Design, Development & Analysis of Bench Vise on Rapid Prototype Machine

Shrikant M. Chougule, D. B. Waghmare and R. S. Pawade
Department of Mechanical Engineering, Dr. Babasaheb Ambedkar Technology University, Lonere, Dist, Raigad, Maharashtra, India.

ABSTRACT
Traditional Rapid Prototyping (RP) is referred to as layered manufacturing free form fabrication. It is used for the physical modelling of a new product design directly from CAD data without the use of any special tooling or significant process engineering. This reduces the lead time required to produce a prototype of product. This paper is related to designing and manufacturing of modified bench vise on rapid prototyping machining process. We have designed the conventional and modified bench vise in Pro-e CAD software and manufactured it on Dimension 1200esRPT machine and analysis is carried out in ANSYS CAE software.

Introduction

Rapid prototyping is an innovating manufacturing technology with inherent capability to transform CAD models directly into physical parts, thereby positively influencing product development effort on time, cost and quality fronts. Global competition, mass customization, accelerated product obsolescence and continued demands for cost savings are forcing companies to look for new ways to improve their business processes. Rapid prototyping (RP) and rapid tooling (RT) have emerged as key enablers for rapid manufacturing, a new mode of operation promising improvements to the competitive position of companies adopting it.

RP is a technology for quickly fabricating physical models, functional prototypes and small batches of parts directly from computer aided design (CAD) data. RT generally concerns the production of moulds and tooling inserts using RP. RP and RT are means for compressing the time-to-market of products and, as such, are competitiveness-enhancing technologies.

Prototyping or model making is one of the important steps to finalize a product design. It helps in conceptualization of a design. Before the start of full production, a prototype is usually fabricated and tested. Manual prototyping by a skilled craftsman has been an age old practice for many centuries. Second phase of prototyping started around mid-1970s, when a soft prototype model by 3D curves and surfaces could be stressed in virtual environment, simulated and tested with exact material and other properties. Third and the latest trend of prototyping, i.e., Rapid Prototyping (RP) by layer-by-layer material position, started during early 1980s with the enormous growth in Computer Aided Design and Manufacturing (CAD/CAM) technologies when almost unambiguous solid models with knitted information of edges and surfaces could define a product and also manufacture it by CNC machining.

Rapid Prototyping (RP) is capable of producing prototypes of almost any geometrical complexity in relatively short time using the additive manufacturing approach.RP is a technology for quickly fabricating physical models, functional prototypes and small batches of parts directly from computer aided design (CAD) data. RT (Rapid tooling) generally concerns the production of moulds and tooling inserts using RP. Following block diagram shows various applications and processes of rapid proto typing.

Rapid Prototyping techniques offer multiple benefits:
- Fast and effective communication of design ideas
- Effective validation of design fit, form, and function
- Greater design flexibility, with the ability to run quickly through multiple design iterations
- Fewer production design flaws and better end-products!
- increase visualization capability during the early phases of design by using rapid physical models;
- detect design flaws before the manufacture of tooling;
- rapidly create tooling to manufacture physical prototypes.

Types of RP systems

Prototyping is an important stage in any product development process and the prototype can be defined as "an approximation of a product (or system) or its components in some form for a definite purpose in its implementation" There are three main Rapid Prototyping systems, depending on initial the form of materials involved:

- **Liquid-based RP systems** – The initial form of material is in liquid state and, by a curing process, the liquid is converted into solid state; the system includes: 3D Systems' Stereo lithography (SLA), Light Sculpting, Rapid Freeze and Two Laser Beams
- **Solid-based RP systems** – The initial form of material is in solid state, except for powders (wire, roll, laminates, pellets); this system includes: Stratasys 'Fused Deposition Modelling (FDM), 3D Systems, Multi-Jet Modelling System (MJM) and Pares lamination Technology (PLT)
- **Powder-based RP systems** – The initial form of material is powder; the system includes: 3D Systems, Selective Laser Sintering (SLA), Precision Optical Manufacturing's Direct Metal Deposition (DMD) and Z Corporation's Three Dimensional Printing (3DP).

Basic Principle of Rapid Prototyping Processes

RP process belong to the generative (or additive) production processes unlike subtractive or forming processes such as lathing, milling, grinding or coining etc. in which form is shaped by material removal or plastic deformation. In all commercial

RP processes, the part is fabricated by deposition of layers contoured in a (x-y) plane two dimensionally. The third dimension (z) results from single layers being stacked up on top of each other, but not as a continuous z-coordinate. Therefore, the prototypes are very exact on the x-y plane but have stair-stepping effect in z-direction. If model is deposited with very fine layers, i.e., smaller z-stepping, model looks like original. RP can be classified into two fundamental process steps namely generation of mathematical layer information an generation of physical layer model. Typical process chain of various RP systems is shown in figure3.1.
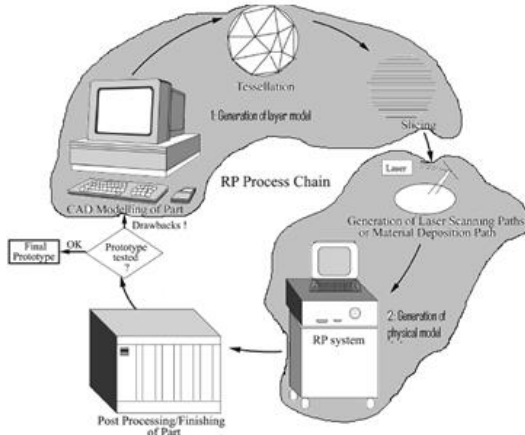

