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COMPUTER AIDED DESIGN—INDIAN SCENARIO

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Classical books on machine design deal with well documented machine elements like shafts, keys, gears, springs which are basically solved using laws governing statically determinate structures. But there are quite a number of problems in mechanical engineering wherein the static indeterminacy is present and the mathematical modelling complicated. Use of finite element method has come in handy in such cases. But its application demands careful planning and efficient use of computer memory and time. Neither the complicated nature of structures nor the complexity of loading like transient or random is no more of concern. Number of ready made packages are available to handle such problems. But it is essential to know what these programmes contain, how they work and what kind of infrastructure they need and how to modify the packages, if need arises.

Pre- and Post-Processing

Enormous amount of material has been pouring in on the subject "Computer Aided Design" in the recent past. It either deals with Computer Aided Graphics (CAG) or Computer Aided Analysis (CAA). Material under CAG usually deals with making component drawings from assembly drawings, layout drawings, enlarging, reducing or rotating a given three-dimensional object, preparing developments of components or interpretation of solids. Under computer aided analysis can be grouped finite element modelling of the given object, identifying the input forces and estimating the resulting response (deformations) and subsequently determining the stress levels at various locations of the components. If the component stresses are within limits, the design is considered safe. Otherwise, dimensions have to be altered, the iteration process repeated till the members are optimally designed, keeping the manufacturing constraints in mind. Even this analysis needs quite a lot of graphics, by way of discretising the object with the descretised information making sure that the input geometry is free of mistakes. This is known as pre-processing.

Once, the deformations are obtained, constructing the deformed shape of the object and identifying the zones of equal intensity of stress on the object under load are also exercises in graphics. Drawing the animated view of the deformed object under dynamic load at discrete time intervals is an interesting exercise in drafting. These can be grouped under post-processing. Both pre- and post-processing come under CAG.

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Nature of Work

Computer aided design has come in handy for proposing indigeneous design for major units in heavy engineering, automobile engineering and power plant engineering. Items like cement mills, kiln's electrostatic precipitators, partially filled storage vessels, pressure vessels, sugar mill stands, centrifugals, gear boxes, centrifugal fan impellers, turbine blade and discs, automobile chassis, crank shafts, nuclear power plant equipment prone to earthquake disturbance and defence equipment like multi barrel rocket launchers, sharp shooters, are some of the examples.

The Present Position

In our country ten years ago there were only a few organisations which were using Computer Aided Design to improve their products. This was primarily due to the inherent aversion in trying anything new. Besides the infrastructure demanded a sizable investment. But today with the advent of p.c's cost of installing a system and buying associated software is within the reach of a medium scale industry. Today a sum of Rupees five lakhs is more than adequate for this infrastructure. Maintenance of the system and software support is also available. What is needed is trained manpower in the design office to make the best use of this facility.

The awareness for insisting on quality in every aspect of manufacture has now been felt with the introduction of ISO 9000. After all design is the only one element of the broad area of manufacture. Insisting on a scientific approach to the design of any product is only logical.

Most of the design offices in manufacturing organisations are mostly drawing offices reproducing the manufacturers' drawings and taking copies these offices were doing. This was understandable since the designs were proven elsewhere and what was needed was to manufacture the products as per the drawings.

Now the situation is changing fast. The manufacturers have to face international competition. Moreover, in many areas which were sellers market have become buyers market. The customers want to get the goods as per their specifications. They do not want to accept what is supplied to them. Hence the need for manufacturing goods as per new specification has been a necessity. Thus, there is a necessity for a sound design base for the items manufactured. This leads one to reverse engineering, preparing a design knowhow for a product already available and functioning.

This leads one to look for design know-how. Design information on well defined products like shafts, keys, bearings, belts and gears has been nicely documented. All of them are statically determinate structure. On the other hand units like gear box houses, frames of presses, portal frames i.e., engine cylinders, pistons, are not statically determinate. These need more sophisticated design tool like the computer aided design using finite element analysis.

The use of finite element has been so versatile and user friendly that quite a number of finite packages have now come into the market. Some of the common ones are NASTRAMS, NISA, ANSYS, NONSAP, ADINA, ASKA. These packages normally are accompanied by a set of instructions for data preparation.

