E-ISSN: 2321–9637
Volume 2, Issue 1, January 2014
International Journal of Research in Advent Technology
Available Online at: http://www.ijrat.org

MATERIAL SELECTION IN STRUCTURAL DESIGN OF MINI MILLING MACHINE

S.B.Chandgude [1] S.S.Patil[2]
[1] Department of Production Engg KKWIEER, Nasik
[2] Student of KKWIEER University of Pune
[1] Email- sbchandgude@gmail.com[1] sandipspatil85@gmail.com[2]

ABSTARCT:
This study work proposes a methodology for optimized structural design for mini milling machine with considering material selection criteria. This study approach consists of three steps as analysing the existed casted structure, material selection and CAD base model analysis. By analysing design parameters obtained best fit design outcome for structure of mini milling machine. Objective of the seminar is to find the better design with cheaper and lesser material by overall cost reduction with better static and dynamic stiffness. Studies carried out on hybrid machine tool structures proved it to be an alternative for the challenge posed by the conventional solo-materials structure. Research is on to study the characteristics exhibited by hybrid machine structures by varying structural design with combination of different material components in it. In this seminar tried to find the material for better structural option in design of mini milling machine. In this study considering materials for hybrid structural design with the combination of cast iron (base) and steel (head) get analysed. It will provide a resultant damping ratio and stiff structure with better design flexibility. Also, it will beneficial for minimize weight, cost with better design of structure as compared to present cast iron structure.

Keywords: *: Structure, Material selection, AHP Mehod .*

1. INTRODUCTION

Mini milling machine low-cost milling machines for home workshop use. While these machines are small in size, with proper adjustment and techniques they can make a wide range of very useful and reasonably precise components that would be difficult or impossible to make by any other means. The mill is an excellent compliment to a lathe, for making things that cannot be made on a lathe. Because lathes are capable mainly of making shapes based on cylinders, a mill is needed for making other parts that are based on cubical shapes rather than cylindrical shapes. With a lathe and a mill together, you can make just about anything you might need in the way of small precision parts. Neither machine though, is very good at making free-form asymmetrical shapes.

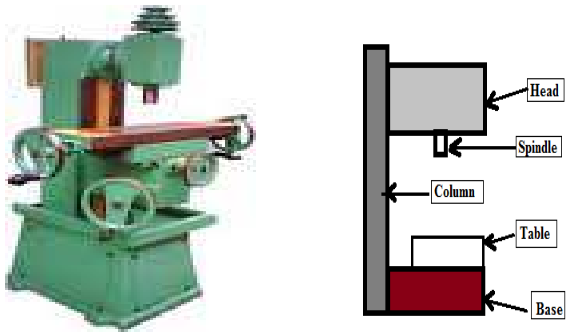

Fig1.: Basic mini milling casted structure

Most of the cases in mini milling the structure is manufactured in casting[Fig.1], here in this study we search for a new alternative like a hybrid structure with combination of casting as well as fabricated structure which covering requirements of design constraints with analyzing the stiffness and in minimum cost and material consumption. As discussed earlier mini milling machine mostly the standard structure is in casting form provided by manufacturer. But casted structure is carrying more material with heavier size and high cost. There is need to search a another option which fulfil the design requirements in cheaper cost and with minimum material consumption. For that selection of proper material is a main task in design stage.

1.1 Fabricated Structures

Traditionally, the base and other major components of a machine tool have been made of gray or nodular cast iron, which has the advantages of low cost and good damping, but the disadvantage of heavy weight. In modern equipment design, lightweight structures are desirable because of ease of transportation, higher natural frequencies, and lower inertial forces of moving members [6]. Lightweight designs are a basic goal in rapid machine design and require fabrication processes such as mechanical fastening (bolts and nuts) of individual components and welding.

1.2 Hybrid structure:

Hybrids menace a combination. In a hybrid structure there is combination of two or more structural design options and form a new one. But for better design of hybrid structure there is need of perfect selection of material with requirement of component with best combination achieve a better result than existed structure. However, fabricated structures have also a few disadvantages associated. These include:

- Comparably high variable costs prohibit large production volumes.
- Structures generally need stress-relief either through thermal or vibrational relaxation.
- All welds should be reasonably accessible, imposing sometimes hard to meet design constraints.
- Fabricated structures have much less damping compared to cast-iron based designs, requiring other forms of damping such as constrained layer damping.

