WEB-BASED CAST METAL DATABASE AND MATERIAL SELECTION

Dissertation
Submitted in partial fulfillment of the requirements
for the award of the degree of

MASTER OF TECHNOLOGY
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JANUARY 2002

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ABSTRACT

Material selection is an important step in product design activity, influencing not only the functionality, but also the manufacturability of the product. An improperly chosen material may lead to the failure of the part or add to unnecessary costs. Owing to the large number of materials available and several decision- making criteria, material selection is however, a difficult problem particularly in metal casting domain. Thus a database for cast metals and facility for material selection will be very useful in considering and selecting the most suitable material. In this project, a database of cast materials have been collected and an XML-based format was developed to store and exchange the materials data in web environment. Two functions to aid product designers have been developed. The first one finds equivalent standards for a particular option of a particular standard. The second function shortlists materials based on the user input of different criteria and their values (minimum, desirable, maximum). A suitability index is computed (based on weighed evaluation of criteria) to enable objective comparison of different alternatives. The program is expected to be useful to even small firms located in remote areas.

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NOMENCLATURE

C = Strength

P = Material price per unit weight

ρ = Material density

σ = Tensile Strength

α = Weighing Factor

γ = Material Performance Index

β = Scaled value

M = Figure of Merit

Mi = Figure of Merit of candidate material

Mb = Figure of Merit of basis material

ABBREVIATIONS

CDML = Cast Metal Markup Language
HTML = Hypertext Markup Language
HTTP = Hypertext Transfer Protocol
MAMPS = Material and Manufacturing Process selection
MatML = Material Markup Language
Mn = Manganese
P = Phosphorous
PHP = Hypertext Preprocessor
RM = Relative Figure of Merit
S = Sulphur
SGML = Standard Generalized Markup Language
Sn = Tin
Ti = Titanium
WebICE = Web Based Integrated Collaborative Engineering
XML = Extensible Markup Language

CHAPTER 1

INTRODUCTION

1.1 Cast Metals

Engineering materials can be divided into metals and non-metals. Most materials that are cast come under the category of metals. A metal casting is a shape obtained by pouring liquid metal into a mold or a cavity and allowing it to freeze and thus taking the form of the mold.

1.1.1 Classification

Cast metals can be broadly categorized into ferrous and non-ferrous. Each of these can be sub-divided into different families. The ferrous metals can be generally classified into cast iron family and steel family. The term cast iron identifies a large family of ferrous alloys. Cast irons are iron carbon base alloys. They contain various amounts of Si, Mn, P, S and trace elements such as Ti, Sb and Sn. They may also contain various amounts of alloying elements. The cast iron family consists of gray iron, ductile iron, and malleable iron. The steels can be classified on the basis of composition, such as carbon, low alloy and high alloy steels. Common use has further subdivided this broad classification. For example carbon steels are often classified according to carbon content as low, medium and high carbon steels. The broad classifications of ferrous alloys and non-ferrous alloys are shown in the Fig 1.1 [Metals hand book, 1982].

The current trend in the worldwide casting production is that, ferrous metals are more widely produced than non-ferrous metals [Modern casting, 1998]. United States of America is the largest producer of castings. This is followed by China, Japan, Germany and India. Among ferrous metals, gray iron is widely produced, followed by ductile iron and steels. Non-ferrous metals are produced to a lesser extend than ferrous metals. Among non-ferrous metals, aluminium is widely used. Copper alloys are produced to a lesser extend than aluminium. Aluminium production shows an increasing trend over the years and has surpassed steel recently (by weight).

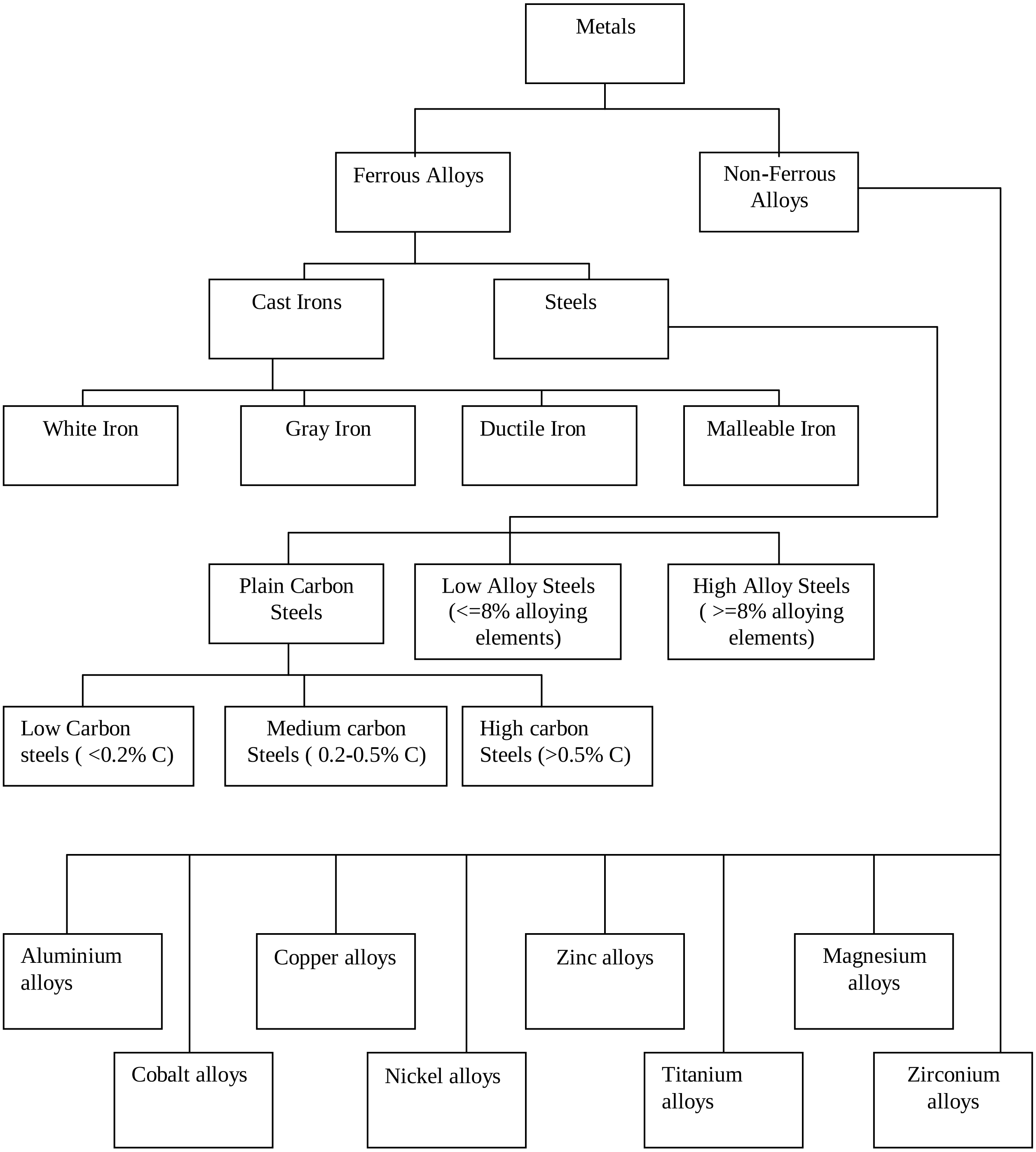


Fig 1.1 Classification of ferrous and non-ferrous alloys

The tables 1.1, 1.2 and 1.3 show the world wide casting production (material wise) for the years 1996, 1997 and 1998 respectively. Only important materials are included. The countries listed in the tables holds the top ten positions for the production of castings for that particular year. The materials included in the tables are gray iron, ductile iron, malleable iron, steels, copper base alloys and aluminium alloys.

Table 1.1 World wide casting production in 1996 ($x10^3$ metric tons) [Modern castings, 1996]

Country	Grey Iron	Ductile Iron	Malleable Iron	Steels	Copper Base	Aluminium	Total
US	6048	4034	232	1369	311	1638	13632
China	6945	1434	367	1404	92	594	10836
Japan	3035	2140	142	375	107	1104	6903
Germany	2013	1056	52	173	73	486	3853
India	2475	189	91	445	24	21	3245
Italy	1043	347	13	84	124	418	2029
Korea	943	450	45	139	19	37	1633
Brazil	1002	301	27	93	22	96	1541
UK	699	454	22	90	35	116	1416
Taiwan	840	270	13	76	37	152	1388

Table 1.2 World wide casting production in 1997 ($x10^3$ metric tons) [Modern castings, 1997]

Country	Grey Iron	Ductile Iron	Malleable Iron	Steels	Copper Base	Aluminium	Total
US	6153	4128	207	1315	318	1731	13852
China	6875	1564	354	1453	96	668	11010
Japan	3094	2159	137	357	106	1104	6957
Germany	2054	1136	49	177	82	537	4035
India	2595	198	96	475		21	3385
France	1014	955	9	142	24	247	2391
Italy	1125	311	3	80	124	501	2144
Korea	881	434	44	135	18	36	1548
UK	685	410	22	64	36	199	1416
Mexico	654	42	14	61	93	267	1131

Table 1.3 World wide casting production in 1998 (x10^3 metric tons) [Modern castings, 1998]

Country	Grey Iron	Ductile Iron	Malleable Iron	Steels	Copper Base	Aluminium	Total
US	5456	3771	1435	295	1619	1731	14307
China	6305	293	293	1304	95	686	8976
Japan	2663	1965	107	286	85	1071	6177
Germany	2170	1254	49	188	86	607	4354
France	1057	1036	12	144	24	272	2545
Italy	1080	337	3	77	126	598	2221
UK	877	716	27	96	16	169	1901
Brazil	970	329	29	93	20	102	1543
Korea	850	438	44	131	18	35	1516
Mexico	628	43	7	103	127	423	1331

1.1.2 Properties and characteristics

The service requirements of a particular part must be matched with properties that can be supplied by the metal. The performance or functional characteristics of a material are expressed chiefly by physical, mechanical, thermal, electrical, magnetic and optical properties. Material properties are the link between the basic structure and composition of the material and service performance of the part. The importance of different properties of a particular component depends on its final application. An important role of the materials engineer is to assist the designer in making meaningful connections between material properties and the performance of the part or system being designed. Each property will serve towards a particular application. For example in mechanical systems tensile strength and yield strength are very important. Some of the important properties of materials are tensile strength, yield strength, shear strength, thermal conductivity, brinnel hardness, density etc.

For castings, physical properties are the most important. Because of the physical properties, some metals can only be cast to shape since they cannot be hot-worked into bars, rods, plates, or other shapes from ingot form as a preliminary to other processing.

These properties are solidus temperature, liquidus temperature, pouring temperature and fluidity.

1.1.3 Standards

Material properties are usually formalized through standards and specifications. The distinctions between those entities is that, a standard is intended for use by as large a body as possible, for example an ASTM or IS standards, where as a specification, though dealing with similar technical content, is intended for use by a more limited group. Some of the most important standards that are followed worldwide are

1) ISO (International Standards Organization)
2) IS (Indian Standard)
3) BS (British Standards)
4) ASTM (American Society for Testing Materials)
5) JIS (Japanese Industrial Standards)

ISO is the worldwide-accepted standard, IS followed in India, BS by United Kingdom, ASTM by America and JIS by Japan.

1.2 Metal Selection

Manufacturability, the ability of a design to consistently satisfy product goals while being profitable is closely linked to the domains of design, process and materials. Material selection has got utmost importance in product design [Satyanarayanan, 1994].

1.2.1 Need for material selection

An incorrectly chosen material can lead not only to failure of the part but also add unnecessary cost. Selecting the best material for a part involves more than selecting a material that has the properties to provide the necessary performance in service; it is also intimately connected with the processing of the material into the finished parts. A poorly chosen material can add to the manufacturing cost and unnecessarily increase the cost of the part. Also processing (beneficially or detrimentally) can change the properties of the material and may affect the service performance of the part. The enormous combination of materials and processes will make the selection process tedious and that task can be done only by introducing simplification and systemization [Dieter, 1997]. So the selection of materials has to be done well before, that is, in the design stage itself. If in the course of manufacturing if we found the material unsuitable, a huge loss will be incurred in changing the material.

1.2.2 Current scenario

An ever-increasing variety of materials are available today, with each having its own individual characteristics, applications, advantages and limitations. The data of these materials are available in data books. Referring through the data books to find the optimum materials is a tedious task. The current scenario existing in foundries is that, the material is selected for a particular application by experience. For such a case help of an experienced engineer in foundry is inevitable. Suppose a product has to be made which was never made before. In such a case even the experienced engineers cannot help. Also the present day foundries loss of expertise is one major problem. In some foundries, the selection of metals is based on history. The disadvantage of such methods of selection is that the optimum material may be left out. There may be newer materials that are better than the materials that are used earlier for a particular application. This is not the correct way to select materials. Even the data available in different data books are not in an organized manner. So it will be very helpful if the data about materials are in an organized manner.

Most general designers have only rudimentary knowledge of casting technology and cannot design for castings without continual reference to experts in foundries or research in the literature for appropriate guidance. Information is difficult to obtain because much of the know-how based on practice for many years is not recorded in literature or in software. Training schemes are becoming rare and the problem faced in many industries is the lost of expertise as skilled personal leave and cannot be replaced. Also even if the casting designer interacts with the experts in order to ensure the products designed is castable, this two way communication may lead to incorrect design incurring a huge loss [Sirilertworakul, 1992]. More over material selection falls into an important class of problems that appears to be candidates for computer assistance. This is because material selection involves a large number of materials and also, the number of materials is ever increasing day by day. So handling these materials manually is a tedious task and also manual selection of materials needs a lot of experience. Even though manual selection is possible, it is a time consuming process. These disadvantages of manual selection can be overcome by implementing a decision support system, with the assistance of computers. As in computers, storage is not at all a problem; the data of the large amount of materials can be efficiently stored and retrieved. There are a large number of databases, relational and non-relational, available to store data. When new materials come, we only need to update the database.

The emergence of web based information systems and its immense development, helps to share information to different people, right across different parts of the world through Internet. So a web based information systems about cast metals can resolve the above said problems, to some extend.

1.3 Problem Definition

There are a wide range of materials that are available to make castings, each with its own properties and characteristics. In the present situation there are not much decision support systems available for castings. So the basic problem is to build a cast metal database and selection system and to implement this system in a web based environment, which will help it to reach a large number of users.

1.3.1 Objectives

- To create a database of ferrous (ductile iron, gray iron, malleable iron, steels) and non-ferrous (aluminium alloys, copper alloys, magnesium alloys and zinc alloys) cast metals.
- To identify critical criteria for material selection for castings
- To develop a methodology for material selection
- To web enable the cast metal selection system in a user friendly environment

1.3.2 Scope and approach

The materials database and selection system is limited to the field of castings only. Alloys of the following groups are included in the database

1) Aluminium alloys
2) Copper alloys
3) Ductile iron
4) Gray iron
5) Magnesium alloys
6) Malleable iron
7) Steels
8) Zinc alloys

Different methods of material selection are studied by conducting a literature survey. The criteria that are very important for castings are identified. Then a well-organized database is created for ferrous and non-ferrous metals using XML. The database covers all the families specified in the objectives. The functions of the selection system have been decided, thinking from the user viewpoint. Existing models of material selection were studied and a new model of material selection is designed. By selecting appropriate tools these functional requirements are implemented in a web environment.

1.4 Organization of the Report

In the **first** chapter, classification of the cast metals and the problem definition is discussed. The **second** chapter is about the literature review conducted on material selection. This chapter discusses about the different methods of material selection and about some of the developed models. This chapter also discusses about the framework of this project. The **third** chapter discusses about the database design for the materials. The **fourth** chapter deals with functions implemented in material selection. The **fifth** chapter deals with the implementation and testing of the material selection program, developed. Finally, the **sixth** states contributions, limitations and scope of future work of this project.