Fig 3.1 RP process chain showing fundamental process steps

It can be seen from figure 2.1 that process starts with 3D modelling of the product and then STL file is exported by tessellating the geometric 3D model. In tessellation various surfaces of a CAD model are piecewise approximated by a series of triangles and co-ordinate of vertices of triangles and their surface normal are listed. The number and size of triangles are decided by facet deviation or chordal error. These STL files are checked for defects like flip triangles, missing facets, overlapping facets, dangling edges or faces etc. and are repaired if found faulty. Defect free STL files are used as an input to various slicing software. At this stage choice of part deposition orientation is the most important factor as part building time, surface quality, amount of support structures, cost etc. are influenced. Once part deposition orientation is decided and slice thickness is selected, tessellated model is sliced and the generated data in standard data formats like SLC (stereo lithography contour) or CLI (common layer interface) is stored. This information is used to move to step 2, i.e., generation of physical model.

The software that operates RP systems generates laser-scanning paths (in processes like Stereo lithography, Selective Laser Sintering etc.) or material deposition paths (in processes like Fused Deposition Modelling). This step is different for different processes and depends on the basic deposition principle used in RP machine. Information computed here is used to deposit the part layer-by-layer on RP system platform. The generalized data flow in RP is given in figure 2.2.The final step in the process chain is the post-processing task. At this stage, generally some manual operations are necessary therefore skilled operator is required. In cleaning, excess elements adhered with the part are removed. Sometimes the surface of the model is finished by sanding, polishing or painting for better surface finish or aesthetic appearance. Prototype is then tested or verified and suggested engineering changes are once again incorporated during the solid modelling stage.
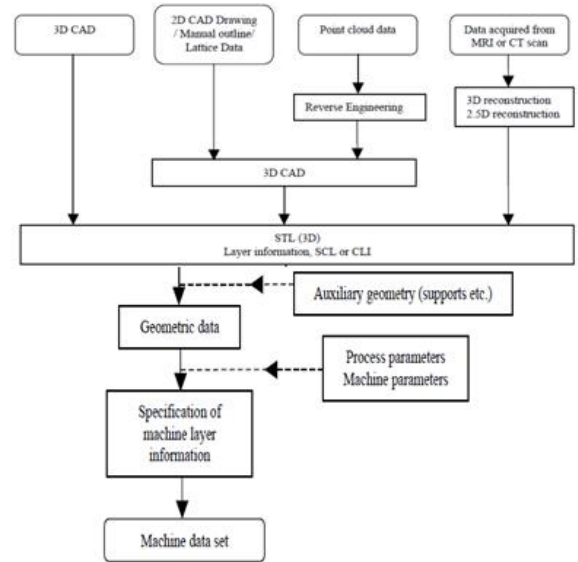

Fig 3.2. Generalized illustration of data flow in RP Applications of Rapid Prototyping Technology

RP models are becoming widely used in many industrial sectors. Initially conceived for design approval and part verification, RP now meets the needs of a wide range of applications from building test prototypes with material properties close to those of production parts to fabricating models for art and medical or surgical uses. In order to satisfy the specific requirements of agro wing number of new applications, special software tools, build techniques and materials have been developed. Five examples in different application areas are described in the following section.

1. Functional models
2. Patterns for investment and vacuum casting
3. Medical or surgical models
4. Art and design models
5. Engineering analysis model

Case Study

Bench Vise

Vise is a mechanical screw apparatus used for holding or clamping a work piece to allow work to be performed on it with tools such as saws, planes, mills, drills, screwdrivers sandpaper, etc. Vises usually have one fixed jaw and another, parallel, jaw which is moved towards or away from the fixed jaw by the screw. Vises are used as holding devise on machines like lathes, milling machine, drilling machine etc. and also by tool makers for holding jobs. Design wise three types of vises are very common in use namely plain vise, swivel vise and tool maker's vise which is commonly known as bench vise.
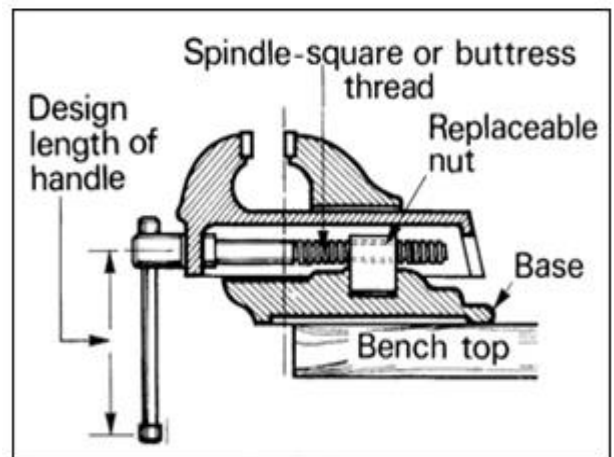