The main pitfalls in using these packages are the choice of wrong elements, choice of wrong infrastructure and inability to rely on the outputs without any bench marks. Sometimes inability to properly model the given shape may also result in totally wrong outputs. Fully trained manpower to run the system is a must. Adequate redundancy must be provided. A modest investment of Rs. 2 to 3 lakhs can cater to the needs of a medium sized design office to take care of the P.C. and the software associated with it.

Let us look at four specific cases of importance to mechanical engineering. Fig. 1 shows a fabricated two speed helical gear box of 195 hp with a net reduction of 8. The box leading demensions have to be designed to withstand the stress levels and to ensure deformations within limits. Typical isostress lines are shown in Fig. 2. This was made possible using the finite element package with shell elements. The whole exercise took less than 20s in a 486 P.C. In fact, it is very easy to alter any of the dimensions and look for the results almost immediately.

The second example is connected with the C frame of a 40 T hydraulic press (Fig. 3). Its isostress lines for a typical load is shown in Fig 4. The finite element model can take care of variation in thicknesses in the C frame, position and number of ribs connecting the two sides. It is easy to generate the response for standard size of plates available in the market.

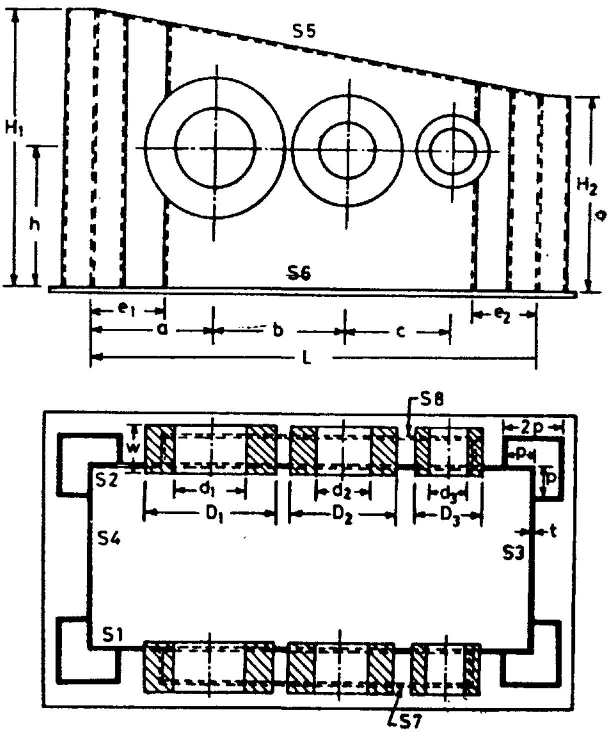

Fig 1 Fabricated gear box

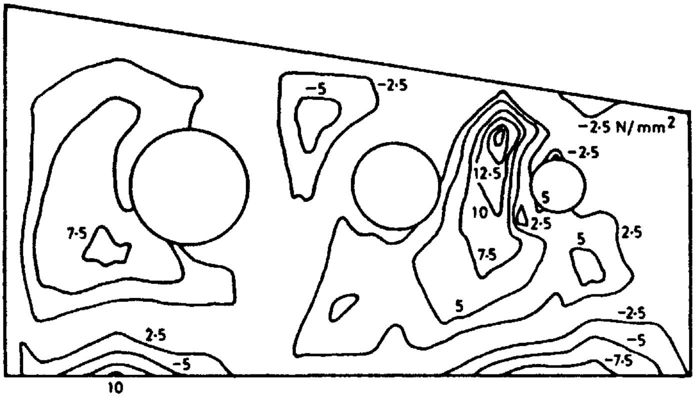

Fig 2 Isostress σ_x for face I of cast gear box

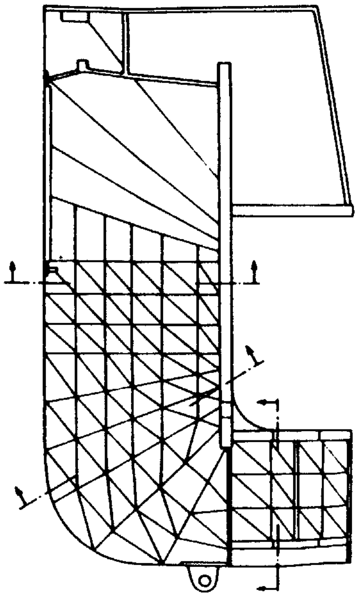

Fig 3 40 tonne c frame hydraulic press

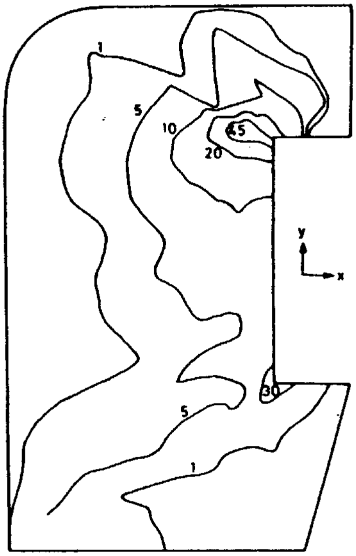

Fig 4 Isostress σ_y in N² mm front face of the press