CHAPTER 2

LITERATURE REVIEW

Material selection process is a complex task involving a large number of materials. Different methods are followed for selecting materials. The material selection process follows a step-by-step procedure of short-listing materials. In the following sections these different methods are discussed. Some of the existing models of material selection are reviewed. Towards the last section of this chapter, recent advances in markup languages, which are used for information transfer across the web, is discussed.

2.1 Overview of Material Selection

An ever-increasing variety of materials are available today, with each having its own characteristics, applications, advantages and limitations. When selecting materials for engineering designs, we must have a clear understanding of the functional requirements for each individual component. In selecting materials for applications, technological considerations of material properties and characteristics are equally important [Dieter, 1997].

The selection of an optimal material for an engineering design from among two or more alternative materials on the basis of two or more properties is a multi criteria decision-making problem. The values of the materials are often qualitatively described or imprecisely measured using ranges. Material properties are also of varying degrees of importance for different design requirements. The desired value and importance weight of a material property are usually described in linguistic fashion, for instance, it is very important that the corrosion resistance property of the selected material must be recommended, for it to work on a specified corrosive environment.

The importance of material selection in design has increased in recent years. The adoption of concurrent engineering methods has brought material engineers into the design process at an earlier stage, and the importance given to manufacturing in present day product design, has reinforced the fact that materials and manufacturing are closely linked in determining final properties.

2.1.1 Relation of material selection to design

An incorrectly chosen material can lead not only to failure of the part but also to unnecessary cost. Selecting the best material for a part involves more than selecting a material that has the properties to provide the necessary performance in service; it is also intimately connected with the processing of the material into the finished parts Fig 2.1. A poorly chosen material can add to the manufacturing cost and unnecessarily increase the cost of the part. Also processing can change the properties of the material, and that may affect the service performance of the part. With the enormous combination of materials and processes to choose from, only introducing a systematic procedure can do the task. Design proceeds from concept design, to embodiment (configuration) design, to detail (parametric) design and, the material and process selection then becomes more detailed as the design progresses through this sequence.

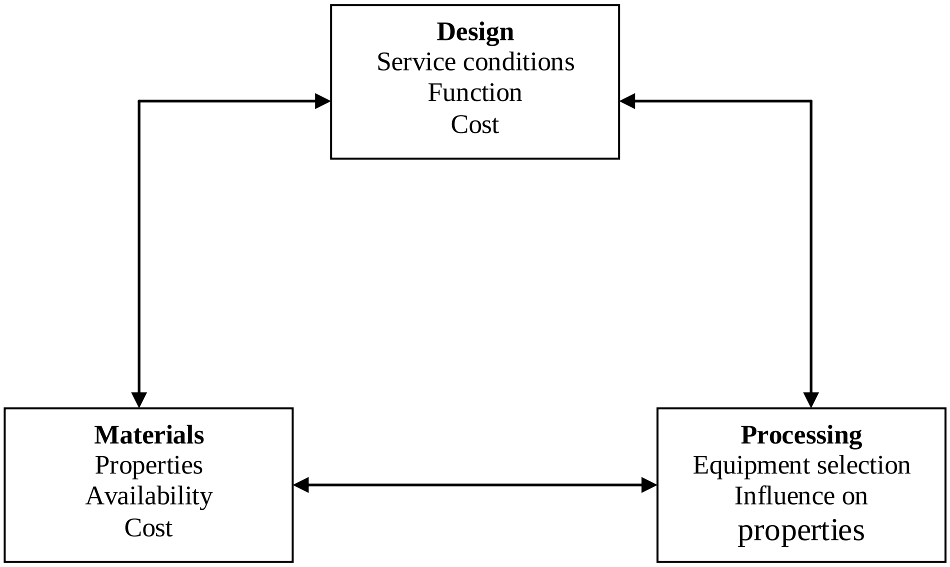


Fig 2.1 Inter-relationship among Design, Materials and Processing [Dieter, 1997]

At the concept level of design, essentially all materials and processes are considered rather broadly. The decision is to determine whether each design concept will be made from metal plastics, ceramic, composite or wood and to narrow it to a group of materials. The precision of the property data needed is very low.

At embodiment or configuration level of design, the emphasis is on determining the shape and approximate size of the part using engineering method of analysis. Now the designer will have decided on a class of materials and processes, for example a range of aluminium alloys, wrought and cast. The material properties must be known to a higher level of precision.

At the parametric level, the decision will have narrowed to a single material and only a few manufacturing processes. Depending on the criticality of the part, material properties may need to be known to a high level of precision. At the extreme, this requires the development of a detailed database from an extensive material-testing program.

In a more detailed approach to engineering design, Dixon and Poli suggest a four level approach to material selection as follows.

Level 1: Based on the critical properties, determine whether the part will be made from metal, plastic, ceramic or composite.

Level 2: Determine whether a deformation process or a casting process will produce metal parts.

Level 3: Narrow the options to a broad category of material. Metals can be subdivided into categories such as carbon steels, stainless steels and copper alloys.

Level 4: Select a specific material according to a specific grade or specification.

Thus, material and process selection is a progressive process of narrowing from a large universe of possibilities to a specific material and process selection. Levels 1 and 2 described above may suffice for conceptual design. Level 3 is needed for embodiment design and sometimes for conceptual design. Level 4 is usually postponed until detailed design. A material selection problem usually involves one of the two situations. One is the selection of the materials and the processes for a new product or design and, the other is the evaluation of alternate materials or manufacturing routes for an existing product or design. Such a redesign effort usually is taken to reduce cost, increase reliability, or improve performance. It is generally not possible to realize the full potential of substituting one material for another without fully considering its manufacturing characteristics. In other words simple substitution of new material without changing the design provides the optimum utilization of the material [Farag, 1984].

2.1.2 Selection of materials for new design

The procedure for selecting materials for a new design can be explained with the help of a flow chart. See Fig 2.2

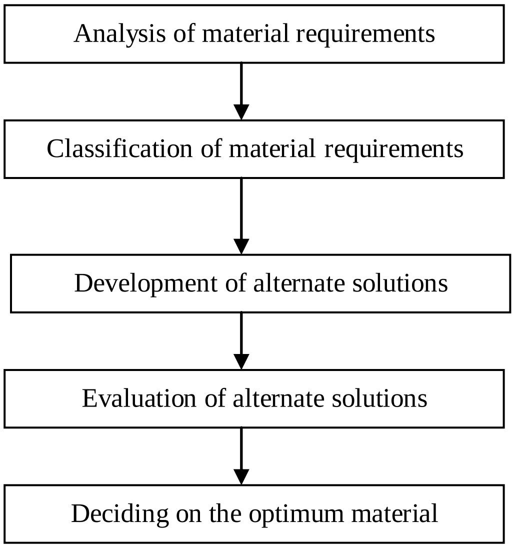


Fig 2.2 Procedure for selecting materials

First step in material selection is to analyze the material requirements. Based on the desired function and expected performance of a particular product material requirements are specified. These requirements are then translated into various groups of properties like physical, mechanical, chemical etc. The material performance requirements of any product can be divided into functional requirements, processability requirements, cost, and reliability [Farag, 1984].

The functional requirements are directly related to the required characteristics of the product and it is not always possible to quantify those values. The processability of a material is a measure of its ability to be worked and shaped into finished product, and it can be defined as castability, weldability etc.

Another important factor in evaluating materials is cost. When the cost limit is exceeded, the design is changed to alter the material requirements to keep below the cost limit. Apart from these requirements, another important requirement for material is its reliability. Reliability of a material can be defined as the probability that it will perform the intended service for the expected life through out the year.

The next step in the material selection is its classification. They can be broadly grouped into two categories, rigid requirements or no-go requirements and soft or relative requirements. Rigid requirements are those, which the material must meet, if it has to be considered at all. Soft requirements are subjected to compromise. Once the material requirements are identified and classified, the rest of the selection process involves the search for the material that best meet the requirements. In this phase almost all materials must be included for screening, without much regard to its feasibility.

Then on the next step, attention is concentrated on materials that look practical. Having narrowed down to the field of possible materials, the search starts to compare the soft requirements. The main objective of the evaluation stage is to weigh the candidate materials against the specified material requirements in order to select the optimum one for the application. Thus the material selection requires the consideration of conflicting advantages and limitations, necessitating compromises and decision-making and as a result different solutions are possible.

After all these steps, the final step in material selection involves the decision on the optimum material. In many cases with the help of evaluation techniques optimum material is found. The engineer should use his judgement and experience in making the final evaluation if the results of evaluation are not clear.

2.1.3 Material substitution for an existing design

In this situation the following steps apply

1. Characterize the currently used material in terms of performance, manufacturing requirements, and cost.
2. Determine which characteristics must be improved for enhanced product function. Often failure analysis reports play a critical role in this step.

3. Search for alternate materials and manufacturing routes. Use the idea of screening of properties to a good advantage.
4. Compile a short list of materials and processing routes, and use these to estimate the costs of manufactured parts. A method of engineering analysis called value engineering has proven useful for this purpose. Value engineering is a problem solving methodology that focuses on identifying the key function of a design so that unnecessary costs can be removed with out compromising the quality of design.
5. Evaluate the results in the above step and make a recommendation of a replacement material.

2.2 Evaluation Methods

The material selection process can be a complex operation in which a large number of materials, often covering a wide range of properties, have to be compared in order to arrive at the optimum material. If the selection process is done in an unordered way there will be a risk of leaving out the optimum material. So in order to avoid that, a set of quantitative methods is used for material selection. All these quantitative procedures described below can be easily adopted for computer-aided selection.

But these procedures are not meant to replace the judgement and experience of the engineer. These procedures are only meant to help the engineer in making sounder choices and trade-off when selecting materials for a given application. Some of these methods are described below [Dieter, 1983].

2.2.1 Cost per unit property method

In some of the simplest cases of material selection, a single material property can stand out as the most critical service requirement. In such cases it is possible to estimate, how much various materials will cost to provide this requirement. Cost per unit tensile strength is usually the most important criteria and by introducing the density and market price, the cost of buying one MN/m^2 of strength (C) can be calculated by equation 2.1

$$P \times \rho / \sigma \qquad (2.1)$$

Where P is the material price per unit weight, ρ the material density and σ the tensile strength.

Equations similar to the above equation can be written to compare materials on the basis of modulus of elasticity, fatigue strength and so forth. The lower the value of C, the better the material. Since comparison between the materials is a fundamental part of materials selection, a basis material can be selected and other candidate materials compared against it.

2.2.2 Weighted property method

The weighted property method can be used in evaluating complicated combination of materials and properties. In this method each material property is assigned a certain weight, depending on its importance. A weighted property value is obtained by multiplying the numeric value by the weighing factor (α). The individual weighted property values of each material are then summed to give a comparative material performance index (γ). The material property with the highest γ is considered to the best.

As this method of weighted property has the drawback of having to combine with unlike units, which would yield irrational results. Such a situation comes when different mechanical, physical and chemical properties with widely different numeric values are combined. The property with the highest numeric value will have more influence than is warranted by its weighing factor. This drawback is overcome by introducing the scaling factors. Each property is so scaled that its highest numeric value does not exceed 100. When evaluating a list of candidate materials, one property is considered at a time. The best value in the list is rated as 100 and the others are scaled proportionally. By introducing this kind of scaling facilitates the normal conversion of normal material property values to scaled dimension less values. For a given property the scaled value (β) for a given candidate material follows equation 2.2

$$\beta = \text{(Numeric value of the property)} \times 100 \,/\, \text{(maximum value in the list)} \qquad (2.2)$$

By this procedure, each property is given an equal importance and affects the comparative material performance index according to weighing factors only. For material factors that can be represented by numerical values application of the above procedure is a simple matter, but with properties like wear resistance, weldability etc. numerical values are rarely given and in such cases scaling of the materials is not possible.

In certain cases where numerous material properties are specified and the relative importance of each property is not obvious, determination of the weighing factors can be largely intuitive, which reduces the reliability of this method. Adopting a systematic approach to the determination of weighing factors can solve this problem. A figure of merit for a material can be given as equation 2.3

$$M = \gamma / P \times \rho \qquad (2.3)$$

Where γ is the material density and P is the total material cost on the job. When it is desired to rank a given list of materials in relation to a basis material, computing the relative figure of merit (RM) can do this. See equation 2.4

$$RM = Mi / Mb \qquad (2.4)$$

Where Mi and Mb are the figures of merit of the candidate material and the basis material respectively.

If *RM* is greater than unity, the candidate material is not suitable than the basis material. In the case where *Mb* represents the minimum requirements, any candidate material with *RM* less than unity should be rejected as unsuitable. When evaluating a large number of materials with a large number of specified properties, the above method can involve a large number of tedious calculations. The steps involved in weighted property method can be written in form of single computer program to select material from the database concerned. In this case the input will be the specified properties and weighing factors for different properties. The computer can be asked to list the candidate materials in order of figures of merit, or for example to select best three materials. This method of selecting the optimum material can be used with the aid of a computer.

2.2.3 Incremental return method

In some cases, the situation arises where a number of materials fulfill certain requirements for a given application. If these materials processed, it can be assumed that the performance level of the resulting components proportional to the comparative performance indices of the materials. The cost of each component is also expected to vary in proportion to the materials and processing costs involved in its manufacture.

The material with the lowest case is used as the basis and compared with the next higher cost material. This is done by computing the incremental comparative materials performance index $(\Delta\gamma)$ and the incremental cost per unit volume (p). These parameters are defined as equation 2.5

$$\Delta\gamma = \gamma_2 - \gamma_1 \text{ and } \Delta P\rho = P_2\rho_2 - P_1\rho_2 \qquad (2.5)$$

If $\Delta\gamma/\Delta P\rho$ is less than unity the material no1 is better than material no 2, which is rejected, and the comparison proceeds between material 1 and 3. If that ratio is greater than unity, material-1 is rejected and the comparison proceeds between material-2 and material-3. The procedure is repeated until all the alternatives have been rejected in favor of one, which is considered the optimum material.

2.2.4 Value analysis

Value analysis or value engineering is an organized system of techniques for identifying and removing unnecessary cost without compromising the quality and reliability of design. The technique is usually applied to a spectrum of problems much broader than just material selection, but the framework of methodology applies to the problems of material selection.

Value analysis asks the following questions and the approach seeks the development of answers to the following questions

Can we do without a part?

Does the part do more than is required?

Does the part cost more than it is worth?

Is there something that does the job better?
Is there a less costly way to make the part?
Can a standard item be used in place of the part?

The functions of the design of a system should be divided into basic functions and secondary functions. A basic function defines a performance feature that must be attained. It answers the question, what must it do. A secondary function defines performance features of the system or item other than those that must be accomplished. It answers the question, what else it should do. For example the basic function of paint is to protect a surface from environment. The secondary function is to improve the appearance. The ability to identify the functions and distinguish between static and secondary functions is important in value analysis. Value is placed only on basic functions, and it is there, attention should be directed.

2.3 Techno-Economic Issues

The selection of materials in industrial application has always been important to product designers. This is a consequence of the fact that selection of material determines not only the basic physical characteristics of the product, but also the processing technologies that can be employed in its manufacture, the specialized properties that can be developed as a function of that processing and ultimately, the cost of the product.

Because of the interplay between material choice, product performance and manufacturing economics, an effective designer must carefully balance the properties and cost and that result from a specific material choice against the willingness of the market to pay that price [Metals hand book, 1982].

2.3.1 Cost versus material performance

Since, cost is the most important criterion in selecting a material, it is natural to use it as one of the key factors in the screening of materials. Cost is the most useful parameter when it can be related to a critical material property that controls the performance of design. Such a cost Vs performance index can be a useful parameter for optimizing the selection of a material.