Fig 5.1 Schematic representation of bench vise

Objective of Project Work

Rapid prototyping manufacturing technology has a capability to transform CAD models directly into physical parts, thereby positively influencing product development effort on time, cost and quality. Vises are used as holding devise on machines like lathes, milling machine, drilling machine etc. and also by tool makers for holding jobs i.e. vise is used on large scale for different applications. So it is necessary to design a rigid, flexible, cost effective and highly durable vise. Safety should also be taken into consideration while designing the vise. There are very few research papers available on the modifications of vise and no one has published a paper related to manufacturing of vise on rapid prototype machine. Therefore present work is to design a bench vise with modifications in conventional vise. Consequently the main objective of this work is to make modifications in present vise and manufacture its prototype on RPT machine.The main objectives of this project are:

The main objectives of this project are:
1. Study of Rapid Prototyping and bench Vise.
2. Designing a conventional bench vise using Pro-E.
3. Design modification by value addition in the bench vise.
4. One side locking arrangement (C Clamp with two screws & base plate) for bench vise to make it portable & fix bench vice on different tables at any location.
5. Providing surface plate with right angle plate on stationary jaw for measurement of right angles between two surfaces of job.
6. Analysis of modified bench vise using ANSYS.
7. Manufacturing a prototype of modified bench vise on RPT machine.
8. Making bench vise more cost effective and reliable.

Design process

Design process can be achieved by relying on new design methods and with the help of computer programs like CATIA/PRO-E. The advantage of using these options when designing these product variants is the speed of manufacturing and time to market and the result is reduction of cost production. The overall process of design, from beginning to end, is defined in following figure. The process begins with identification of need and then making the decision. After many iterations, the process ends with the presentation of the project which fulfils the request.
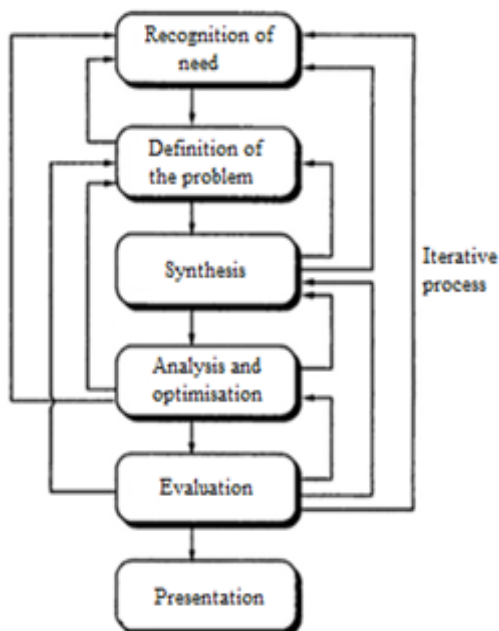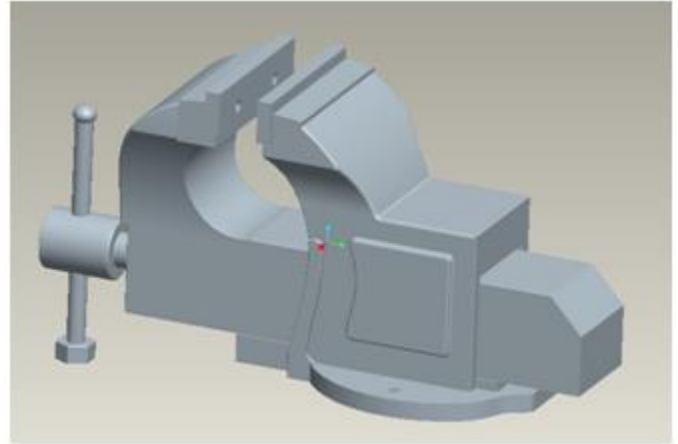

Existing Vise

Fig 5.2 Existing Bench Vise

Design Modification

Providing surface plate (anvil) with right angle plate on stationary jaw for flat reference surface and measurement of right angles

The existing vise is used for performing different operations by holding the jab in jaws. After some operations the worker has to check the dimensions, accuracy, flatness etc. by using surface plate which is kept somewhere in the shop. For this he has to travel number of times from workplace to surface plate, which consumes more transport time for the job from vise to surface plate and vice-versa.

Therefore to minimize the production time and reduce the transportation delay, the existing bench vise is modified as shown in fig.5.2. in which surface plate (anvil) with right angle plate on stationary jaw is provided by which flat reference surfaces and right angles can be measured on the same vise. This modification also reduces the material required for manufacturing the stationary jaw and overall weight of bench vise can be reduced to some extent.
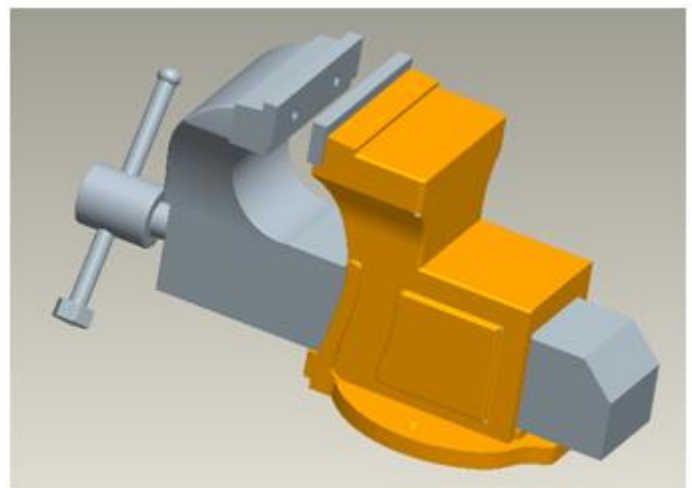