The third example is connected with a turbo generator set of a nuclear power plant (Fig. 5). This is an ideal case of reverse engineering. We, in this country, have a long history of importing machinery from different countries, Generator and turbine from two different countries and the supporting structure manufactured from the drawings of a third source. The system can misbehave if the supply frequencies are not identical, soil properties different and dynamic model different from how it was at source. All these have to be looked into.

Last let us consider the dynamic analysis of multi barrel rocket launcher. The necessity for the analysis is to find the settling time of the launcher system

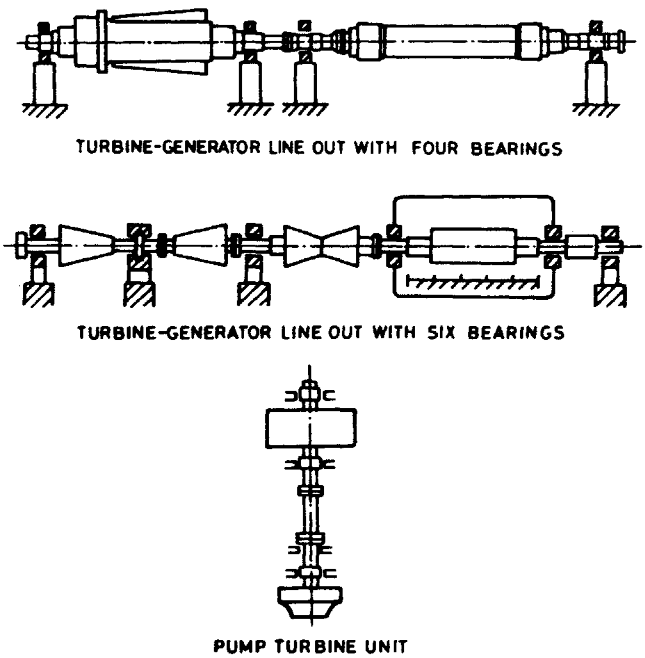

Fig 5 Turbo generator set of a nuclear power plant

which gets disturbed due to firing of the rocket and to determine the minimum time gap required between two successive rocket launches. This is a must because if the rocket is fired when the launcher pod is under disturbance, the accuracy of hitting the target cannot be achieved. In addition to this, dynamic analysis helps to find the maximum deflection and stresses experienced in the structure to check the strength of the structure for firing.

In the general arrangement of the multi barrel rocket launcher, which essentially is used for launching rockets of size 200 mm diameter and 6 m long, there are 2 launcher pods fastened on the cradle structure (Fig. 6). These two launcher pods are loaded with a maximum of 12 rockets at a time, but fired one after the other. The launcher system consists of four major structures namely, (1) Cradle (2) Revolving base (3) Underframe and (4) TATRA 8×8 815 VVN chassis. The cradle unit is pivoted at one end of the revolving base and at the other end on the clevis joint of the elevating cylinder. The other end of the elevating cylinder is pivoted by another clevis joint on the revolving base. Revolving base is mounted on a slewing ring bearing, which in turn fixed on the underframe and is driven by a hydraulic motor to alter traverse angle. The elevation angle of cradle unit can be changed by controlling the stroke of the elevating cylinder. The whole launcher structure is mounted on a truck to make it mobile. All these features make it a very versatile launcher.