Often materials provide more of a space filling function rather than a load bearing function and dollars per cubic foot is a more valid criterion. For example the cost of plastics is expressed as cost per unit volume rather than cost per unit weight. Total life cycle cost is the most appropriate cost. It consists of the initial material cost plus the cost of manufacturing and installation plus the cost of operation and maintenance. Consideration of factors beyond just the initial material costs leads to a relation as shown in the Fig 2.3

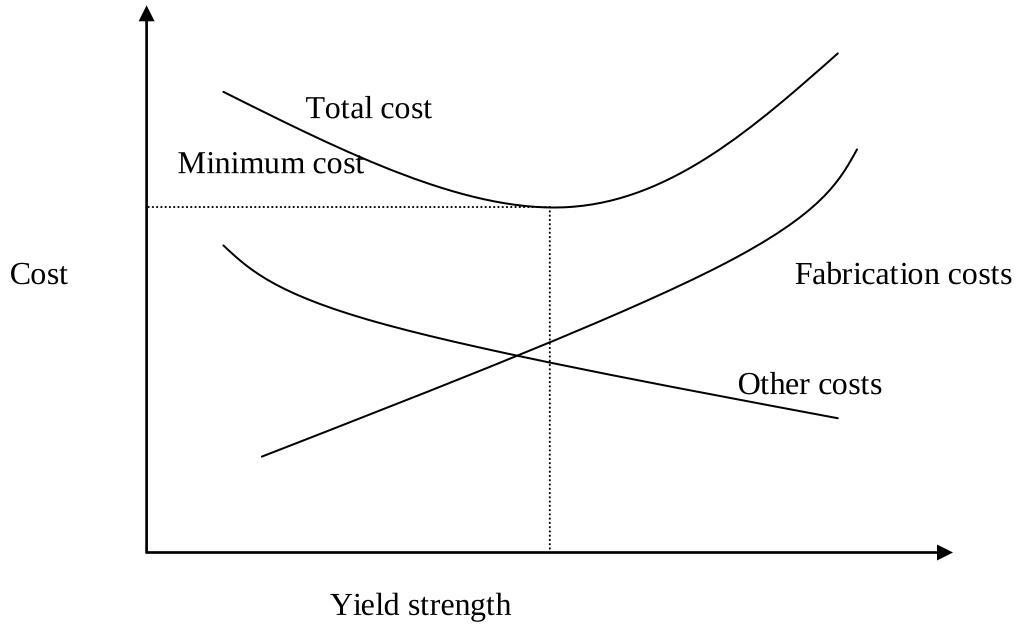


Fig 2.3 Relation between cost factors and material property [Dieter, 1983]

2.3.2 Relation between selection parameters

The required function, the material and the manufacturing processes directly affect the selection of a design as shown in Fig 2.4. Secondary relationship also exists between material properties and manufacturing processes, between material properties and consumer requirements and between manufacturing processes and functional requirements. In many cases several alternative designs, materials and manufacturing routes are available and the basic function of the engineer is to select the most appropriate combination.

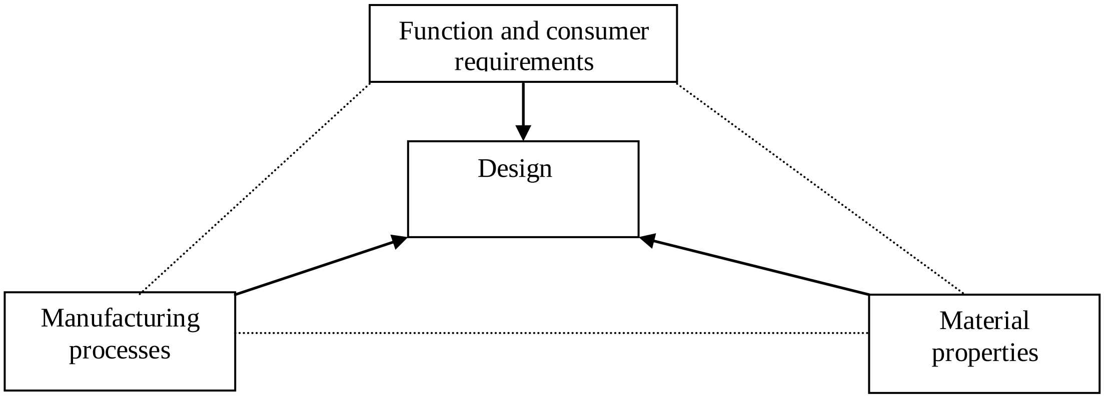


Fig 2.4 Factors affecting component design [Farag, 1984]

A useful tool in this type of selection is cost analysis. Each of the alternate solutions is broken down into individual items, which are separately cost analyzed and totaled. In a typical analysis the items are separated into fixed costs and variable costs. Once the costs are computed then the breakeven point between the alternatives is determined.

2.4 Existing Models

Several people have come up with different models for material selection which constitute rule-based systems, fuzzy approach, decision support systems etc. some of the systems are explained below.

2.4.1 Rule-based system

An existing model is a rule-based system for alloy and process selection. The user has to specify the certain mechanical and physical properties, and the quantity of casting to be made. The system will select a list of alloys whose properties fall within the input specification. Once an alloy has been selected, the most suitable casting process may be determined by specifying the number of casting parameters. The structure of the knowledge base is shown in Fig 2.5

From the flow chart it can be seen that the material needs to be selected before the process. This is because the physical and mechanical properties of the alloy underlie the specification of the component to be made [Sirilertworakul, 1993]. Alloy first approach is most suitable. The different possible routes of alloy selection is shown in Fig 2.5

Selecting an alloy by specifying engineering properties: The knowledge prompts to the user in the following way, asking the user to select an option every time, also allowing the user to go back to any stage and to make any modification.

Fig 2.5 Structure of the Knowledge Base [Sirilertworakul, 1993]

Fig 2.6 Different possible routes for Alloy Selection [Sirilertworakul, 1993]

1. Mechanical properties
    a) Tensile Strength
    b) Proof Stress
    c) Elongation
    d) Brinnel Hardness Number
2. Casting characteristics
    a) Fluidity
    b) Resistance to Hot Tearing
    c) Pressure Tightness
3. General properties
    a) Machinability
    b) Corrosion Resistance
    c) Strength at Room Temperature
    d) Strength at Elevated Room Temperature
    e) Electroplating
    f) Bright Anodizing
    g) Anodizing against Corrosion

Selecting an alloy from its chemical composition: There may be occasions when a preference for an alloy exists, but all that is known is about its most important constituents. In such cases a standard alloy is being suggested from the alloy knowledge database based on the composition specified by the user.

Selecting an alloy from its international specification: International specifications for each type of alloy are prompted to the user to help him to choose the right one. Access to information is provided in such a way that two alloys can be compared at the same time. This information includes all chemical, physical, chemical, mechanical and casting properties of an alloy.

Another model developed is a knowledge-based system [Tretheway, 1998]. In its simplest form, a knowledge-based system is a combination of a database and an inference engine. The transfer of knowledge from an expert to a computer is rarely straightforward, for experts often have a limited understanding of how they perform the complex tasks readily associated with their expertise.

The system basically contains knowledge base, database and an inference engine. Knowledge is mostly expressed in plain language, but also involves rules and relationships by which the data content of that knowledge can be considered to interact. Inference engine is the mechanism by which the databases are interrogated. Simple retrieval of the knowledge is of little value when it is done without interacting with the user. There will be frequent interactions between the user and the system. After a comparison of the cases from the experience of the expert, an answer is suggested as likely.

2.4.2 Multiple criteria decision making system

Another existing model is a decision support system for material and process selection [Ronald, 1998]. The material and process selection problem is a multi attribute decision-making problem. These decisions are made during the preliminary stages of design in an environment characterized by imprecise and uncertain requirements, parameter and relationships. Material and process selection must occur before design for manufacture begins.

The material and process selection must satisfy the product lifecycle requirements imposed by design engineering, marketing, reliability, aesthetics and quality. Consequently the selection problem is a multi attribute decision-making problem where the attribute corresponds to one of the product profiles requirements. The relevant decision criteria are

Mechanical

- Hardness
- Stiffness/density
- Strength/density
- Yield strength

Physical

- Density
- Cost/Kg

- Thermal conductivity
- Corrosion resistance

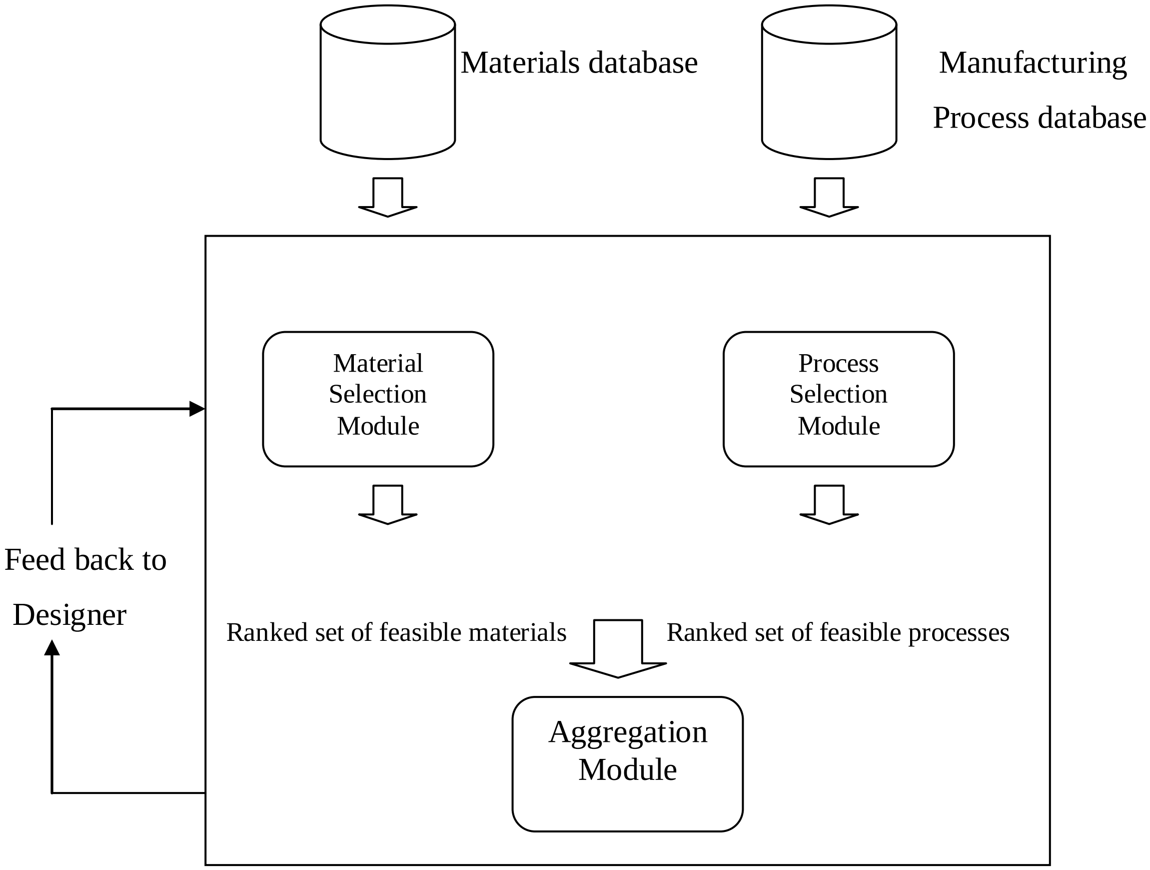


Fig 2.7 MAMPS architecture [Ronald, 1998]

Material properties critical to material selection problem are categorized as either mechanical properties or physical properties. Some criteria are represented as ratios of two properties. For example specific stiffness and specific tensile strength are employed, since these ratios are aiming at typical design objectives of maximizing a property for a given weight.

A decision support system for material and process selection called MAMPS has been developed to support designers for preliminary engineering Design State. The MAMPS architecture is as shown in Fig 2.7

Three modules work together to support the decision making task. The material selection module and the process selection module are order independent. These modules evaluate the compatibility between each alternative and the product profile requirements. The ranked feasible material and manufacturing process alternatives are provided to the designer. The material property and manufacturing process capability data are stored in a relational database.

2.4.3 Fuzzy approach

The values of materials are often qualitatively described or imprecisely measured using ranges. The importance of the material properties depends on the design requirements. Some material properties can be described using range of values. The desired value and the priority weight of a material property are usually described in linguistic terms. This impreciseness motivated Warren Liao T to develop a multi criteria decision-making method using fuzzy set theory [Warren, 1996].

Every material has different physical, mechanical and chemical properties. Physical properties include density, specific heat, thermal expansion and conductivity. Important mechanical properties are strength, toughness, hardness, elasticity, strength to weight ratio. Oxidation, corrosion etc are some of the important properties to be considered. These material properties can be generally classified into two main categories

Qualitative properties: Some material properties cannot be easily quantified, but instead are qualitatively described in terms of fuzzy terms such as "recommended", "acceptable', "not recommended" or other terms like “excellent”, “poor”, “good” and so on. One example of such a resistance is corrosion resistance.

Quantitative properties: Such properties can be expressed numerically. Due to stochastic nature of material processing operation, such properties are usually not fixed but range between two values. Such quantitative properties are fuzzy numbers.

A systematic approach to the material selection problem by using the concept of fuzzy set theory is proposed; the schematic diagram of this method is shown in Fig 2.8.

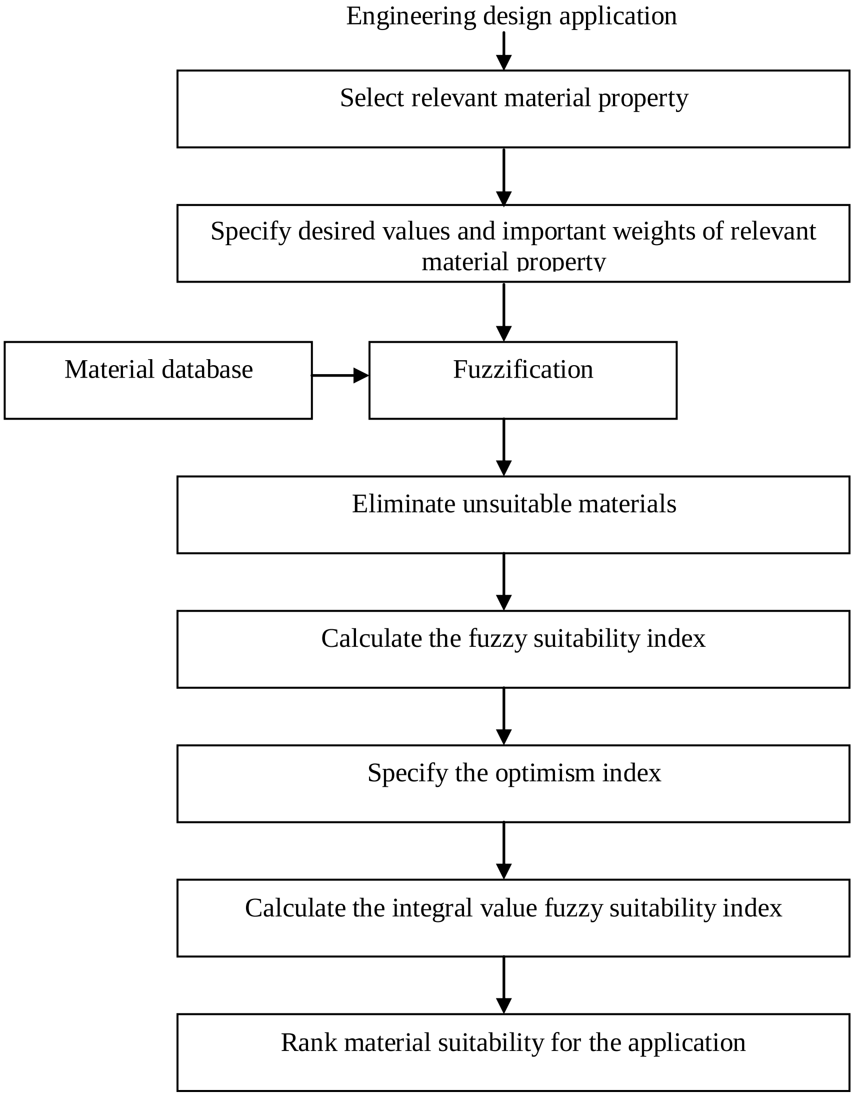


Fig 2.8 Fuzzy set theory based material selection methodology [Warren, 1996]

The proposed method currently assumes a single decision maker-the design engineer. The design engineer is responsible for selecting relevant properties and assessing the importance of the selected properties based on the requirements of a particular application. Each material in the database is an alternative to be selected for an application. The system assesses the suitability of all materials in the database, eliminates unsuitable materials from further consideration, and gives a final ranking of all suitable materials.