Fig 5.2 Modified Bench Vise

One side locking arrangement (C Clamp with base plate type) bench vise to move & fix bench vice for any table any position

The existing Bench vise is fixed at one particular location on the table for performing different operations. In this case worker has some limitations for carrying out the operation as it is not moveable. So we have decided to modify the existing stationary bench vise to movable bench vise as shown in fig. 5.3 In this we have provided a separate 'C' clamp with base plate arrangement on which the assembly of exist bench vise can be fixed. The modified bench vise can be taken from one location

to another location on the table for performing different operations as per workers convenience. Also we can take this bench vise from one place to another place as per the requirement.
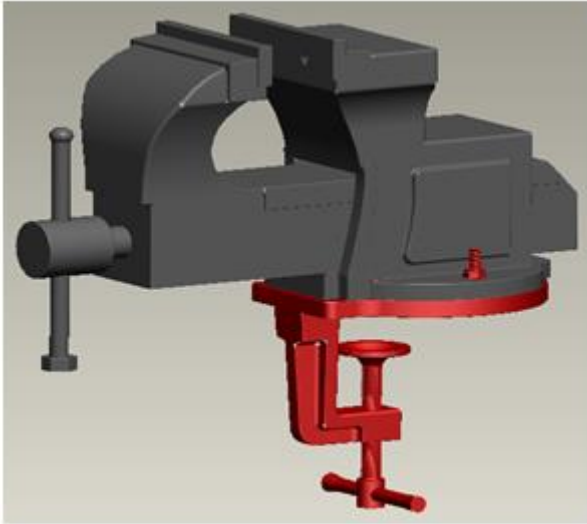

Fig 5.3 Modified Bench Vise

Modified bench vise can be fixed with the 'C' clamp with base plate arrangement to any table only by one side locking arrangement without drilling the holes on the table. This modified bench vise can be used for performing the different operations at different places as it is movable. This modification increases the value of the product.

Analysis of Modified Bench Vise

ANSYS offers engineering simulat1ion solution sets in engineering simulation that a design process requires. Companies in a wide variety of industries use ANSYS software. The tools put a virtual product through a rigorous testing procedure (such as crashing a car into a brick wall, or running for several years on a tarmac road) before it becomes a physical object. ANSYS simulation software enables organizations to confidently predict how their products will operate in the real world.

ANSYS will help us to understand structural and thermal analysis of modified bench vise. ANSYS apply the various forces on a given component in the required direction at a required point to calculate the various effects such as bending, equivalent stress, maximum and minimum principal stress, fatigue etc. ANSYS simulates the result and provides most approximate results with plots and 3D interpretation of output data. The analysis of various parts of bench vise carried out on ANSYS is shown in figures below.

Overview of structural analysis

Static structural analysis is one in which the load/field conditions does not vary with time and the assumption here is that the load or field conditions have to be met in any stress analysis, equilibrium of forces (or stress), compatibility of displacements and satisfaction of state of stress at continuum boundaries. Various kinds of loads like force, pressure, inertia, thermal or specified displacements can be applied. An important point to consider is that at least one of the displacements must be known before the rest can be determined. The known displacements are referred to as boundary conditions and are often times a zero value.

Analysis of different parts of Bench Vise

It is basically used for analysis of structural element under structural loading and thermal stresses. ANSYS stands for

'Advanced Numerical System Synthesis'. In general, a finite element solution may be broken into following three stages;

Preprocessing: (Define the problem) the major steps in preprocessing are given below;

• Defining key points/lines/volumes

• Define element type and material/geometric properties

• Mesh the lines/areas/volume as required

• The amount of detail required will depend on the dimensionally of the analysis

Solution: (Assigning loads, constraints and solving) Here we specify the load (point are pressure), constraint (translational and rotational) and finally solve resulting set of equations.

Post processing: In this stage one may wish to see:

• List of nodal displacements

• Element forces and moments

• Deflection plots

• Stress contour diagrams

Thus every object has been imported and simulated in the given condition. Corresponding values of stresses and SCF have been tabulated and results are interpreted in the graphical form. While doing so following steps are followed.