With considering advantages and disadvantages of fabricated and casted structure there is need of manufacturing a structure in hybrid way. Despite the shortcomings listed above, designing and building a machine as a hybrid structure has the big advantage of a much lighter design, a substantially shorter lead-time compared to a cast design with a better design option. This is especially true for the case where the base is built from round tubes as opposed to flat plates, because round structures offer better strength-to-weight ratios and are more readily available.

Concept of this dissertation work is going to design and analyse a hybrid structure alternative to solo-casted or fabricated mini milling machine structure with considering design, weight and total cost criteria's. New hybrid structure is supposed to be suitable for the mini milling machine of wide range with less weight, with lesser material consumption and with easily affordable price and with follows all acceptable criterions like load, static and dynamic stiffness, vibrational stability etc. This will be done by working on selection of best suitable material selection, manufacturing processes, joining techniques along with designing in CAD, and software analysis of design by FEA tool.

Structural materials used in a machine tool have a decisive role in determining the productivity and accuracy of the part manufactured in it. The conventional structural materials used in precision machine tools such as cast iron and steel at high operating speeds develop positional errors due to the vibrations transferred into the structure. Studies carried out by researchers to build stiff structures by increasing the outer wall thickness for conventional materials indicates an improvement in stiffness, but not matching with the increased mass of the structure. Hence an alternative material which possesses good damping and stiffness has to be developed as structural materials [3]

Studies carried out on hybrid machine tool structures proved it to be an alternative for the challenge posed by the conventional solo-materials structure. Research is on to study the characteristics exhibited by hybrid machine structures by varying structural design with combination of different material components in it [4]. Results indicate that with the combination of cast iron base and fabricated steel head structure structures will provide a resultant damping ratio and stiff structure with better design flexibility. Also, it will beneficial for minimize weight, cost with better design of structure as compared to present cast iron structure

E-ISSN: 2321–9637
Volume 2, Issue 1, January 2014
International Journal of Research in Advent Technology
Available Online at: http://www.ijrat.org

For this dissertation work mini milling machine selected as a case study or for reference is vertical type min milling machine with box type structure which is widely used in India with its standard configuration.Most of the cases in mini milling the structure is manufactured in casting, here in this study we search for a new alternative like a fabricated structure with all covering requirements of design constraints with analyzing the parameters.

- Determination Of Overall portion & dimensions of supporting framework & selection of individual members.
- It should according to the requirements of customer or client.
- It should be according to safety requirements.
- Serviceability (How well structure performs in terms of appearance & deflection)
- Economy (Structure should be rudge with efficient use of material)

2 Material Selection in Design

Select the appropriate materials for each element of the machine so that they can sustain all the forces and at the same time they have least possible cost.

An incorrectly chosen material can lead not only to failure of the part but also to excessive life-cycle cost. Selecting the best material for a part involves more than choosing both a material that has the properties to provide the necessary performance in service and the processing methods used to create the finished part (fig.1). A poorly chosen material can add to manufacturing cost. Properties of the material can be enhanced or diminished by processing, and that may affect the service performance of the part.

Faced with the large number of combinations of materials and processes from which to choose, the materials selection task can only be done effectively by applying simplification and systemization.}As design proceeds from concept design, to configuration and parametric design7embodiment design), and to detail design, the material and process selection becomes more detailed. (Fig.2) compares the design methods and tools used at each design stage with materials and processes selection. At the concept level of design, essentially all materials and processes are considered in broad detail.

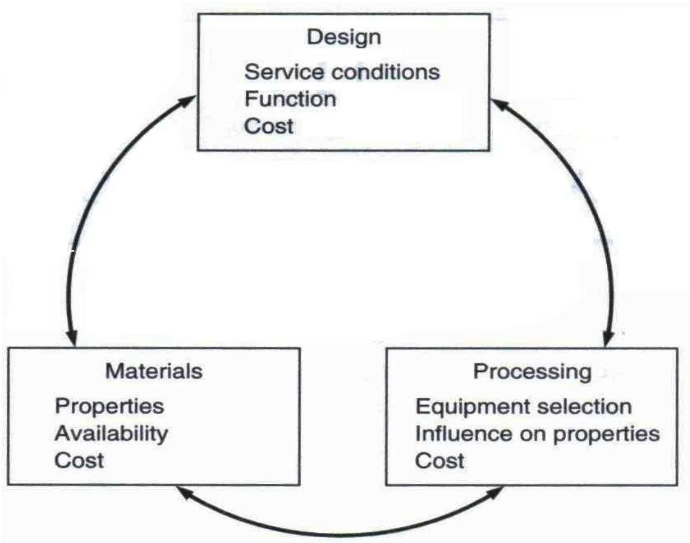

Fig2: Integrations of design,material & processing to produce a product [4]