Hydraulic outriggers attached to the underframe supports the entire structure at the time of firing. However, there is a possibility of front tyres of the vehicle touching the ground. This may affect the settling time of the launcher sys-

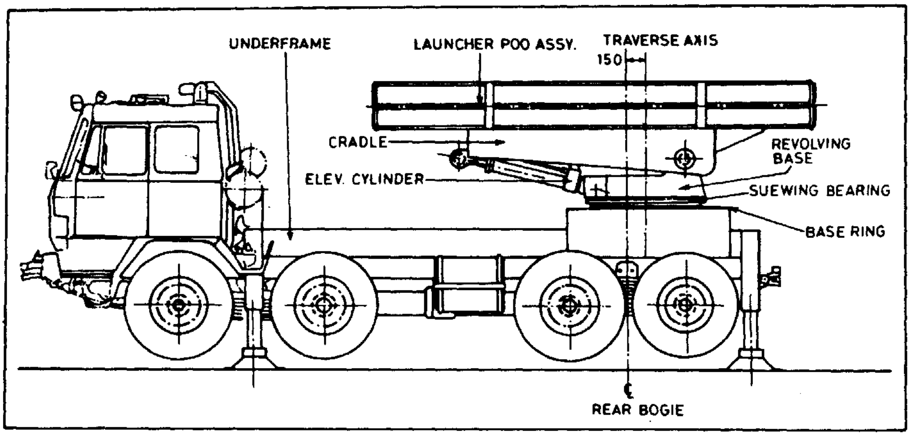

Fig 6 Multi barrel rocket launcher on our rigger cylinders

tem. Hence, two sets of analysis have to be performed, one with front tyres entirely off the ground and the other with front tyres touching the ground. The stiffness of tyres, leaf springs, outriggers and elevating cylinder are supplied. The launcher is meant for firing from 0-99° traverse on either side of the vehicle horizontal axis and 0.55° elevation. [3° for elevation is included to compensate the error due to ground inclination]. Hence, it as decided to perform analyses for the worst cases. Details of the launcher system positions for which analysis performed is given below (Table I).

Table I

Launcher system positions

Analysis case	Traverse (°)	Elevation (°)	Condition
MBR1	0	58	Front tyres not
MBR2	90	0	touching the
MBR3	90	58	ground
MBR4	0	58	Front tyres
MBR5	90	0	touching
MBR6	90	58	the ground

Traverse: Reference from longitudinal axis of the vehicle.
Elevation: Reference from horizontal.

The first 10 frequencies are tabulated in Table III for the cases MBR1, MBR2, MBR3, MBR4, MBR5 and MBR6. Maximum dynamic displacement, stress and their locations are tabulated in Table II for all these cases. The displacement and stress history upto one second for the nodes and elements are given for the above cases. A sample displacement and stress history upto two seconds for case MBR1 is given from this figure it is clear that displacements and stresses are almost zero after 1.5 seconds. Deformed shape and stress contours for a maximum dynamic response for case MBR1 is given in Fig. 7. Since