Following steps are used in ANSYS for stress analysis in bending;

1) Pro-E file of given dimensions is imported to ANSYS.
Static Structural > Geometry > Import Geometry > Browse > File position > Open >Ok
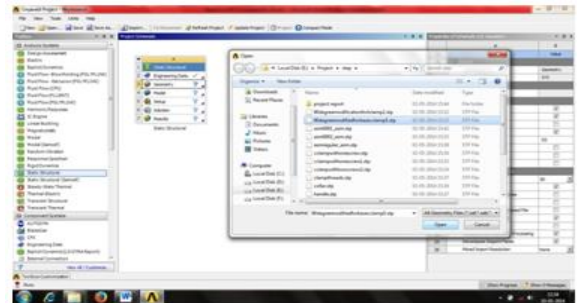
2) After importing file, right click on Model and click edit then part will open in new window.
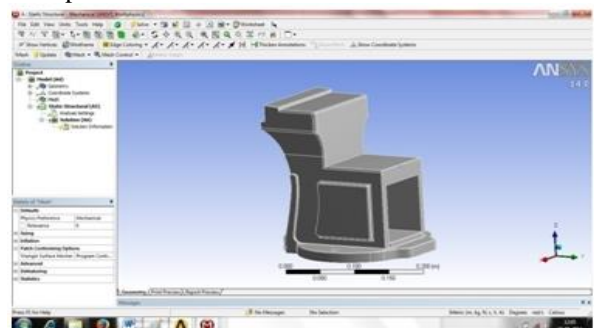
3) Now we have to generate mesh on the part to see the material structure of the part. Then right click on mesh at the left of the screen and click on generate mesh.
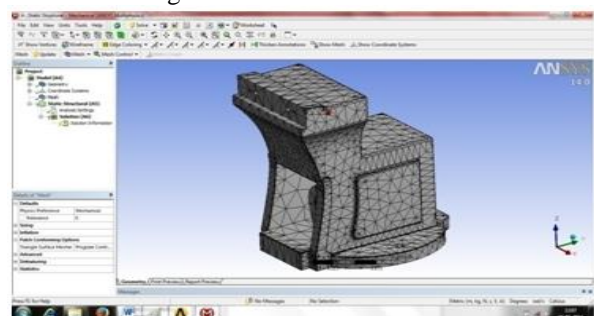
4) We have to fix the part so that it will not move when force is applied on that part. Click on Static Structural then click supports and choose the face of part which is fixed.
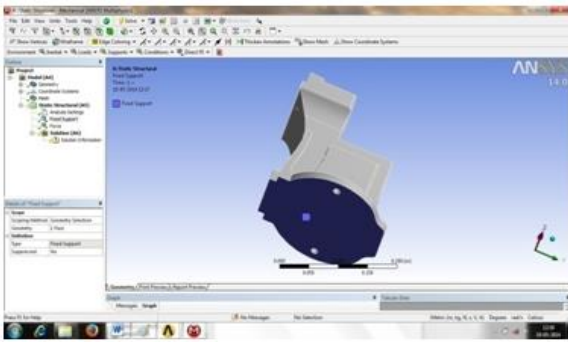

5) We can select the amount and direction of force to be apply on the part by giving force value at the left bottom of the window. Static Structural > Loads > Force > Select face > Apply
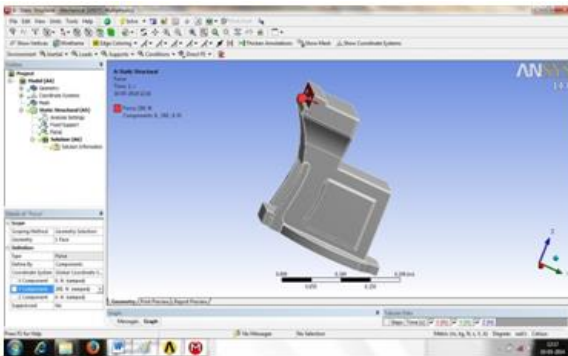

6) After applying the load on part to see the various effects of stresses produced in the part follow the following steps:
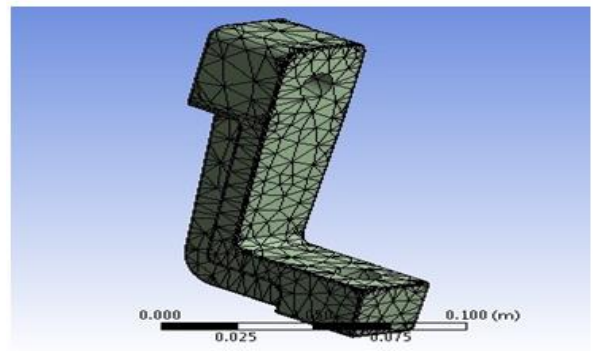Solution> Stress > Maximum shear stress
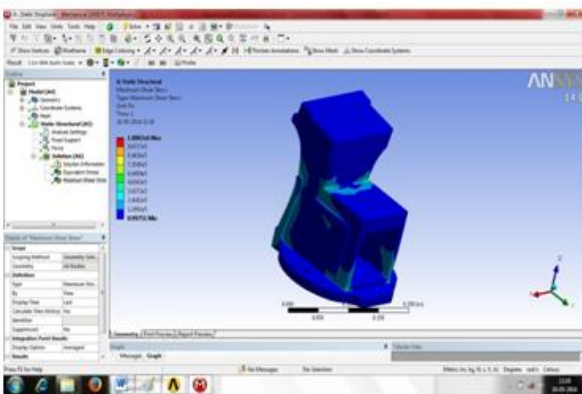
7) In the similar way, meshing of movable jaw is done. After meshing movable jaw will look like figure below.
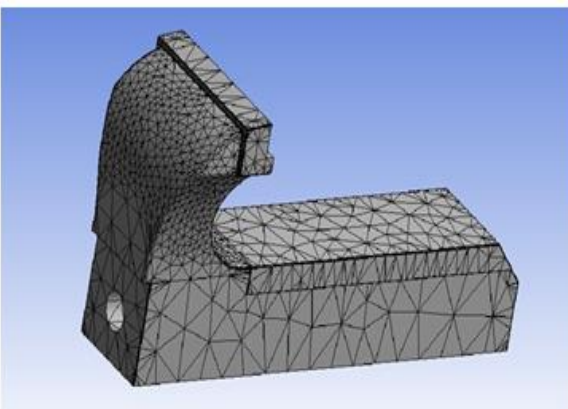