E-ISSN: 2321–9637
Volume 2, Issue 1, January 2014
International Journal of Research in Advent Technology
Available Online at: http://www.ijrat.org

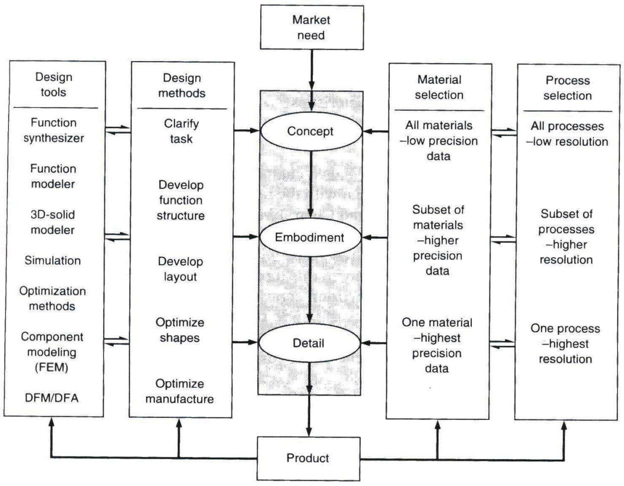

Fig3. Schematic of the design process, with design tools shown on the left and materials and process selection on the right [4]

2.1 General Criteria for Selection

Materials are selected on the basis of four general criteria:

- Performance characteristics (properties)
- Processing (manufacturing) characteristics
- Environmental profile
- Business considerations

When choosing materials for the structures and especially the motion-related components on a machine or a piece of assembly equipment, the physical properties of those materials are vitally important to the overall life of the end product. The primary considerations when selecting materials must include the following:

- Strength-Will the material selected withstand the impact, torque and friction forces placed on it?
- Brittleness-If the part is to be impacted on a repetitive scale, will it crack/shatter?
- Hardness-If pressure is applied to the surface, how much will it deform?
- Weight-How much will the part weigh, if made from a certain material, and will that weight create problems in other areas of the machine's design?
- Machinability-How difficult is the material under consideration to machine, as this will effect manufacturing and build times?
- Weldability-How well does the material react to various types of welding and what impact will welding have on the resulting structure?
- Price-How expensive is the material under consideration and is it available from local sources?
- Corrosion Resistance-Will the part corrode when subjected to the ambient conditions in use?
- Ferrous-Is the material magnetic?
- Conductivity-Does the material conduct electricity or is it subject to static electricity?
- Wear Resistance-When subjected to repeated forces over time, how well does the material under consideration resist wear and what surface finishes might be considered?
- Temperature?

2.2 Materials Substitution in an Existing Design

In this situation the following steps pertain:

1) Characterize the currently used material in terms of performance, manufacturing requirements, and cost.

2) Determine which properties must be improved for enhanced product function. Of. ten failure analysis reports play a critical role in this step

3) Search for alternative materials and/or manufacturing routes. Use the idea of screening properties to good advantage.

4) Compile a short list of materials and processing routes, and use these to estimate the costs of manufactured parts

5) Evaluate the results of step 4 and make a recommendation for a replacement material. Define the critical properties with specifications or testing, as in step 5 of the previous section.

2.2.1Methods of Material Selection

There is no single method of materials selection that has evolved to a position of prominence. This is partly due to the complexity of the comparisons and trade-offs that must be made.

Some of the more common and more analytical methods of materials selection are:

1. Selection with computer-aided databases
2. Performance indices
3. Decision matrices

Pugh selection method

Weighted property index

Analytic Hierarchy Process (AHP) Method.

2.3 Analytic Hierarchy Process (AHP) Method

One of the most popular analytical techniques for complex decision making problems is the Analytic Hierarchy Process (AHP). Saaty developed AHP which decomposes a decision making problem into a system of hierarchies of objectives, attributes (or criteria) and alternatives. The main procedure of AHP using geometric mean method is as follows:

Step 1: Determine the objective and the evaluation criteria.