2.4.4 Websites related to material selection

The *www.matweb.com* is a useful site for getting basic information on different materials. This site contains information of over 20,000 materials. It contains details about metals like aluminum, cobalt, lead, magnesium, steel etc along with thermosetting polymers and also has got details about semiconductors and other engineering materials. Property lists of materials, provided in that site are not extensive. However, there is no particular selection methodology for cast metals available at this site.

This site allows the user to search the material database using different criteria viz., material type, trade names, manufacturer, property and material composition [Matweb, 2001]. But the selection is on a general basis. It gives a list of short listed materials, but not the optimum material. However, it does not facilitate prioritization of different criteria relative to each other.

The site *www.granta.co.uk* provides an engineering selector system named Cambridge engineering selector (CES). The services include access to reference databases and software customization.

This selector is an implementation of the engineering selection methodology developed by Professor Michael Ashby and co-workers at Cambridge University [ASM handbook, 1999]. It enables quantitative optimal selection of materials, processes, components or other engineering entities from relational databases. Large quantities of supporting information are available on CD-ROM and on the Internet, via links. There is a complete database development kit (constructor) for this selector. It enables users to create, edit, import, link and modify databases for selection, based on existing databases or in-house data [Granta, 2001].

This system connects materials, processes, sections and supplier records in its databases to the whole world of information sources on the Internet. It runs inside this selector and constructor.

Another website w*ww.cybercut.berkeley.edu/mas2* gives a working version of material and process selection. The peculiarity of this system is that as and when we enter the properties of the material, an applet will show which categories of materials will exhibit the characteristics so far entered [Berkeley, 2001].

2.5 Databases

A database is a collection of data that is organized, so that its contents can easily be accessed, managed, and updated. Large amount of data can be organized in a database. There are a large number of databases available. Each database has its own characteristics. Databases can be either relational or non-relational. A database management system (DBMS) consists of a collection of interrelated data and a set of programs that access those data. The collection of data, usually referred to as the database, contains information about one enterprise. The primary goal of DBMS is to provide an environment that is both efficient and convenient to use in retrieving and storing database information. Database systems are designed to manage a large body of information. Some of the examples of the databases are oracle, Sybase, mySQL etc. What these database systems do is that they will store information in an organized manner. By storing information in such a way it will be very easy to query the database in any manner, according to our need.

Material selection involves a large number of materials, with each having its own individual properties and characteristics. By creating a well-organized database of materials, the material selection problem can be simplified.

2.5.1 Material markup language

Materials property data distributed on the World Wide Web in documents using hypertext markup language (HTML) present two problems for computer applications intending to use the data: interpretation and interoperability.

Figure 2.8 contains an HTML code fragment, which is part of a table in a document from NIST ceramics web book and is used here to illustrate these problems [NIST, 2001]. Since the data are not self-describing, one would need a complete data dictionary and glossary of terms as well as exact detailed knowledge of the document structure in order to write a computer application that uses these data without human intervention. In Figure 2.8, it is difficult to distinguish the measurement parameters of magnetic Field, temperature and critical current density.

```
<tr>
<td align="center"><b>Magnetic Field (T)</b></td>
<td align="center"><b>Temperature (K)</b></td>
<td align="center"><b>Critical Current Density
(kA/cm<sup>2</sup>)</b></td>
</tr>
<tr>
<td align="center">0</td>
<td align="center">3</td>
<td align="center">3040</td>
</tr>
```

Figure 2.9: HTML Code Fragment from the NIST Ceramics WebBook [NIST, 2001]

Assuming a consistent structure within and across documents from the data source, it would then be possible to parse and interpret those data programmatically for subsequent use in another computer application. In absence of tightly and consistently structured documents, a data dictionary, and a glossary of terms, however, interpretation arises as a key stumbling block for automated use of the materials property data contained in HTML documents.

If interpretation of data were not an issue, the computer application developed to parse and use the data would likely encounter serious difficulties when it tries using data from other structurally dissimilar sources. Interoperability, then, would be a limiting condition for the use of the computer application across structurally dissimilar data sources even if data dictionaries and glossaries of terms were available.

The MatML effort is addressing the problems of interpretation and interoperability through the development of an extensible markup language (XML) for materials data, that will permit the storage, transmission, and processing of materials property data distributed via the World Wide Web. The example given in Figure 2.9 might be coded as in Figure 2.10 and would allow an application to interpret and use data regardless of their sources [NIST, 2001].

```
<PropertyDetails>
<Name>Critical Current Density</Name>
<Units>kA/cm<sup>2</sup></Units>
<DataSource>Journal</DataSource>
<DataType>Evaluated</DataType>
</PropertyDetails>
<Value>3040</Value>
<Parameters>
<Name>Magnetic Field</Name>
<Value type="integer">0</Value>
<Units>T</Units>

<Name>Temperature</Name>
<Value type="integer">3</Value>
<Units>K</Units>
</Parameters>
</Properties>
```

Figure 2.10: MatML Structure [NIST, 2001]

The strategy for MatML's development encompasses 6 steps:

1. Establishment of a working group
2. Delineation of the scope and specifications for MatML
3. Development of the formal MatML document type definition (DTD)
4. Development of a catalog of examples
5. Application development and acceptance testing

2.5.2 Casting database markup language

Right information at the right time in the life cycle of a cast product is an important factor for improved decision-making and in reducing the lead-time for its manufacture. This kind of improved decision making can be achieved by a systematic approach of managing and sharing the relevant information by the team of engineers who are responsible for the development of the product. Considering that the team members are at different parts of the world, the world wide web is the most suitable environment for this kind of information management and transfer. By using web, information can reach a large number of people with in a short time.

Like MatML, many XML based information models were developed. Some of them are Mathematical markup language (MathML), Chemical markup language (CML) etc., [NIST, 2001]. Casting Data Markup Language (CDML) is one such XML based 'self-describing' language for castings [Akarte, 2001]. It permits definition of domain specific tags. The following sections describe different types of information captured by the CDML, its classification and modeling for the web application.

CDML Structure: The CDML is a template for storing casting life cycle data (also referred as the casting *project data*). The approach to classify the casting project information in a hierarchical tree structure, which when used with other tools can be very helpful in web based information systems. This is a good candidate for web-based databases.

The basic requirements for an information system are easy location of the required information and fast retrieval over the Internet. Hierarchical structure enables easy location of the required information. However, the quick retrieval of information over the Internet is governed by the file size and the access speed. File size is taken into account while developing this structure.

The CDML consists of two parts, CDML tree and data blocks. The tree represents the hierarchical relationship between different types of life cycle information involved in a casting project, where as the data blocks are used for storing the actual project data. Tree is used for high level classification while data blocks is used for detailed level information. Hierarchical classification is supported with a well-defined numbering scheme, which provides flexibility to incorporate additional information in tree as well the data blocks. Each type of information is uniquely named and numbered, that allow linking of tree with data blocks. The data blocks are of smaller size. This helps in fast retrieval of information. As the tree structure is separated from the data blocks, it enables restructuring of the tree without modifying any associated programs using the data.

The tree is the hierarchical representation of different types of information required for or produced by different tasks in casting life cycle. Each node in the CDML tree represents unique information. For example, information about the cast materials will come under the node 'MATERIAL'. In the similar way, total 200 nodes have been defined for the initial version of CDML. Some of the other nodes are administration, product, process, equipment, quality etc. these are some of the main nodes of the structure. Each of these nodes has child nodes. A four level hierarchy is followed in this structure.

The hierarchical node structure of CDML has been converted into the standard XML (version '1.0') format by using node name as starting and ending tags. The tags are just like an HTML format. A unique number is followed for each node.

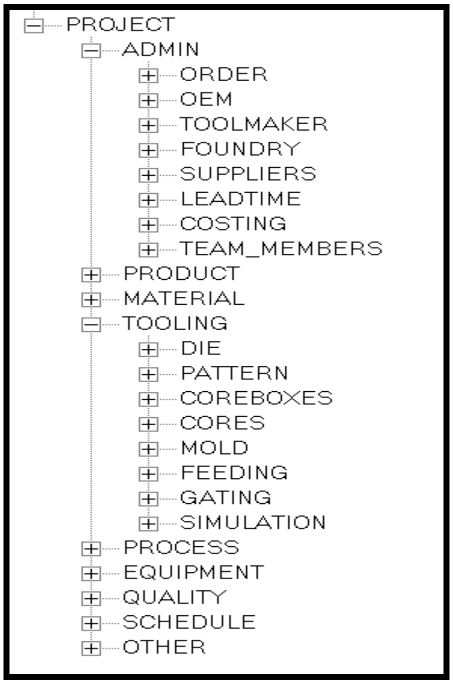


Fig 2.11 CDML tree structure

Each data block comprises several pairs of field names (with unit, if any) and their values representing the detailed content of a particular node. For linking node and data block, the node number has been used as a basis to obtain the file name for the corresponding data block. For example, the file name of MATERIAL, which comes under casting node is given by CD310.XML, which is obtained from the MATERIAL node number 310.

Web integrated casting engineering (WebICE): The web was originally developed to provide a low cost means for dispersed groups of people, all around the world, to share information with one another. Now a days we see the web evolving into a globally distributed computing environment, where software applications share information with one another. The XML, the universal format for structured documents and data on the web make this exchange possible.

The WebICE (Web-based integrated collaborative engineering) has been designed to provide facilities for creating, viewing, modifying and updating casting project data (stored in CDML) over the Internet from any location worldwide [Akarte, 2001]. WebICE framework also supports application interface (by linking application program for decision making) as XML based data storage (CDML data block) enables easy extraction of the required casting life cycle data.

The architecture of WebICE is shown in Figure 2.12. It consists of two parts: client side and server side. Client side has been used to provide the graphical user interface while databases and functions has been stored at server side. Important features of the architecture and the client-server approach have been discussed next. The system is designed for satisfactory performance even in low networks with low speed. The user interface is so designed, to display all the details of a particular project in different frames of a single window. The system is platform independent and can be used through a web browser. Programs developed with in the CDML structure can be linked with the WebICE for improved decision making. It facilitates display, browsing and copy of library options into the project, which reduces the need for manual input [Akarte, 2001]. Client-server computing is the logical extension of modular programming approach, where the program modules developed for the better interaction and maintenance can be placed and executed either completely at the server side, or at the client side, or distributed between them. The calling module is the client and it requires the service, whereas the called module is the server and it provides the service.

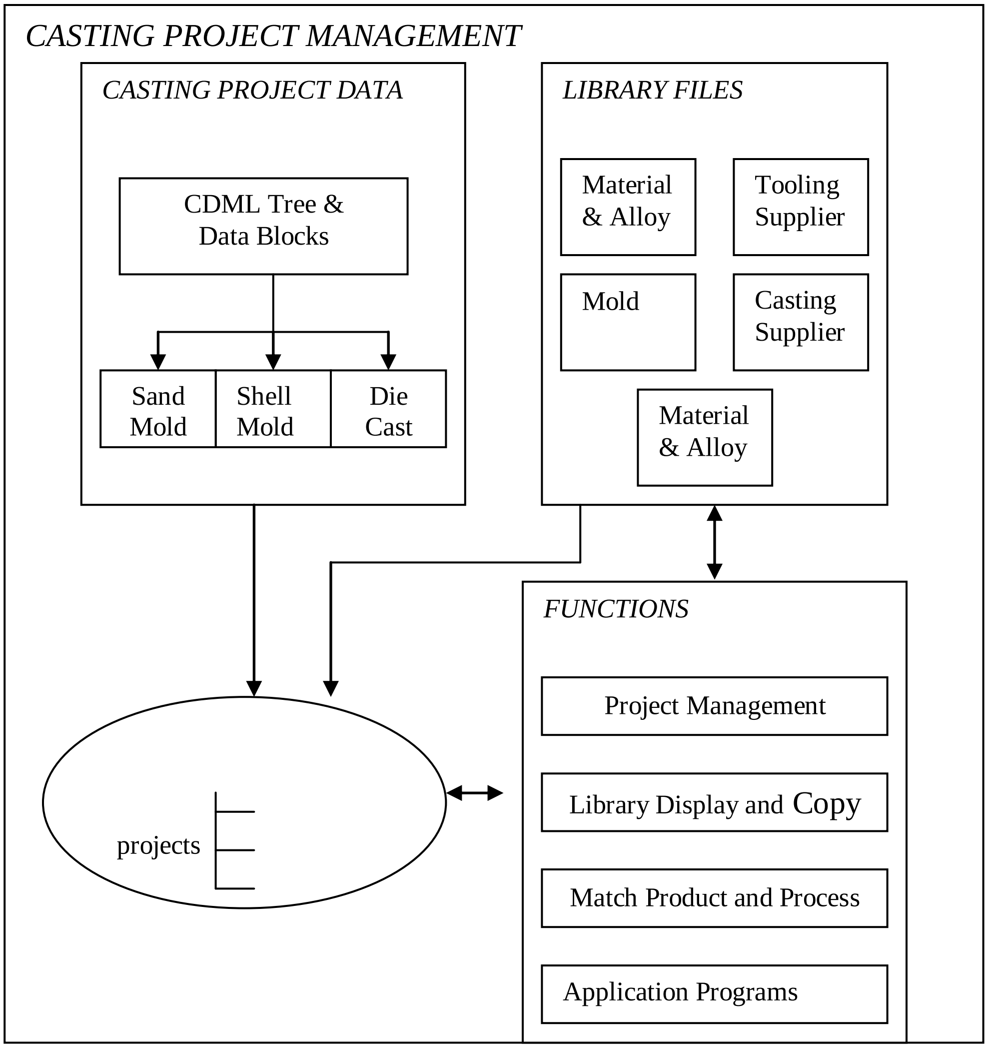


Fig 2.12 Layout of WebICE

A two-tier client-server model has been used for WebICE, where distributed environment has been chosen to minimize the client-server interaction and to use the standard XML-DOM functions at the client side. In particular, the client side user interface has been build with the help of HTML, JavaScript and XML-DOM functions while at server side PHP3 (platform independent scripting language) has been used.

The client side consists of display of CDML tree, data blocks, functions, image/model, library options, user inputs and the results of the computations. The server side has four main components: casting project databases, library database, user projects and functions (application and supporting programs).

The web-based environment for engineering application involves lot of interaction between the client-browser and the server and hence it should be carefully planned. During interaction, tracking the program variables is the most important issue in client-server model as HTTP 1.0 is a stateless protocol. Considering this aspect of web environment, programs should be planned to minimize the user input. Logical flow charts can be effectively used for understanding the interactions involved between the client and the server. Based on the interaction involved in WebICE, the server side implementation is planned in three parts, these are project initialization, working of functions and working of application programs. The project initialization is the commencement of a new project by the user. Once the project is initialized, user can browse, modify and update the casting project information. The user can also run the application programs by selecting specific functions in his project.

2.6 Summary of Literature Review

It is a well-established fact that material selection is an important step in product design. Since a large number of materials are available to choose from, selecting the right material from several alternatives based on a set of desirable properties becomes a multi criteria decision-making problem. Hence the current practice of manual selection may not yield optimum results. Moreover, with skilled persons leaving the industry, their expertise in selecting the right material is often lost. The literature review has shown that different methodologies have been developed for selection of materials for a particular application some work. Also, there is some work in information modeling of materials over the web. However, very few decision support systems are available for cast metal selection, especially over the Internet. There is a need for a web-based material selection system specifically for castings.