8) Maximum shear stress induced in the part can be obtained by following procedure given above and then distribution of forces on the part will be seen as per shown in figure below.
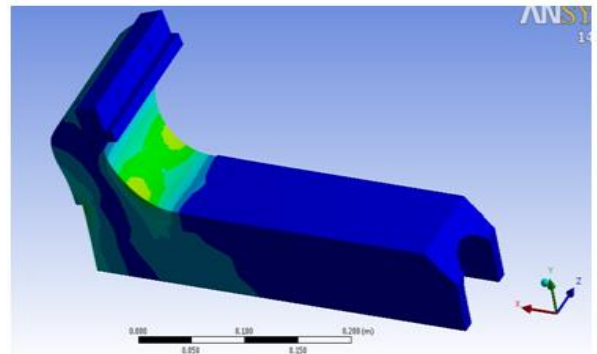
9) Meshing of c-clamp is shown in following figure. For applying meshing to c-clamp above procedure is followed.

10) Maximum shear stress in the c-clamp will be distributed as shown in figure below.
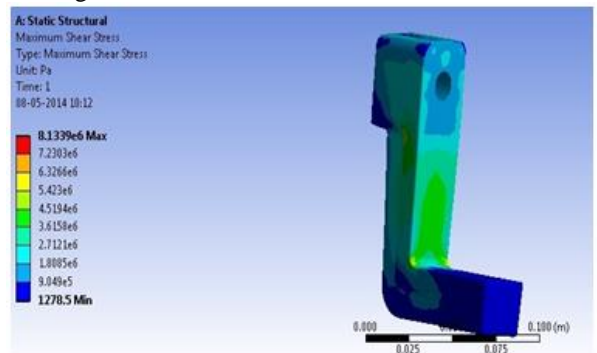
It is clear from above analysis; the designed parts of bench vise are in safe zone. The blue colored part of parts shows the minimum shear stress whereas, as the color changes from blue to red followed by sky blue, green and yellow color, the stress concentration increases to maximum. In above figures of analysis there are no red zones on any part when maximum force is applied by a man on any of the part.

Rapid Prototyping of Bench Vise

Dimension 1200es printers are designed with ultimate simplicity in mind. The systems enable you to build parts quickly, even if you have never used a 3D printer before. The systems model with ABS*plus* plastic, so modeled parts are strong and durable. ABS*plus* so ensures that you will be able to drill, tap, sand, and paint your creations. With the speed and convenience of Soluble Support Technology, completed parts are quickly available for review and test.

Dimension 1200es printers are an innovative combination of proprietary hardware, software, and material technology. Dimension 1200es printers build models, including internal features, from CAD STL files. Three dimensional parts are built by extruding a bead of ABS plastic through a computer-controlled extrusion head, producing high quality parts that are ready to use immediately after completion. With two layer

resolution settings, you can choose to build a part quickly for design verification, or we can choose a finer setting for higher quality surface detail. The Dimension 1200es systems consist of two primary components-the Dimension 1200es 3Dprinter and Catalyst EX. Catalyst EX is the preprocessing software that runs on a Windows XP Pro, Windows Vista or Windows 7 platform. The build envelope measures 254 x 254 x 305 mm (10 x 10 x 12 in). Each material cartridge contains 922 cc (56.3 cu. in.) of usable material (10).

Assembly 1: Assembly of conventional bench vise

Assembly 2: Assembly of modified bench vise with C-clamp having base plate

Assembly 3: Assembly of modified bench vise with C-clamp having one screw

Assemble 4: Assembly of movable jaw and modified fixed jaw

Manufacturing of modified Bench vise on RPT

For better visualization we used CatalystEx software which gives model material, support material, model cartridge and support cartridge in cubic inch. Also it gives estimated time for manufacturing of part.