Step 2: Find out the relative important MATRIX of different criteria with respect to the goal or objective. Construct a pair-wise comparison matrix using a scale of relative importance.

Table 1: Relative importance

Numerical assessment	**Linguistic meaning**
1	Equal importance
3	Moderately more importance
5	Strongly more importance
7	Very strongly importance
9	Extremely more importance
2,4,6,8	Intermediate value of importance

Step 3: The next step is to compare the alternatives pair-wise with respect to how much better (*i.e.*, more dominant) in satisfying each of the criteria.
Step 4: The next step is to obtain the overall or composite performance scores for the alternatives by multiplying the relative normalized weight (w_j) of each criteria with its corresponding normalized weight value for each alternative and making summation over all the criteria for each alternative [1].

2.4 Material selection for Individual component:

a) Base/Bed

The three most popular choices currently used for the main structural components of machine tools are steel weldments, metal (cast iron) castings and polymer composites.

All three approaches have been employed in the design of machine tools to meet the criteria for required rigidity, impact resistance and vibration damping. The final choice is also affected by additional factors including cost footprint (space) requirements and lead times.

By studying various literature reviews & different excellent properties of material & availability here will compare above three materials & will select best one by using AHP method.

2.4.1. Calculation of criteria weightage by using AHP

Pair wise comparison matrix which is used to find criteria weightage is as follows:

Tab l: Properties to be consider for material selection of material

		Unit
ME	Modulus of Elasticity	10^6 Psi
PS	Poisson Ratio	
D	Density	lbs/in3
TS	Tensile Strength	psi
CS	Compressive Strength	psi
DAM	Damping Ratio	

Tab2 : Material consider for study

M1	Steel carbon/low alloy
M2	Cast Iron (Grade 35 Gray)
M3	Polymer composite (Harcrete by Hardings)

Tab 3 : Pair wise importance matrix

Criteria consideration	**L**	**H**	**H**	**L**	**H**	**L**	**Geometric Mean**	**Weight**
Properties	**ME**	**D**	**CS**	**TS**	**DAM**	**PS**		
ME	1	3	3	2	5	5	2.768229	0.34993
D	0.333	1	3	2	5	5	1.919063	0.242588
CS	0.333	0.333	1	2	5	5	1.330382	0.168173
TS	0.5	0.5	0.5	1	5	5	1.209136	0.152846
DAM	0.2	0.2	0.2	0.2	1	1	0.341995	0.043231
PS	0.2	0.2	0.2	0.2	1	1	0.341995	0.043231
						TOTAL	7.91080	1

E-ISSN: 2321–9637
Volume 2, Issue 1, January 2014
International Journal of Research in Advent Technology
Available Online at: http://www.ijrat.org

Tab 4: Typical properties for material for design of structure[10]

	L	H	H	L	H	L
	ME	**D**	**CS**	**TS**	**DAM**	**PS**
M1	30	0.28	0	61000	0.00008	0.3
M2	15	0.26	116000	30000	0.00085	0.27
M3	5.4	0.093	15600	2290	0.008	0.24

Tab 5: Normalised matrix

	ME	**D**	**CS**	**TS**	**DAM**	**PS**
M1	0.18	1	0	0.0375	0.01	0.8
M2	0.36	0.9285	1	0.0763	0.1062	0.8889
M3	1	0.3321	0.1344	1	1	1

Tab 6: Ranking of material as per the Weightage by calculation:

Normalized matrix x weight	**Ranking**
0.346324	3
0.574072	2
0.692405	1

Tab 7: Ranking of material as per Cost, Availability & Manufacturability

	M1	**M2**	**M3**
Cost	2	1	3
Availability	2	1	3
Manufacturability	2	1	3

b) Column/head

Steel Grades

According to the World Steel Association, there are over 3,500 different grades of steel, encompassing unique physical, chemical and environmental properties.

In essence, steel is composed of iron and carbon, although it is the amount of carbon, as well as the level of impurities and additional alloying elements that determines the properties of each steel grade.

The carbon content in steel can range from 0.1-1.5%, but the most widely used grades of steel contain only 0.1-0.25% carbon. Elements such as manganese, phosphorus and sulphur are found in all grades of steel, but, whereas manganese provides beneficial effects, phosphorus and sulphur are deleterious to steel's strength and durability.