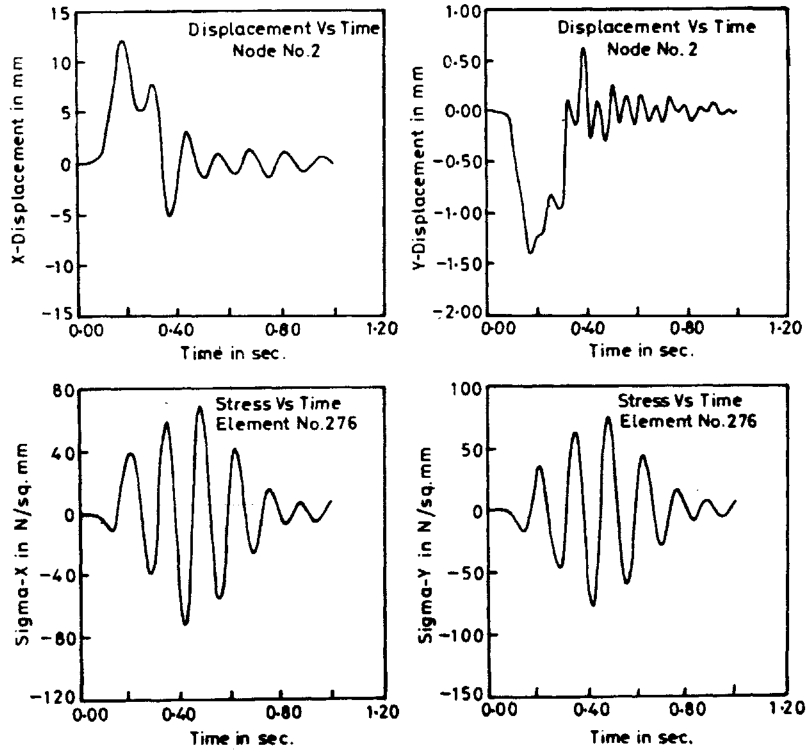

Fig 7 Displacement and stress history

Table II

Gearbox dimensions (All dimensions in mm)

Case	HP	*i*	L	H1	H2	*B*	*h*	*a*
1	1940	8	2350	1500	1000	1000	65	65

HP—Horse power transmitted in HP
i—Speed ratio

Table III

Frequencies of MBRL for various cases

Case	Frequencies (Rad/sec.)									
	ω_1	ω_2	ω_3	ω_4	ω_5	ω_6	ω_7	ω_8	ω_9	ω_{10}
MBR1	37.5	41.3	48.7	52.7	75.5	109.7	123.4	145.2	172.6	191.6
MBR2	27.7	36.3	44.0	47.3	64.5	92.6	125.1	131.7	134.3	144.6
MBR3	26.3	32.9	41.6	44.1	75.9	86.3	124.2	134.6	143.5	167.0
MBR4	37.5	41.3	48.7	52.7	75.5	109.7	129.5	138.3	174.2	189.8
MBR5	27.7	36.3	44.0	47.3	64.5	92.6	125.1	129.7	138.6	142.3
MBR6	26.3	32.9	41.6	44.1	75.9	86.3	128.6	131.4	142.1	166.8

the printout is in black and white, the stress contours are not clear in the figure.

The static displacement and stresses due to wind load is tabulated for all the cases. To determine the total effect at any given time, the static displacement (or) stress due to wind load has to be added to the dynamic value at that time.

From the frequencies it is clear that 90° traverse and 58° elevation position is the most flexible position. However, the maximum deflection of 16.7 mm along Y-axis occurs near the tip of the cradle unit and maximum stress of 303.6 N/mm^2 (Material-StE 690). The stresses die down to the negligible value of 20 N/mm^2 at around 0.5 sec. after firing is initiated. Therefore, the structure is strong and rigid enough to take firing in every 2 seconds.

Regarding the displacement history, the displacement comes down to 2 mm at around 0.5 sec. and to nearly 1 mm at 1 sec. This displacement is within the permissible limit of the positional accuracy of the rocket launcher which is 1 milli radian of the cradle unit. Hence, the rocket can be fired after 2 seconds with the same positional accuracy.

Maximum displacement in the chassis is 1 mm and is negligible at 1 sec. There is no change in the response with two boundary conditions namely the outriggers only supporting the vehicle and structure at the time of firing and the second condition is that front tyres touching the ground in addition to outriggers' supports.

Maximum displacement due to wind load is 1.16 mm and maximum stress is 20.2 N/mm^2. These values are very small compared to the maximum response values and hence will not have any adverse effect open the structure.

The multi barrel rocket launcher has been analysed for dynamic under firing load. Static analysis for the wind load also performed. The structure is rigid enough to take firings in every two seconds with the same positional accuracy and strong enough to withstand that load. The effect due to wind load is negligible on the structure compared to the maximum response values.

To summarise, there is an urgent need for scientifically documenting the design procedures, for all our equipment. This calls for the use of computer aided design using finite element method. This needs trained manpower. This has to be done by the Engineering Colleges by offering courses under the senior undergraduate level.

Reference

1 V Ramamurti *Computer Aided Mechanical Design and Analysis* TMH New Delhi (1992)