CHAPTER 3

DATABASE DESIGN

3.1 Overall Hierarchy of Material Database

A four level of hierarchy has been designed for the material database. The first level is the cast metals. These are broadly classified into ferrous and non-ferrous, which constitute the second level. The different families of metals, which fall into ferrous and non-ferrous categories, like ductile iron for ferrous and aluminium for non-ferrous, fall into the third level of hierarchy. The individual options of each of these families constitute the fourth level of hierarchy. The levels are shown in Fig 3.1

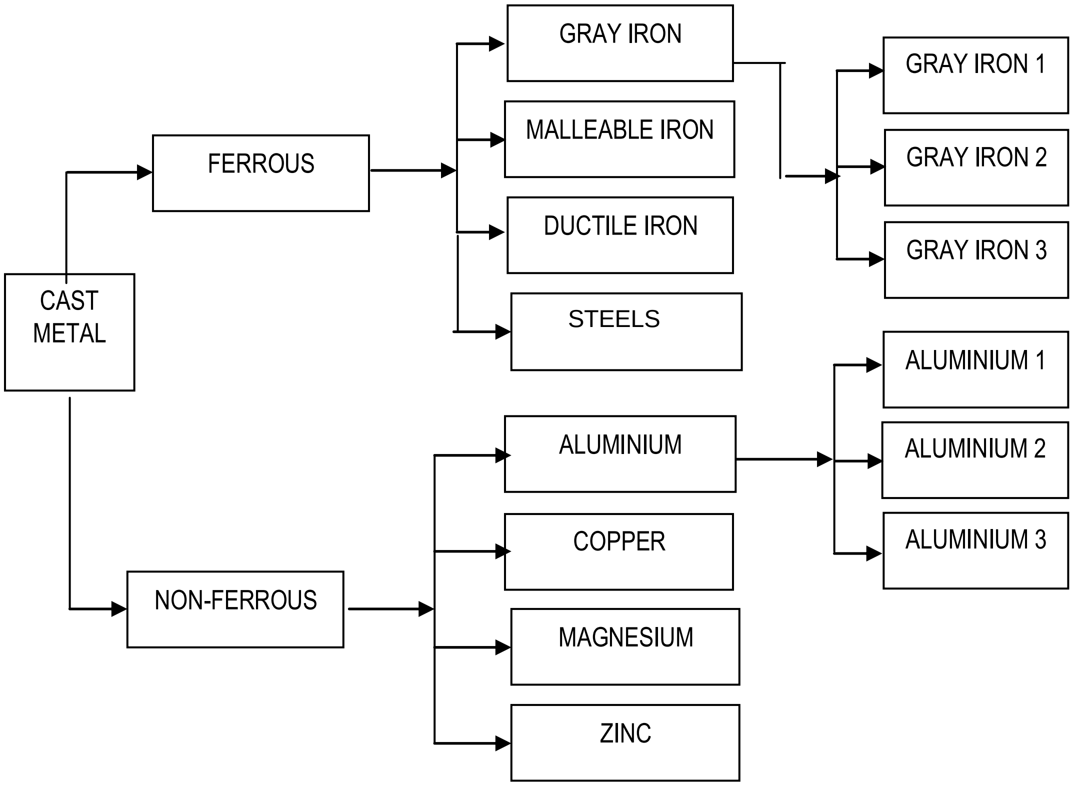


Fig 3.1 Four Level of hierarchy of materials

3.1.1 *Representation of libraries*

The cast materials are stored in a separate group of data blocks in CDML. The four level of hierarchy can be easily represented in XML. Each level starts with an opening tag and closes with a closing tag. The opening of the tags will be in the ascending order of levels, that is, level 1, level 2, level 3 and level 4, while the closing of the tags is just in the opposite way. The last level will be the one, which closes first and continues in the descending order of levels. The portion of the CDML library structure where material block falls, is shown in Fig 3.2

```
<CD310_LIB-001>
    <METAL TYPE= "FERROUS">

       <MATERIAL NAME="GRAY_IRON">
           <CD310_LIB-101> GRAY_IRON_150</CD310_LIB-101>
           <CD310_LIB-102> GRAY_IRON_200</CD310_LIB-102>
             …………………………………………………………
      </MATERIAL>
      …………………………………………………………..
      <MATERIAL NAME="STEEL">
          <CD310_LIB-401> STEEL_AUST_MN_1 </CD310_LIB-401>
          <CD310_LIB-402> STEEL_AUST_MN_2 </CD310_LIB-402>
            ……………………………………………………………….
     </MATERIAL>

   </METAL>

  <METAL TYPE= "NON_FERROUS">

      <MATERIAL NAME="ALUMINIUM">
         <CD310_LIB-501> ALUMINIUM_SI_1</CD310_LIB-501>
         <CD310_LIB-502> ALUMINIUM_SI_2</CD310_LIB-502>
          ……………………………………………………………….
    </MATERIAL>

        <MATERIAL NAME="COPPER">
         <CD310_LIB-601> COPPER_DCB_1 </CD310_LIB-601>
         <CD310_LIB-602> COPPER_DCB_3  </CD310_LIB-602>
            ……………………………………………………………….
       </MATERIAL>
      ……………………………………………………………………..

  </METAL>
</CD310_LIB-001>
```

Fig 3.2 Material block of the library structure

3.2 Fields and Values

Each CDML data block is stored in XML format, where the starting and ending tags are the field names and the value residing between them is the field value. The use of XML for data storage also allows easy representation of units of properties. If there are units for the properties, they are attached to the starting tag. Any number of attributes of a particular tag can be added along with the starting tag. Following example shows two field names: Tensile Strength and Modulus of Elasticity. The value of Tensile Strength is 400 while for Modulus of Elasticity is 50. The Tensile Strength has a unit ‘MPa’ while the Modulus of Elasticity has a unit ‘GPa’.

```
<TENSILE_STRENGTH UNIT="MPa> 400</ TENSILE_STRENGTH >
<ELASTICITY_MODULUS UNIT="GPa">50</ ELASTICITY_MODULUS >
```

First eight fields names of each data block are constant. These are root node – CDML, VERSION, NAME, FILE, DATE, TIME, MODEL and IMAGE. The importance of these field names is given below.

The root node – CDML is an essential part of XML and it represents the parent for all information classified into a particular data block.

The field name VERSION represents the current version of a particular data block. This can be useful to check the incompatibility of a program for a particular version of a data block.

NAME field indicates the name of the data block, which represents three levels in the CDML tree hierarchy: child, its parent and grandparent giving clear view of information classification.

FILE gives the file name of the data block that can be used either to read from or to modify the content of the file.

The field name DATE and TIME stores the date and time of data block creation or last update. The casting materials will fall within the casting block under the material as shown in Fig 3.3

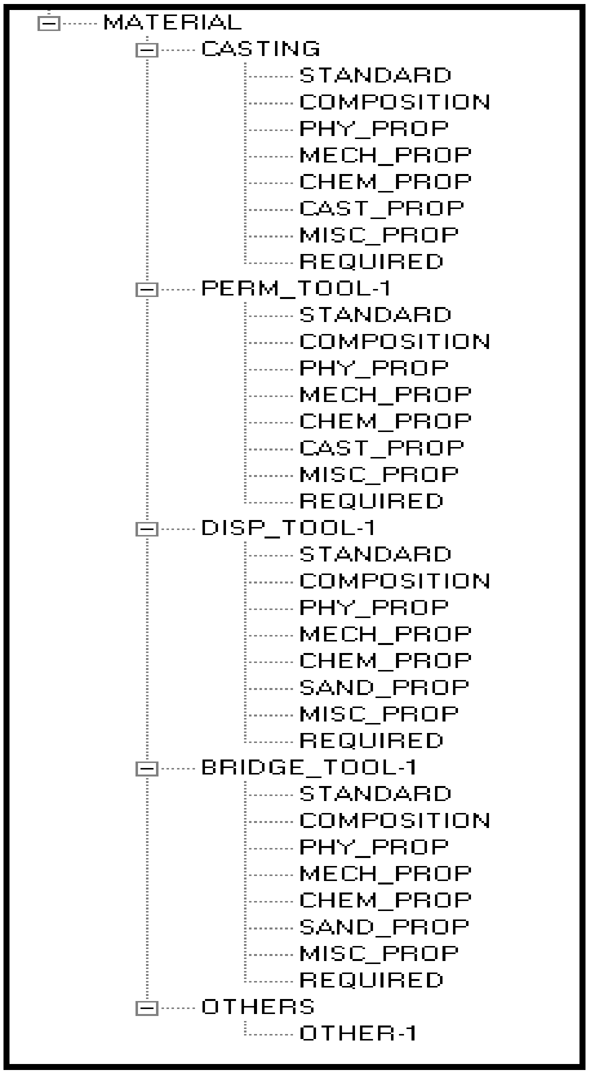


Fig 3.3 Exploded View of Material Block

This particular project deals with the materials that come under CASTING node. The CASTING node includes name of the casting and alloy material, its family, the standards and composition. It also include property information associated with it, such as physical properties (density, melting temperature, specific heat, latent heat, viscosity, thermal expansion), mechanical properties (tensile, yield, shear strength, compressive strength, fatigue limit, elongation, hardness, wear resistance), chemical properties (oxidation, moisture, and corrosion resistance), casting properties (solidus and liquids temperature, liquid shrinkage, pouring temperature), and other properties (recycleability, castability, machinability, weldability). Each of the above information has been stored into the separate data block. Targeted properties and attributes to be included in the database are shown in the table 3.1

Table 3.1 Targeted properties for the material database

Group	Targeted Criteria
Physical Properties	Density, Melting Temperature, Softening Temperature, Specific Heat, Latent Heat, Viscosity, Thermal Conductivity, Magnetic Permeability
Mechanical Properties	Tensile Strength, Compressive Strength, Shear Strength, Yield Strength, Elongation, Brinnel Hardness, Poissons ratio
Chemical Properties	Oxidation Resistance, Corrosion Resistance, Calorific Value
Casting Properties	Fluidity, Solidus Temperature, Liquidus Temperature, Pouring Temperature, Liquid-Solid Shrinkage

3.3 Library Files

The casting node consists of eight blocks. Each block stores properties, which falls into distinct groups like physical properties, mechanical properties, casting properties etc. so eight library files will be required to define a metal.

The XML format of the library block is similar to that of the data block, to which it belongs, except with an additional field called ‘target file’. It enables uniquely identifying the type of library block (with or without child) and simplifies the coding. In case of a block without child, the target file field uses the value of a single targeted data block. While for the data block with children the target file field uses the range of blocks

```
<TARGET_FILE> CD314.XML </ TARGET_FILE >
<TARGET_FILE> CD311.XML_TO_CD318.XML </ TARGET_FILE>
```

The options information for each data block is stored in a separate file (XML format). This target file represents the option meta data information – data about the options available for a particular data block. The meta data information enables fast tracking and retrieval of option using XML-DOM functions. Here the particular tag TARGET_FILE targets to seven different XML files. The structure of the eight blocks for each of the material option is shown in figures given below

```
<?XML VERSION="1.0" ?>
<CDML DOMAIN="CASTING DATA MARKUP LANGUAGE">
                    <VERSION> 1.1.0 </VERSION>
                        <NAME>  PROJECT.ADMIN.FOUNDRY  </NAME>
                          <FILE>  CD310_LIB-201.xml      </FILE>
             <TARGET_FILE> CD311.XML_TO_CD317.XML  </TARGET_FILE>
                         <DATE>   2001.05.01  </DATE>
                         <TIME>   09:34:08    </TIME>
<MODEL CREATED="NO">      NIL       </MODEL>
<IMAGE CREATED="NO">      NIL      </IMAGE>
</CDML>
```

Fig 3.4 General block for a particular option

```
<?XML VERSION="1.0" ?>
     <CDML DOMAIN="CASTING DATA MARKUP LANGUAGE">
             <VERSION>           1.1.0                    </VERSION>
             <NAME>MATERIAL.CASTING.STANDARD</NAME>
             <FILE>        CD311_LIB-201.xml              </FILE>
             <TARGET_FILE>     CD311.xml                  </TARGET_FILE>
             <DATE>              2001.01.01               </DATE>
             <TIME>              09:34:08                 </TIME>
             <IMAGE CREATED="NO">   NIL                   </IMAGE>
             <STD_NAME>              DUCTILE_IRON_350_22      </STD_NAME>
             <FAMILY>              DUCTILE_IRON           </FAMILY>
             <STANDARD_ASTM>         NIL                  </STANDARD_ASTM>
             <STANDARD_BS>           350_22               </STANDARD_BS>
             <STANDARD_DIN>          GGG_35.3             </STANDARD_DIN>
             <STANDARD_ISO>          350_22               </STANDARD_ISO>
             <STANDARD_IS>           350_22               </STANDARD_IS>
             <STANDARD_JIS>          NIL                  </STANDARD_JIS>
     </CDML>
```

Fig 3.5 Template block for different standards for a particular option

```
<?XML VERSION="1.0" ?>
<CDML DOMAIN="CASTING DATA MARKUP LANGUAGE">
<VERSION>                    1.1.0                </VERSION>
<NAME>MATERIAL.CASTING.COMPOSITION                </NAME>
<FILE>                       CD312_LIB-201.xml    </FILE>
<TARGET_FILE>                CD312.xml            </TARGET_FILE>
<DATE>                       2001.01.01           </DATE>
<TIME>                       09:34:09             </TIME>
<MODEL CREATED="NO">         NIL                  </MODEL>
<IMAGE CREATED="NO">         NIL                  </IMAGE>
<ALUMINUM UNIT="%">          0.00                 </ALUMINUM>
<ANTIMONY UNIT="%">          0.00                 </ANTIMONY>
<BERYLLIUM UNIT="%">         0.00                 </BERYLLIUM>
<BISMUTH UNIT="%">           0.00                 </BISMUTH>
<BORON UNIT="%">             0.00                 </BORON>
<CADMIUM UNIT="%">           0.00                 </CADMIUM>
<CARBON UNIT="%">            3.60                 </CARBON>
…………………………………………………..
</CDML>
```

Fig 3.6 Template block for composition

```
<?XML VERSION="1.0" ?>
<CDML DOMAIN="CASTING DATA MARKUP LANGUAGE">
<VERSION>               1.1.0                                 </VERSION>
<NAME>          MATERIAL.CASTING.PHY_PROP                     </NAME>
<FILE>                       CD313_LIB-201.xml                </FILE>
<TARGET_FILE>                CD313.xml                        </TARGET_FILE>
<DATE>                       2001.01.01                       </DATE>
<TIME>                       09:34:09                         </TIME>
<MODEL CREATED="NO">         NIL                              </MODEL>
<IMAGE CREATED="NO">         NIL                              </IMAGE>
<DENSITY UNIT="kg/m3">                           7100.0       </DENSITY>
<MELTING_TEMP UNIT="C">                          1150.0       </MELTING_TEMP>
<SOFTENING_TEMP UNIT="C">                        0.0          </SOFTENING_TEMP>
<GLASS_TRAN_TEMP UNIT="C">                       0.0          </GLASS_TRAN_TEMP>
<SPECIFIC_HEAT UNIT="J/kg.k">                    515.0        </SPECIFIC_HEAT>
<LATENT_HEAT UNIT="kJ/C">                        0.0          </LATENT_HEAT>
<VISCOSITY UNIT="stokes">                        0.0          </VISCOSITY>
<THERMAL_EXPANSION UNIT="um/m.K">                12.5         </THERMAL_EXPANSION>
<THERMAL_CONDUCTIVT UNIT="W/m.K">                35.8         </THERMAL_CONDUCTIVT>
<MAG_PERMEABILITY UNIT="uH/m">                   2136.0       </MAG_PERMEABILITY>
<ELEC_RESISTANCE UNIT="uohm.m">                  0.76         </ELEC_RESISTANCE>
</CDML>
```

