – Development of blower test rigs for Kulkarni Power Tools (KPT), Shirol, M.S. India

MEMBERSHIP: ISTE Life Member: LM 22832 dated 18.10.1996

ACHIEVEMENTS:

- **Patent Filed –** Patent on "Liquid Level Controller" in December 2007 at Patent Office, Mumbai.
- **Faculty Development:** Lab Development, Signing MoU with National/International companies, Coordinates training programs, Instrumental in convening a PG course ME Mech. (PDD).
- **Examination Supervisors & Expert Faculty** at other Engg. Colleges.
- **Recognized as Permanent PG Teacher** by Shivaji University, Kolhapur for M.E. (Mech./Prod.) Course.
- **Conferences, Short-Term Courses etc. participated:** 18 Nos. within India and 01 International Training at SMC Pneumatics, Sidney Australia (10-15 Dec 2006)
- Recognized as Outstanding Performance in Teaching by Textile & Engg Institute, Ichalkaranji in year 2005-06.