Fixed jaw

Inserting STL file - orientating as per requirement (minimum support material should be used) - packing it for final printing (locating its position on base clamp) – checking availability of enough material for manufacturing a packed part and printing finally on rapid prototype machine
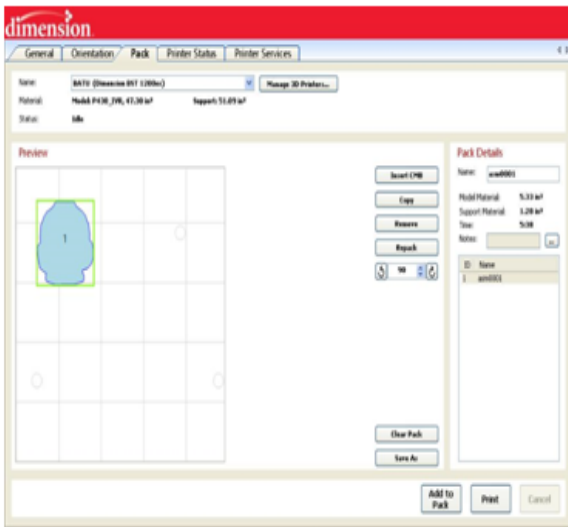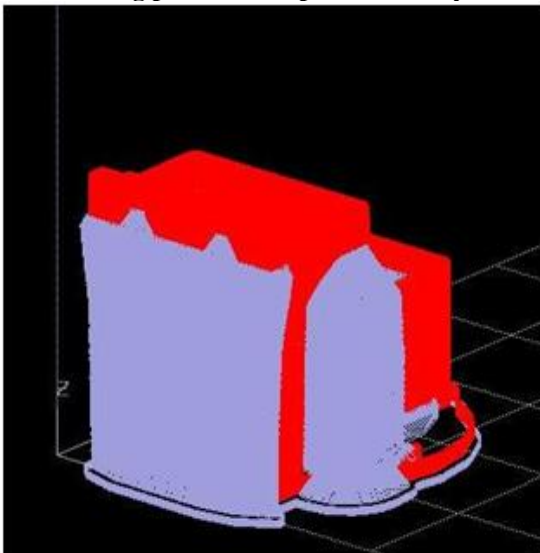

Fig 7.1 Locating part on base plate in Catalyst software

Fig 7.2 Visualization of fixed jaw in catalyst software
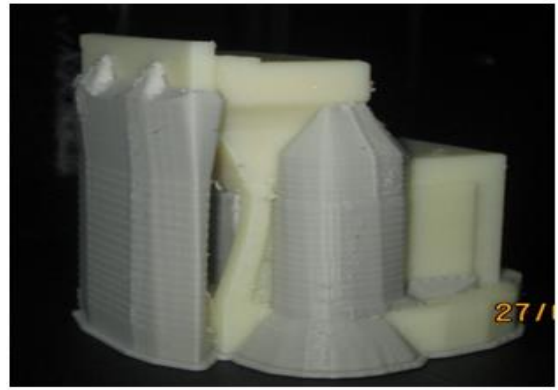
Fig 7.3 Visualization of fixed jaw in its final manufacturing

Movable Jaw

Movable jaw of bench vise manufactured on RPT machine, by converting its CAD model into STL format.

Fig 7.4 Movable jaw manufactured on RPT machine

Lead Screw with handle

For better visualization we used Catalyst Ex software which gives model material, support material, model cartridge and support cartridge in cubic inch. Also it gives estimated time for manufacturing of part. By using Catalyst Ex software we get following data for Vise Screw with vise handle

Fig 7.5 Preview and final manufactured view of lead screw

Table 7.1 Manufacturing details of various parts of bench vise
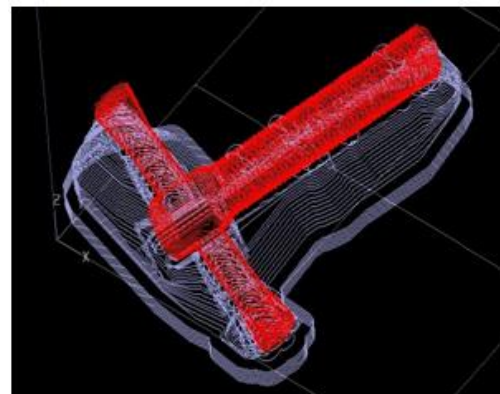
Name of Parts	Model Material (in3)	Support Material (in3)	Estimated Time (Hrs)	Weight (gm)
Movable Jaw	3.62	2.05	5.36	57.3
Fixed Jaw	3.26	1.59	6.02	83.3
Vise screw with handle	0.52	0.46	1.32	8.2
C-clamp fixing screw	0.07	0.04	0.14	1.6
C-clamp with base plate	1.13	0.22	1.24	17.4
Collar	0.04	0.01	0.04	1.9
Screw	0.02	0.01	0.06	1.6
Assembly 1	7.52	4.16	12.94	150.3
Assembly 2	8.7	4.37	13.82	166.4
Assembly 3	7.48	4.13	12.78	149.1

Table no 7.2 Comparison between Existing and Modified Bench Vise

Sr. No.	Part Name	Existing Bench Vise	Modified Bench Vise
01	Fixed Jaw	Traditional Fixed Jaw used for clamping the work-piece firmly while performing the operation.	Fixed jaw takes the shape of surface plate. This will help to insure that either two faces are in 90^0or not. Also it saves time while measuring this angle between two faces of work-piece.
02	C Clamp With Base Plate	C clamp with Base plate is not provided in traditional bench vise.	C clamp with base plate performs the same function as mentioned above but with this bench vise can be clamped rigidly to the table at any place as per requirements.