Fig 3.7 Template block for mechanical properties

```
<?XML VERSION="1.0" ?>
<CDML DOMAIN="CASTING DATA MARKUP LANGUAGE">
<VERSION>                  1.1.0                </VERSION>
<NAME>          MATERIAL.CASTING.CHEM_PROP      </NAME>
<FILE>                     CD315_LIB-201.xml    </FILE>
<TARGET_FILE>              CD315.xml            </TARGET_FILE>
<DATE>                     2001.01.01           </DATE>
<TIME>                     09:34:08             </TIME>
<MODEL CREATED="NO">       NIL                  </MODEL>
<IMAGE CREATED="NO">       NIL                  </IMAGE>
<COLOR>                    NIL                  </COLOR>
<OXIDATION_RESIST>         0.0                  </OXIDATION_RESIST>
<CORROSION_RESIST>         0.0                  </CORROSION_RESIST>
<MOISTURE_RESIST>          0.0                  </MOISTURE_RESIST>
<INFLAMMABILITY>           0.0                  </INFLAMMABILITY>
<CALORIFIC_VALUE>          0.0                  </CALORIFIC_VALUE>
<TOXICITY>                 0.0                  </TOXICITY>
</CDML>
```

Fig 3.8 Template Block for Chemical Properties

```
<?XML VERSION="1.0" ?>
<CDML DOMAIN="CASTING DATA MARKUP LANGUAGE">
<VERSION>                          1.1.0           </VERSION>
<NAME>MATERIAL.CASTING.CAST_PROP                   </NAME>
<FILE>                     CD316_LIB-201.xml       </FILE>
<TARGET_FILE>                      CD316.xml       </TARGET_FILE>
<DATE>                             2001.01.01      </DATE>
<TIME>                             09:34:09        </TIME>
<MODEL CREATED="NO">               NIL             </MODEL>
<IMAGE CREATED="NO">               NIL             </IMAGE>
<FLUIDITY UNIT="mm">               0.0             </FLUIDITY>
<SOLIDUS_TEMP UNIT="C">            1150.0          </SOLIDUS_TEMP>
<LIQUIDUS_TEMP UNIT="C">           1161.0          </LIQUIDUS_TEMP>
<POURING_TEMP UNIT="C">            1300.0          </POURING_TEMP>
<LIQ-SOL_SHRINKAGE UNIT="%">       3.5             </LIQ-SOL_SHRINKAGE>
<POROSITY_PRONENESS>               0.0             </POROSITY_PRONENESS>
<PHASE_STABILITY>                  0.0             </PHASE_STABILITY>
<GRAIN_SIZE UNIT="um">             0.0             </GRAIN_SIZE>
<GRAIN_SHAPE>                      0.0             </GRAIN_SHAPE>
<GRAIN_DISTRIBUTION>               0.0             </GRAIN_DISTRIBUTION>
</CDML>
```

Fig 3.9 Template block for casting properties

```
<?XML VERSION="1.0" ?>
<CDML DOMAIN="CASTING DATA MARKUP LANGUAGE">
<VERSION>              1.1.0                          </VERSION>
<NAME>         MATERIAL.CASTING.MISC_PROP             </NAME>
<FILE>                      CD317_LIB-201.xml         </FILE>
<TARGET_FILE>               CD317.xml                 </TARGET_FILE>
<DATE>                      2001.01.01                </DATE>
<TIME>                      09:34:09                  </TIME>
<MODEL CREATED="NO">        NIL                       </MODEL>
<IMAGE CREATED="NO">        NIL                       </IMAGE>
<PRICE UNIT="Rs/kg">        0.0                       </PRICE>
<LOSS_PER_WASTAGE UNIT="%">0.0                        </LOSS_PER_WASTAGE>
<RECYCLING UNIT="%">0.0</RECYCLING>………………………</CDML>
```

Fig 3.10 Template block for miscellaneous properties

3.3.1 Indexing mechanism of material database

The casting material falls into the block number 310. That means the XML files starting with the CD310 will be related to casting materials only. To identify that the particular file is a library file, a LIB will be followed by CD310, that is, 310_LIB. The last three numbers of a particular material file will identify individual materials. The number series for different materials is as follows

100-199 - Gray Iron
200-299 - Ductile Iron
300-399 - Malleable Iron
400-599 - Steels
600-699 - Aluminium
700-799 - Copper
800-899 - Magnesium
900-999 - Zinc

The numbering scheme has been so designed so that up to 100 materials can be added to each family. This will be very useful in future, when new materials have to be added to the database. This way of numbering scheme also helps in programming, for example, if we want to screen the database, the file names can be easily put a in a loop. The naming convention followed will help the programmer in identifying the files easily. There are separate block numbers for each group of properties. The block numbers for each group are given below.

310 - General
311 - Standards
312 - Composition
313 - Physical properties
314 - Mechanical properties
315 - Chemical Properties
316 - Casting Properties
317 - Miscellaneous Properties

So a particular file name CD314_LIB-102.XML will be very much self-describing using this indexing scheme. This particular file is a material library file, which gives the mechanical properties of a particular member of Gray Iron family.

The CDML-based scheme described in this chapter provides a convenient and web-friendly approach to store, exchange and manage casting material data. The following chapter describes the methodology developed in this project for selecting and evaluating the most suitable material for a given application.

CHAPTER 4

MATERIAL SELECTION

4.1 Overall Approach

The first step is to identify the functional requirements of the material selection system considering the end users. The system is meant to provide the following functions:

- Facility for browsing through the database and view material properties
- Select a material based on a given standard (and view equivalent standards)
- Select a material based on a set of weighted criteria
- Determine the suitability of a selected material for an end application

The basic structure of the system being developed is as shown in Fig 4.1. The database of the cast metals, that is, aluminium alloys, cast irons, copper alloys, magnesium alloys, steels and zinc alloys are created at the back end. There after the material selection system is developed. The material selection system is directly linked to the database of cast metals. The user is communicating with the database through the user interface.

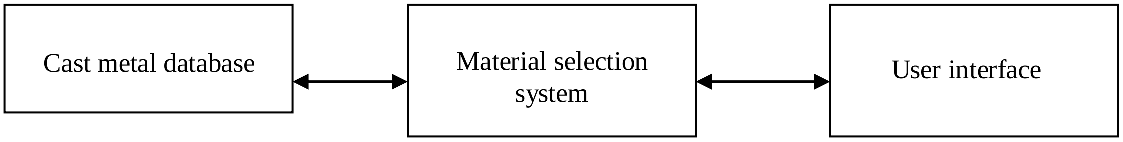


Fig 4.1 Basic structure of material selection system

4.2 Flow Chart

A simplified flow chart for the material selection system is shown in the Fig 4.2. The functionalities mentioned earlier have been developed for the materials selection system.

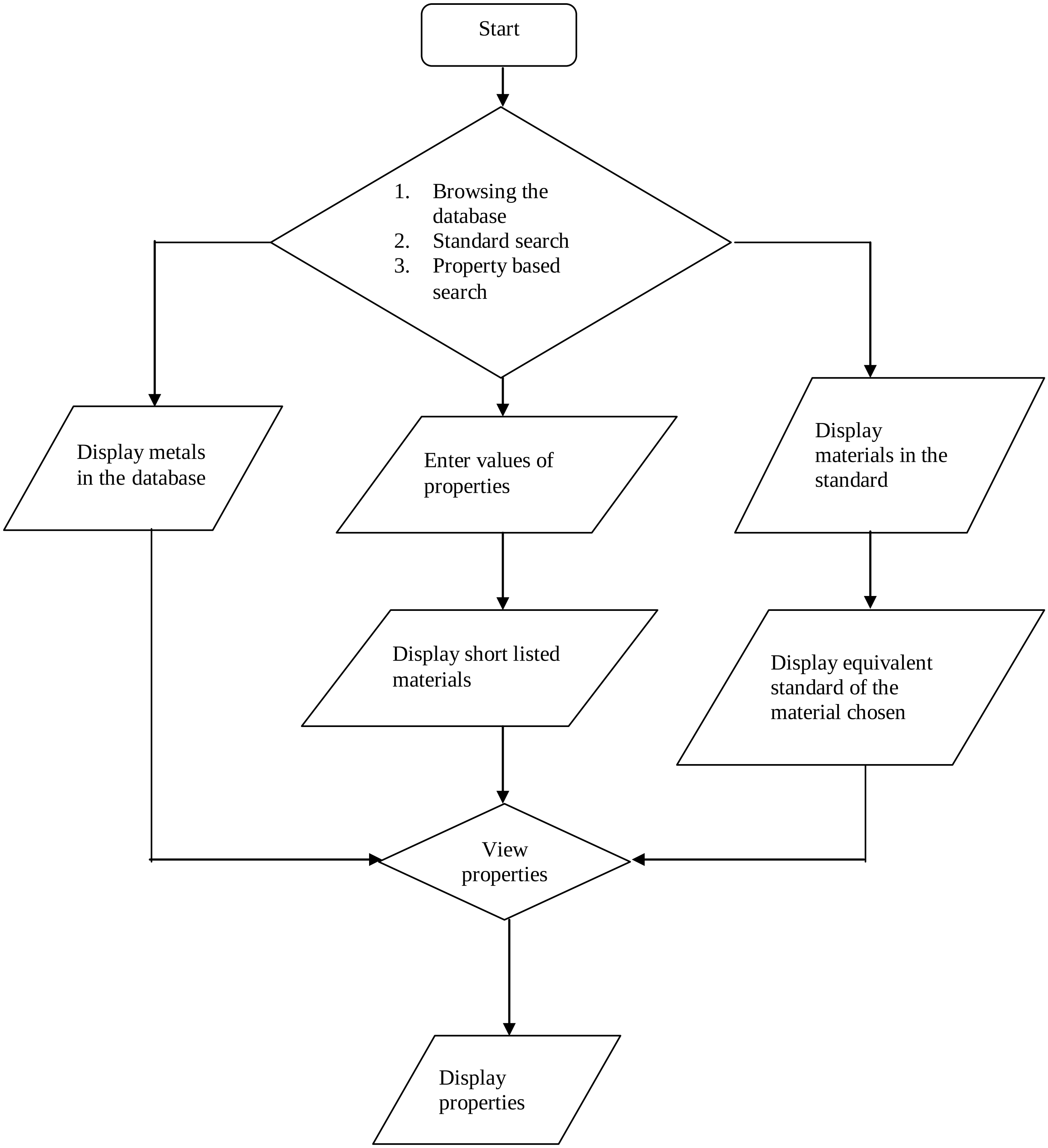


Fig 4.2 Flow Chart for the Material Selection System

The user can go to any of these options. If he is selecting the function: browsing through the database, he is allowed to see the entire metals in the database. He can also go to other functions like standards search and property-based search. In either case he will be provided with metals matching his input. Then he can select any metal and view its properties. The options are described in detail next.

4.3 Browsing the Database

The user can directly browse the information available in the database. When the material block is selected a function called ‘library’ will appear in the fifth frame. The function of this library is to show all the top-level hierarchy of the materials in the display frame. In this case, ferrous and non-ferrous will be shown as radio buttons. The user can select any of the two and then proceed. Then the next level will be shown. The different families coming under ferrous or non-ferrous will be shown according to the selection done by the user. Then the user should select a family and proceed. After the user selects a family, all the materials coming under that family will be displayed. The user should then select which material he wants to view. Once he selects a particular metal, hyperlinks for various properties of that particular metal will be displayed in the browser window, through which the user can view the different properties of the selected material.

4.4 Equivalent Standards Search

This is another way of selecting materials. The user can go by different standards for selecting material. If the user chooses that function, he will be provided with the options available, that is, ASTM, BS, IS, ISO, JIS. He can choose which option to start with. Then the complete list of standards available, which the user has chosen, will appear in a drop down list, from which he can choose his option. Each metal standard displayed in the list box will be preceded by the name of its respective family. Once he selects a particular metal, he can submit the form for finding its equivalent standard. The selection system, after querying the database, the equivalent standards of the particular metal, the user has chosen, will be displayed in a table format. He can also view the different properties of that particular metal.

4.5 Property based Search

This functionality is developed, to help the users in selecting the cast metals, based on their properties. The importance of different properties of a particular component depends on its final application. This search requires quantitative values for different properties to be entered by the user. This functionality basically helps users, who know the desired values for different properties of a component he wish to manufacture. He can strengthen his search by giving limits to different property values and also by giving relative importance to properties. The result displays the most optimum metals available in the database, according to values entered by the user.

4.5.1 User input

Once the user goes to material selection, he will be provided with two options, either, he can go for a search based on different standards, or, he can go for a property-based search. After he selects property-based search, he will be provided with a form, which contains a list of properties along with three importance values for each property. The properties provided in the form are density, melting temperature, thermal conductivity, specific heat, tensile strength, shear strength, modulus of elasticity, brinnel hardness, poissons ratio, solidus temperature, liquidus temperature and pouring temperature. Three levels of importance are included. They are 'very important', 'important' and 'desirable'. These important values are given in a drop down list box along with the properties. The default importance value for all properties is 'very important'. The user has to select the properties, along with the importance values, which he wishes to give values. After selecting the properties and their relative importance, he has to submit the form. This opens another form, which contains only the properties the user has selected in the previous form. Three text boxes per property will be provided to the user. They are provided for entering minimum value, desired value and maximum value of a particular property. Then the user has to fill in the values in the corresponding text boxes. Now the form is ready to be submitted. All the above steps are done in the client side only. Once this form is submitted, the values from the form, entered by the user are assigned to HTTP postscript variables and are taken to the server side for evaluation.

4.5.2 Evaluation

The first step in finding the suitable materials is to screen the entire database according to the maximum and minimum values of the different criteria. After short-listing the materials according to the minimum and maximum values entered by the user, the system finds out the closeness of the actual value with the desired value, the user has entered. The individual suitability of the values of the different criteria is summed up for the candidate materials. Individual suitability values for different criteria are found out for a maximum suitability value of 10. But according to the importance given to the criteria, by the user, the maximum suitability of each criterion is multiplied by an integer. The weightage values given for importance levels 'very important', 'important' and 'desirable' are 3, 2 and 1 respectively. In this way the relative importance value given by the user is taken into account. The sum of all the suitability of different criteria for the candidate materials is then scaled to value of 100. A suitability value of 100 means the material is perfectly close to the desired values specified by the user, while a value of 0 indicates that the material is farthest away from the desired values. The suitability value of a particular metal is found out by the following equation

$$SI = \sum_{i=1}^{n}\left[\left(10 - \frac{|P_{di} - P_{ai}| \times 10}{D_{\max i}}\right) \times W_i\right] \times \frac{100}{\sum_{j=1}^{n}(10 \times W_j)}$$

Where

SI = suitability index of a particular metal in the database

P_{di} = desired value of i_{th} property as entered by the user

P_{ai} = actual value of i_{th} property of that particular metal in the database

D_{maxi} = maximum deviation of values of i_{th} property as entered by the user

n = total number of properties the user has selected

W_i, W_j = weightage value of the i_{th} or j_{th} property selected by the user

4.5.3 Sample calculation

Suppose the user selects two criteria, density and thermal conductivity and he also gives 'very important' and 'important' as the weight for the properties respectively. So he has to enter minimum, maximum and desired value for the two criteria.

den_min - minimum value of density (value entered by the user = 7100)
den_des - desired value of density, P_{d1} (value entered by the user = 7550)
den_max - maximum value of density (value entered by the user = 8000)

tc_min - minimum value of thermal conductivity (value entered by the user = 25)
tc_des - desired value of thermal conductivity, P_{d2} (value entered by the user = 40)
tc_max- maximum value of thermal conductivity (value entered by the user = 100)

Let the actual values of the criteria for a particular option (GRAY_IRON_260) be
P_{a1} - actual value of density for particular option (value=7200)
P_{a2} - actual value of thermal conductivity for particular option (value=46.8)

After screening the database this material will definitely be short-listed, as the actual values of the criteria lies between the maximum and minimum values specified by the user. The calculation of the suitability value is as follows. Each property is scaled to a value of 10 × y, where 'y' is the weightage value of a particular property.

$$\begin{aligned} \text{Maximum deviation of density, } den\_dev &= \max((den\_max-den\_des),(den\_des-den\_min)) \\ &= \max((8000-7550),(7550-7100)) \\ D_{max1} &= 450 \end{aligned}$$

Similarly for thermal conductivity, $D_{max2} = 60$

This maximum deviation is scaled to a value of 10. That is, if the deviation between the actual value of density for a particular option and the desired value specified by the user is 450 then suitability value for that property will be 0 out of 10 and if the difference is 0 then the weightage value will be 10 out of 10.