Different types of steel are produced according to the properties required for their application, and various grading systems are used to distinguish steels based on these properties According to the American Iron and Steel Institute (AISI), steels can be broadly categorized into four groups based on their chemical compositions:

The study represents simultaneous cost, topology & standard cross section optimization of single storey building structures. The considered structures are consisted from main portal frames, which are mutually connected with

E-ISSN: 2321–9637
Volume 2, Issue 1, January 2014
International Journal of Research in Advent Technology
Available Online at: http://www.ijrat.org

purlins. The optimization is performed by the Genetic Algorithm (GA). The proposed Algorithm minimizes the structures material &labor cost, determines the optimal topology with the optimal number of portal frames & purlins as well as the optimal standard cross sections of the steel.

This paper concluded that Genetic Algorithm method is most suitable for solving the encountered problem in civil engineering. The mathematical problem such as derivatives, Integration are not included in this method which makes the method easy to use.The main aim of paper is to obtain the simultaneous cost, topology & standard cross section optimization of single storey industrial building structures.[2]

1.Carbon Steels 2. Alloy Steels
3.Stainless Steels 4.Tool Steels

As per the various literature study and references on structural design of machine most common material to be taken for consideration of in machine design are study Steel Grade 1015, 1040, 1080 1070.Hence these material were taken for comparison base analysis.

As per analysis Grade 1070 & Grade 1080 has similar compared properties, Hence for comparison here considering Steel grade 1015, 1040 & 1080

Table8: comparison between Steel Grade 1015 1040 1080

AISI Refrance (Grade)	Manufactured	Strength Tensile Psi(lb/in2)	Strength yield Psi(lb/in2)	Elongation (%)	Hardness Bhn
015	Hot rolled Normalized (1700f) Annealed (1600f)	61000 61500 56000	45500 47000 41250	39 37 37	126 121 111
1040	Hot rolled Normalized (1650f) Annealed (1450f)	90000 85500 75250	60000 54250 51250	25 28 30.2	201 170 149
1080	Hot rolled Normalized (1650f) Annealed (1450f)	140000 146500 89250	85000 61000 54000	12 11 24.7	293 293 174

Table9 :Material Ranking as per comparison

Steel grade	Ranking
1015	3
1040	2
1080	1

Hence as per analysis Steel grade 1080 is better material foe structure making in mini milling machine which fulfil all the requirements of design.

V. CONCLUDING

Hence as per analysis in the structural design the material will get selected by AHP method for bed is cast iron (Grade 35 gray) and Steel grade 1080 is better material for structure of spindle column making in mini milling machine which fulfil all the requirements of design.and from this analysis will get a hybride design option for strucuture with a greter flexibility

E-ISSN: 2321–9637
Volume 2, Issue 1, January 2014
International Journal of Research in Advent Technology
Available Online at: http://www.ijrat.org

REFERENCES

[1] Syath Abhuthakeer, P.V. Mohanram, G. Mohan Kumar, Structural redesigning of a CNC lathe bed to improve its static and dynamic characteristics, 2011, Faculty of engineering - hunedoara, Romania, 389-394
[2] Ishan B Shah, Kishore. R. Gawande, Optimization of Cutting Tool Life on CNC Milling Machine Through Design Of Experimnets-A Suitable Approach – An overview, 2012, IJEAT-189-194
[3] A.Selvakumar, P.V. Mohanram, Analysis of alternative composite material for high speed precision machine tool structures. department of mechanical engineering, psg college of technology, coimbatore – 641 004, tamil nadu, india
[4] Emmanuil F. Kushnir; Mahendra R. Patel; Terrence M. Sheehan Hardinge Inc., Elmira, Material Considerations in Optimization of Machine Tool Structure, Proceedings of 2001 ASME International Mechanical Engineering Congress and Exposition November 11–16, 2001, New York, NY
[5] TALAT (Lecture 1502)'Criteria in Material Selection, 36 pages, 38 figures Advanced Level Iprepared by: Rolf Sandström, Stockholm
[6] Kalpak jain ,manufacturing engg and technology (6th edition)
[7] Modern Steels and their properties (Carbon and Alloy Steel Bars and Rods), Akron Steel Treating Company (AST).