C-clamp

Assembly of C-clamp and fixing screw manufactured on RPT machine which is further assembled to modified fixed jaw.

Fig 7.6 C-clamp with base plate and without base plate Assembly of modified Bench vise Manufactured by RPT

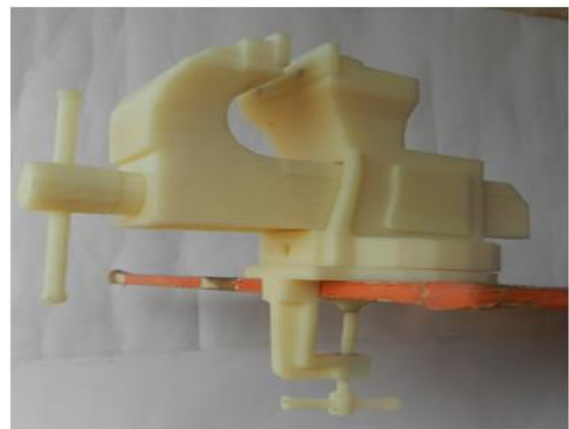**Fig 7.7 Assembly of movable jaw and modified fixed jaw**

Fig 7.8 Assembly of modified bench vise with C-clamp having base plate

Results of Prototyping

• A visualized specification in the form of an interactive prototype of future applications is obtained, enabling easier communication between the designer and the manufacturer.

• It will help ensure more specific feedback from the manufacturer in the early stages of the project.

• The accuracy of every detail of the design /functionalities /product/services can be checked before programming starts.

• The speed of incorporating the changes to the prototype is more, the entire process of creating the application can be speeded and the number of requests for changes in advanced stages of development can be reduced.

• It will help ensure better defined application requirements and validate their implementation in the prototype.

• A better idea of the estimated cost of application development can be obtained.

• In prototype, a visual representation of the final application is gained and enables better demonstration of the feasibility of our idea to other people (investors, colleagues, and superiors).

Future Scope

RP pattern can be used in sand casting when pattern making is troublesome meaning that the design of the pattern is

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complicated which is not possible to make in wooden or metallic forms. They can be successfully used in mass production after making a metallic master pattern usually made of aluminum or by spraying layers of metal over the pattern Future modification in the bench vise

1. Job recovery mechanism for catching work-piece to avoid accidents
2. Fixing different types of job holders for different materials and different types of shape and size
3. Providing Quick return mechanism for fixed jaw.
4. Providing guide ways in table for movement of vise in longitudinal direction (to and Fro direction).

Conclusions

Design process is achieved by relying on new design methods and with the help of computer software's like CATIA, UG, Solid works and Pro-E. The need of modifications in actual design is to reduce overall cost of the product, increase the products life, minimizing material waste etc. These are achieved in the modifications of bench vise. In the next phase of the project all designed parts has to be converted into STL format. Using conventional methods, such as casting, forging, machining etc. engineers are limited in the ability to design bench vise by the drastic length of time required to prototype an idea.

Modified traditional fixed jaw to the shape of surface plate which helps to insure that either two faces of work-piece are in 90 degree or not. When it is necessary to measure the 90 degree angle between any two faces repetitively then this modification saves the time.

Most of the traditional bench vises are attached or clamped to a bench permanently with the help of two or three bolts. In modified design C-clamp with base plate is designed which is attached below the base of traditional fixed jaw. The base plate provides the extra strength for clamping the vise to the wooden table. This modified bench vise can be used at any place where required as it is flexible to fix on any table. The rapid prototyping technique is affordable methods for fast product development. The engineering practice uses a lot of computational methods to achieve the design which will fulfill all demands. Anyway, no numerical method is 100% accurate, and it is necessary to manufacture the physical model and to be tested before the product is manufactured in large series.

References

1. Gebhardt, A., Rapid Prototyping, Hanser Gardner Publications, 2003.
2. Hajra S. K., Choudhari Elements of workshop and technology volume 2, Media promoters and publishers pvt. Limited, 2007.
3. Sanjay Joshi, Zhi Yang, et al. Conventional Machining Methods for Rapid Prototyping and Direct Manufacturing. The Pennsylvania State University, 2012.
4. Mihaiela Iliescu, Kamran Tabeshfar, et al. Importance of Rapid Prototyping to Product Design, 1454-2358, August - 2009.
5. Pulak M. Pandey, Rapid Prototyping Technologies, Applications and Part deposition planning, Department of Mechanical Engineering, Indian Institute of Technology Delhi. June - 2012.
6. Jain Pranjal, Kuthe A. M., Feasibility Study of manufacturing using rapid prototyping: FDM Approach. MESIC 2013.
7. Dimension BST/SST 1200es 3D Printer user guide.
8. Kantaros Antreas, Karalekas Dimitris, Fiber Bragg grating based investigation of residual strains in ABS parts fabricated by fused deposition modeling process. 50 (2013) 44–50.
9. C. J. Luis Perez Analysis Of the surface roughness and dimensional accuracy capability of fused deposition modelling. 14 Nov 2010.