Here actual deviation =7550-7200 = 350

Suitability Index = 10 - (350/(450/10))

= 2.22

Since the weight given to density is 'very important', the suitability index has to multiplied by 3. So the new value of suitability index is 6.66. This suitability value is out of 30.

Similarly proceeding, the suitability value for thermal conductivity for that particular option will be 8.66. Since weight for the criteria, thermal conductivity is ‘important’; the suitability value has to be multiplied by 2. So the new suitability value is 17.32, which is out of 20.

Total Suitability (*SI*)= 6.66+17.73 = 11.32 (out of 30+20=50)

Scaling to a value of 100 we will approximately get the total suitability as 48.The above said detailed procedure for calculating suitability index is done by a single equation given in the previous section.

Similar procedure can be repeated for all other cases. The materials along with the suitability are listed as results of the selection. The suitability will be represented by a colored bar. Then the user can select any metal and view its properties. Separate links are given to physical properties, mechanical properties, casting properties and composition. Another function is that the user can find the closeness of the actual values of different criteria of the metal chosen, with the values given by him. This evaluation is done in the similar manner by which the suitability values of individual metals are found out. In this case, only the suitability value of individual criteria is found out. Colored bars then display these suitability values.

The material database and selection methodology has been implemented in a web-based framework, described in the following chapter.

CHAPTER 5

IMPLEMENTATION AND TESTING

5.1 Implementation Tools

This particular type of application follows client server architecture. The application, mainly database oriented, has database created at the server side. The tools needed for this application are described here.

Tool for user interface: HTML (Hypertext Markup Language) is the tool used for developing user interfaces at the client side. HTML is an application of SGML (Standard Generalized Markup Language). It is a simple language used to define and describe the layout of a web page. HTML consists of special codes, which when embedded in text, adds formatting. The Internet protocol, which is used to communicate between clients and servers, is HTTP (Hypertext Transfer Protocol).

Tool for database: In today's changing world of technology, XML (Extensible Markup Language) is a valuable tool in facilitating the exchange of data between systems. It is based on the same principles of markup languages that make HTML work. However for many complex operations, XML is the most widely used extension of HTML But the basic difference is that, unlike HTML, it allows us to define our own tags, which make it much more flexible than HTML. By utilizing this property, databases for web can easily be created. The version of XML used in this project is version-1.0.

Client side scripting tool: Whenever the user submits a form, if the request has to travel all the way to the server without checking the validity of the data entered in the form, then it will lead to loss of time for getting the useful results. So there should be some tool which when used will do some function, that is not required to be executed at the server side. For this kind of client side scripting JavaScripts are used. Usually client side scripting language is used for validating forms. JavaScripts facilitates the developer with properties related to document windows, frames, forms, loaded documents and links.

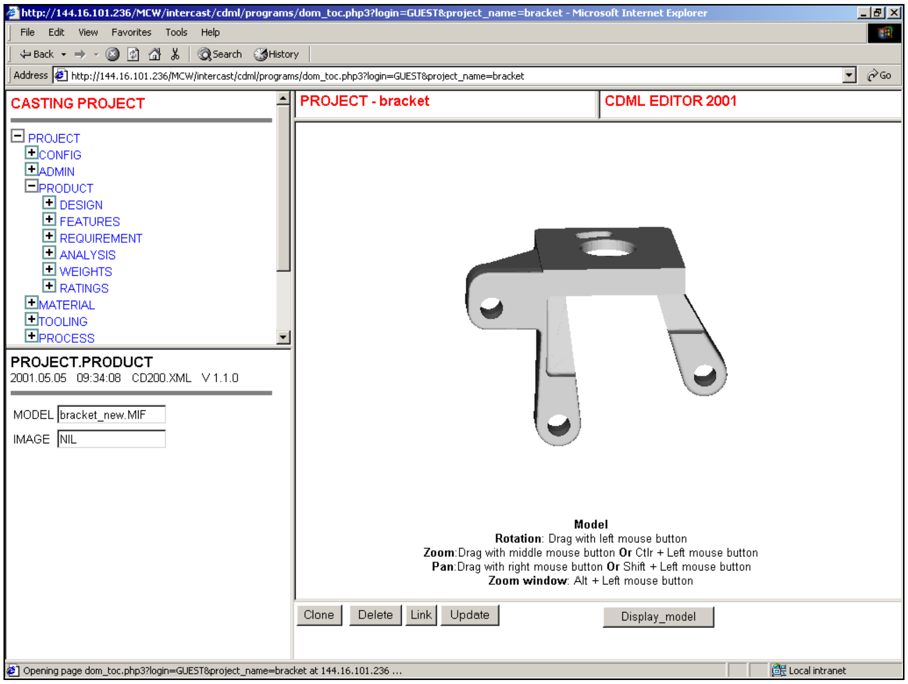
Server Side Scripting Language: The server side scripting language used in this project is PHP3.0. Server side scripting language will communicate with the database at the server side and get the desired results. PHP can be called as an interface through which the user communicates with the database. PHP is a server-sided, cross-platform, HTML embedded scripting language. PHP is a tool that lets you create dynamic web pages. PHP-enabled web pages are treated just like regular HTML pages and you can create and edit them the same way you normally create regular HTML page. Unlike other server side scripting languages, PHP is an open source. This means that we can view the source code of each and every function of this language and can change that according to our need. Connecting a database to Internet is made very easy by using PHP.

5.2 User Interface

To facilitate the easy interaction between the remote server and the client (web browser) a separate program have been developed called WebICE GUI. When the user initializes the casting project the program is automatically downloaded into the client-browser. It has been developed to provide graphical user interface in the client-browser and linking mechanism between CDML tree, data block, functions, image display, application programs and library options. The size of the program is very small and it uses XML-DOM functions for accessing the CDML tree and data blocks, HTML for better visual representation and JavaScript for dynamic content. The user interface is shown in Fig 5.1
For better visual representation the browser window at client side is divided into seven Frames and the output of various tasks performed by the WebICE GUI are ported into different Frames. The use of seven Frames on the client-browser is shown below.

1. The first Frame is used to display the CDML tree, which allows the user to browse though it with the help of mouse clicks. On mouse click, the CDML tree will either expand or collapse.

2. The second Frame is used to display the detailed information classified under a particular data block. It allows the user to browse and modify the required casting project data.
3. The third Frame displays the name of the casting project.
4. Fourth Frame shows the WebICE GUI version.
5. The fifth Frame, which is the largest, is used to display 2D images or 3D models. Other important use of this Frame is to display the application program and its interface; the computational results are also displayed in the same Frame.
6. Casting project management functions (clone, delete, link and update) are ported in to the sixth Frame.
7. The seventh Frame shows data block functions specific to a particular application, for example, Library and Calculate weights. Any application or library option attached to a specific data block will have a link through this Frame. The selection (by mouse click) of a particular function in this Frame will automatically initiate the respective program in Frame five.



http://144.16.101.236/MCW/intercast/cdml/programs/dom_toc.php3?login=GUEST&project_name=bracket

PROJECT.PRODUCT
2001.05.05 09:34:08 CD200.XML V 1.1.0

MODEL bracket_new.MIF
IMAGE NIL

Model
Rotation: Drag with left mouse button
Zoom:Drag with middle mouse button **Or** Ctlr + Left mouse button
Pan:Drag with right mouse button **Or** Shift + Left mouse button
Zoom window: Alt + Left mouse button

Opening page dom_toc.php3?login=GUEST&project_name=bracket at 144.16.101.236 ...

Fig 5.1 User interface of WebICE system

5.3 Databases

The families that are to be included in the database were already explained in the previous chapter. So as to fit properly into the CDML structure, each material database is divided into eight XML files. There will be a basic file, which will point to the other files of that particular material. This is some sort of a relational approach to the material database. Another advantage of splitting each materials data is that file reading will be easy in the case of smaller files. By splitting we are actually reducing the size of files. This will definitely help to increase the efficiency of the system. The following figure Fig 5.2 shows how the files are linked. A field in the basic file of every material contains the file names of its component files. The basic file of every material contains complete information about that particular metal. The basic file is a sort of metadata for the component files.

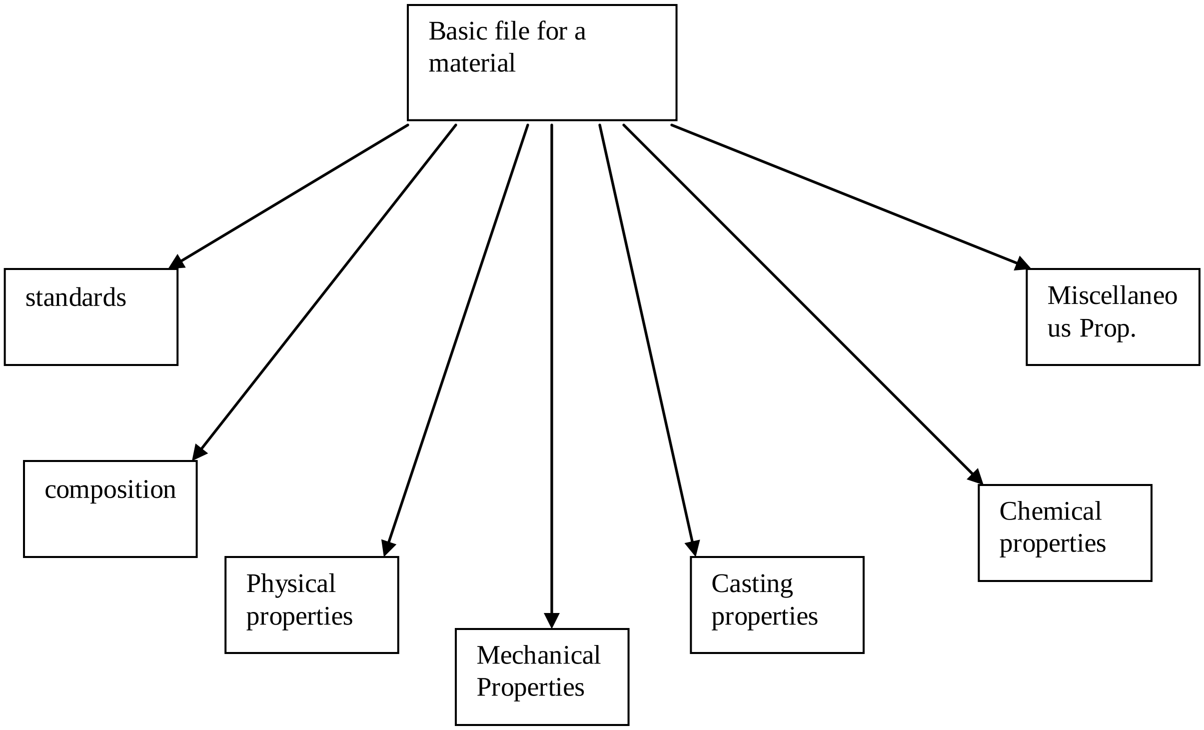
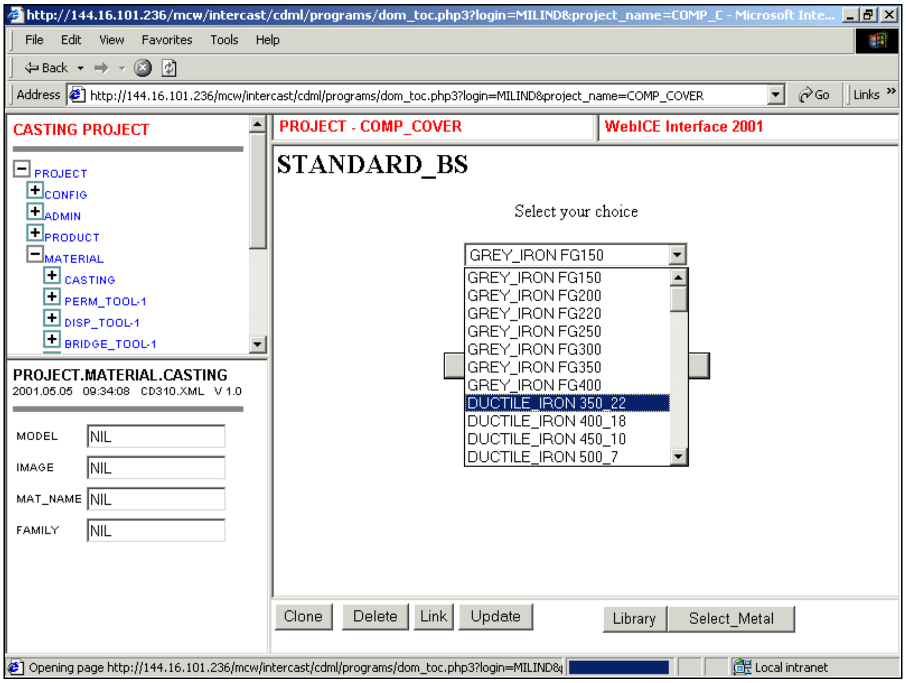


Fig 5.2 Relationship between the database files

5.4 Sample Sessions

In this section, important results of this project are shown. The user first has to connect to the local server at IIT Bombay (http://144.16.101.236/mcw/intercast/cdml/index.html). After logging into that (user name: GUEST, password: guest) he must initiate a new project. Then the server will display the main page of WebICE. To go into the material selection program he must click the CASTING node, which is a child node of MATERIAL node. Then he will be provided with two functions, library and material selection. The user will be provided with two hyperlinks, one for standard based search, and the other for property based search, once he enters the material selection function. He can choose any of the two options. If he chooses standard based search, he will be provided with five standards. They are ASTM, BS, ISO, IS and JIS. They are provided to the user as radio buttons. He can choose any of the above five standards and submit the form. Here in this session the user chooses BS (British Standard). The database will be queried and all the BS standards available in the database will be taken and will be displayed in a drop down list box. This is shown in Fig 5.3. He can select any of the option and find out the equivalent standards. Here the user chooses a particular option and views its equivalent standard. This session is shown in Fig 5.4. The next screen shot Fig 5.5 shows the user viewing the physical properties of a particular option. He can also view its composition, mechanical properties and casting properties also.

The next screen shot Fig 5.6 shows the form for property-based search. Here different properties along with its importance will be provided. The user has to select the criteria he wants to give property values along with its importance. Here the user makes some selection and he submits the form. Fig 5.7 shows only the criteria the user selected in the previous form along with text boxes for inputting the values. Here the user inputs some values. The short listed material as per the input of the user is shown in the Fig 5.8. The next session Fig 5.9 shows, how close are the actual property values of a short-listed metal, with respect to the values entered by the user. The closeness values are given out of 100. That means a value of 100 means the actual value is exactly matching the value entered by the user. Colored bars represent these suitability values. The last session shows, user browsing through the database, see Fig 5.10



PROJECT.MATERIAL.CASTING
2001.05.05 09:34:08 CD310.XML V 1.0

MODEL	NIL
IMAGE	NIL
MAT_NAME	NIL
FAMILY	NIL

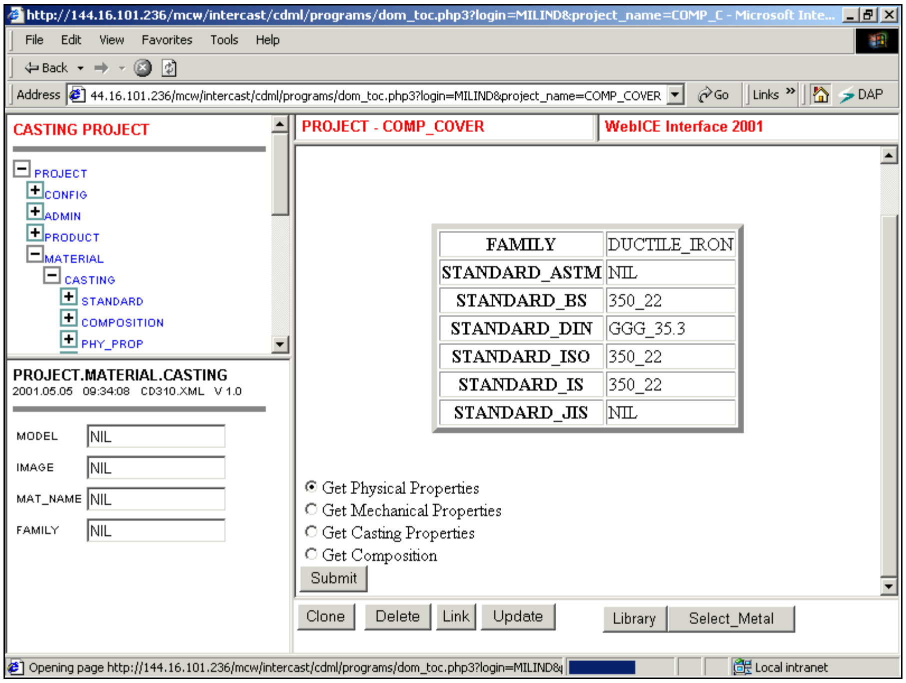
STANDARD_BS

Select your choice

GREY_IRON FG150

- GREY_IRON FG150
- GREY_IRON FG200
- GREY_IRON FG220
- GREY_IRON FG250
- GREY_IRON FG300
- GREY_IRON FG350
- GREY_IRON FG400
- DUCTILE_IRON 350_22
- DUCTILE_IRON 400_18
- DUCTILE_IRON 450_10
- DUCTILE_IRON 500_7

Fig 5.3 Screen shot showing the metals in British Standard



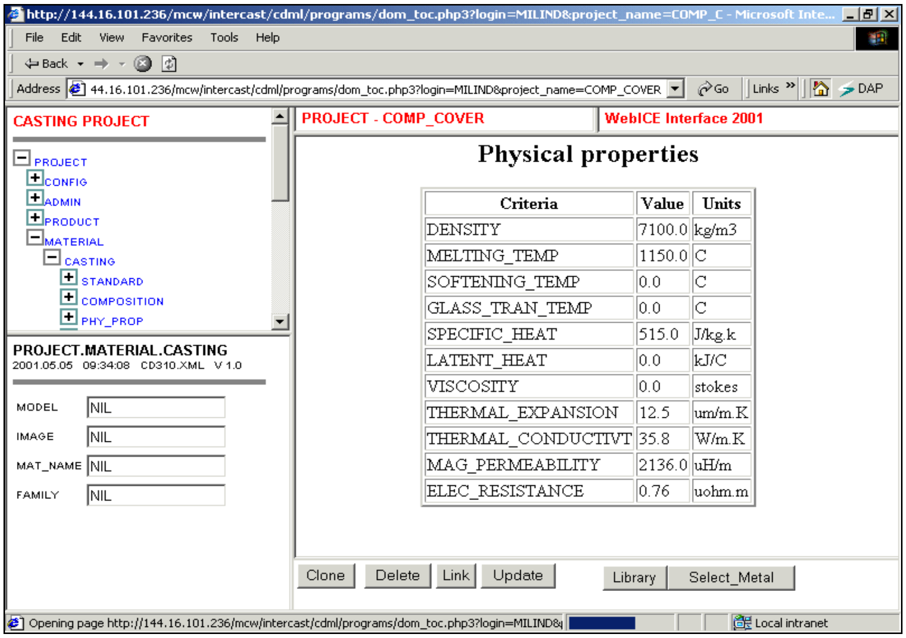
PROJECT.MATERIAL.CASTING
2001.05.05 09:34:08 CD310.XML V 1.0

MODEL	NIL
IMAGE	NIL
MAT_NAME	NIL
FAMILY	NIL

FAMILY	DUCTILE_IRON
STANDARD_ASTM	NIL
STANDARD_BS	350_22
STANDARD_DIN	GGG_35.3
STANDARD_ISO	350_22
STANDARD_IS	350_22
STANDARD_JIS	NIL

● Get Physical Properties
○ Get Mechanical Properties
○ Get Casting Properties
○ Get Composition

Fig 5.4 Screen shot showing the equivalent standard of the metal chosen



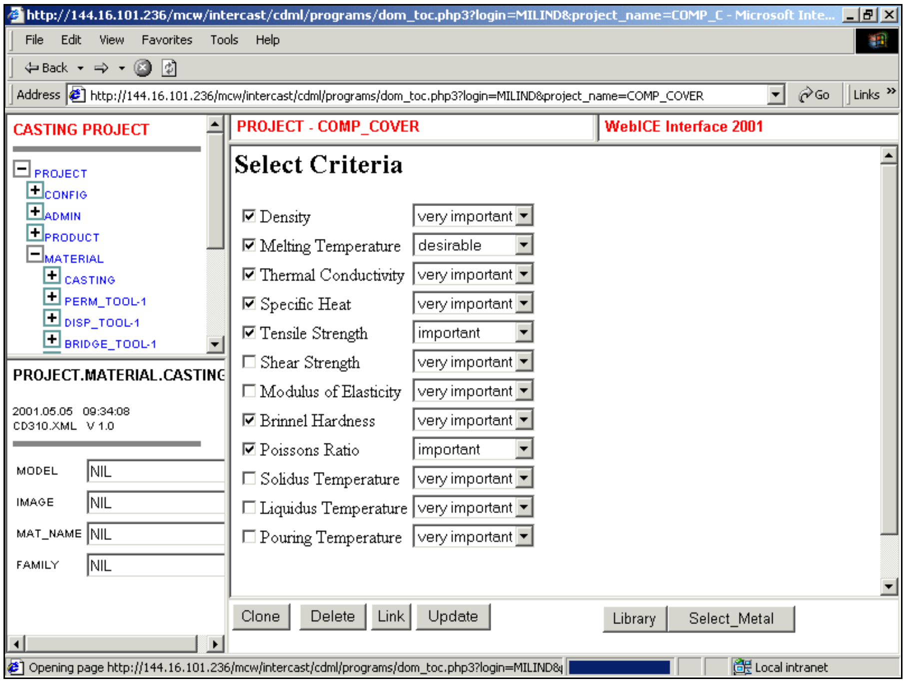
PROJECT.MATERIAL.CASTING
2001.05.05 09:34:08 CD310.XML V 1.0

MODEL NIL
IMAGE NIL
MAT_NAME NIL
FAMILY NIL

Physical properties

Criteria	Value	Units
DENSITY	7100.0	kg/m3
MELTING_TEMP	1150.0	C
SOFTENING_TEMP	0.0	C
GLASS_TRAN_TEMP	0.0	C
SPECIFIC_HEAT	515.0	J/kg.k
LATENT_HEAT	0.0	kJ/C
VISCOSITY	0.0	stokes
THERMAL_EXPANSION	12.5	um/m.K
THERMAL_CONDUCTIVT	35.8	W/m.K
MAG_PERMEABILITY	2136.0	uH/m
ELEC_RESISTANCE	0.76	uohm.m

Fig 5.5 User viewing the physical properties of a particular Metal



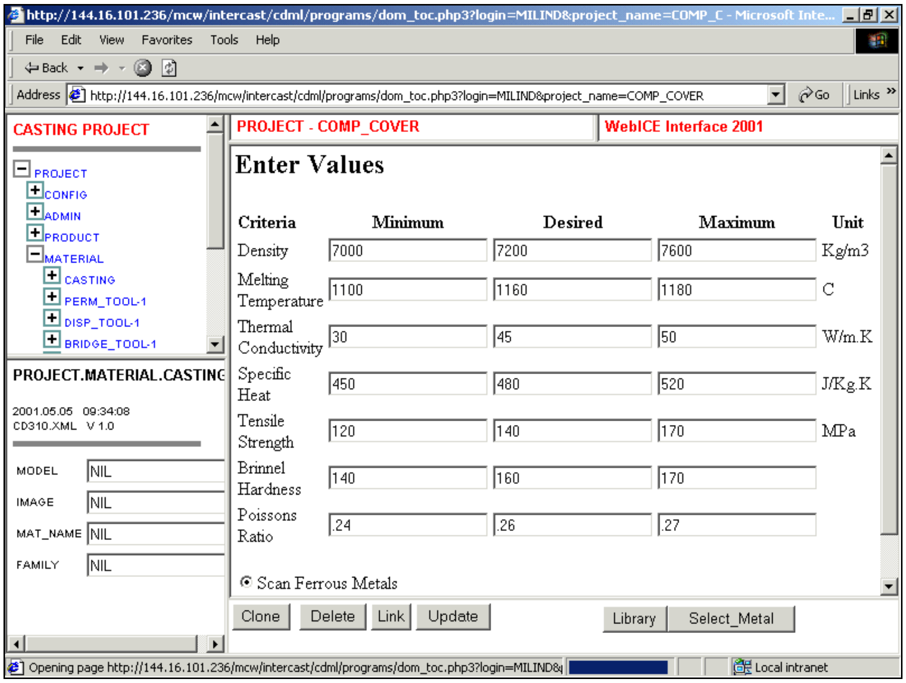
PROJECT.MATERIAL.CASTING
2001.05.05 09:34:08
CD310.XML V 1.0

MODEL NIL
IMAGE NIL
MAT_NAME NIL
FAMILY NIL

Select Criteria

☑ Density very important
☑ Melting Temperature desirable
☑ Thermal Conductivity very important
☑ Specific Heat very important
☑ Tensile Strength important
☐ Shear Strength very important
☐ Modulus of Elasticity very important
☑ Brinnel Hardness very important
☑ Poissons Ratio important
☐ Solidus Temperature very important
☐ Liquidus Temperature very important
☐ Pouring Temperature very important

Fig 5.6 User selecting the criteria and their importance



PROJECT.MATERIAL.CASTING

2001.05.05 09:34:08
CD310.XML V 1.0

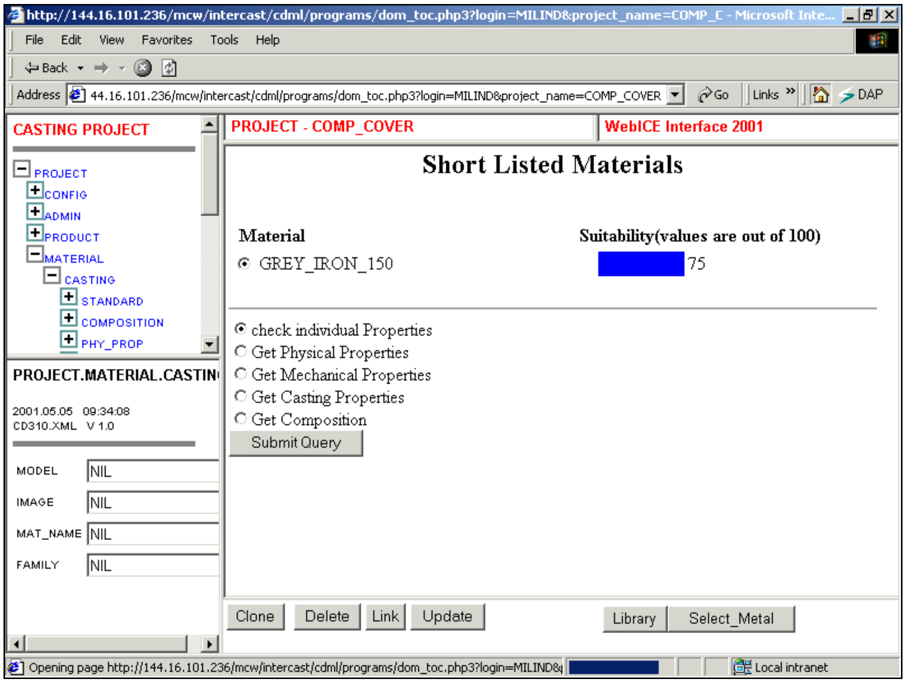
MODEL	NIL
IMAGE	NIL
MAT_NAME	NIL
FAMILY	NIL

Enter Values

Criteria	Minimum	Desired	Maximum	Unit
Density	7000	7200	7600	Kg/m3
Melting Temperature	1100	1160	1180	C
Thermal Conductivity	30	45	50	W/m.K
Specific Heat	450	480	520	J/Kg.K
Tensile Strength	120	140	170	MPa
Brinnel Hardness	140	160	170	
Poissons Ratio	.24	.26	.27	

● Scan Ferrous Metals

Fig 5.7 Form filled by the user for property based search



PROJECT.MATERIAL.CASTIN

2001.05.05 09:34:08
CD310.XML V 1.0

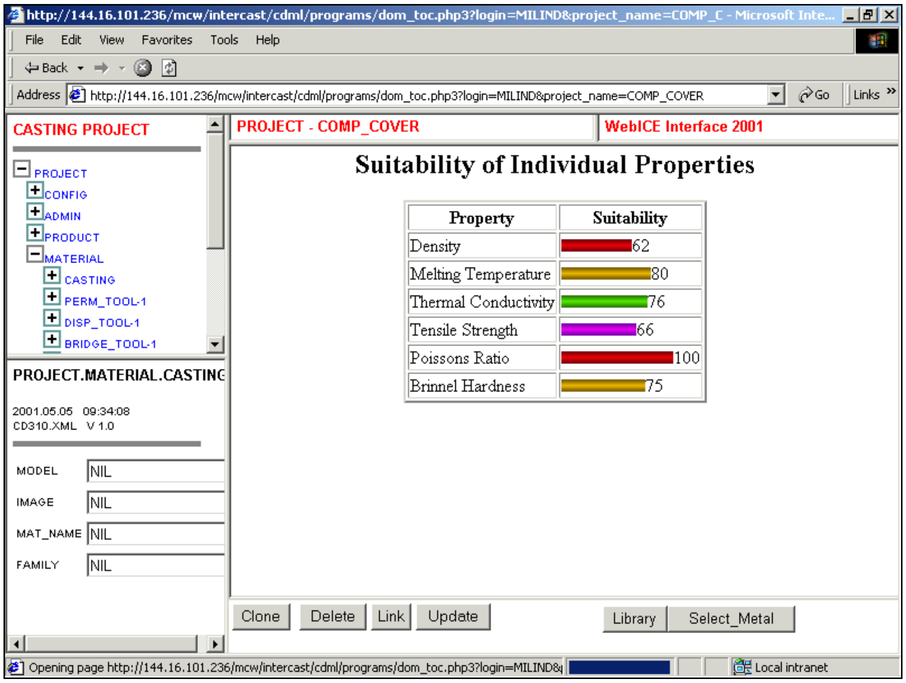
MODEL	NIL
IMAGE	NIL
MAT_NAME	NIL
FAMILY	NIL

Short Listed Materials

Material	Suitability(values are out of 100)
● GREY_IRON_150	75

● check individual Properties
○ Get Physical Properties
○ Get Mechanical Properties
○ Get Casting Properties
○ Get Composition
Submit Query

Fig 5.8 Short-listed materials according to the user input



PROJECT.MATERIAL.CASTING

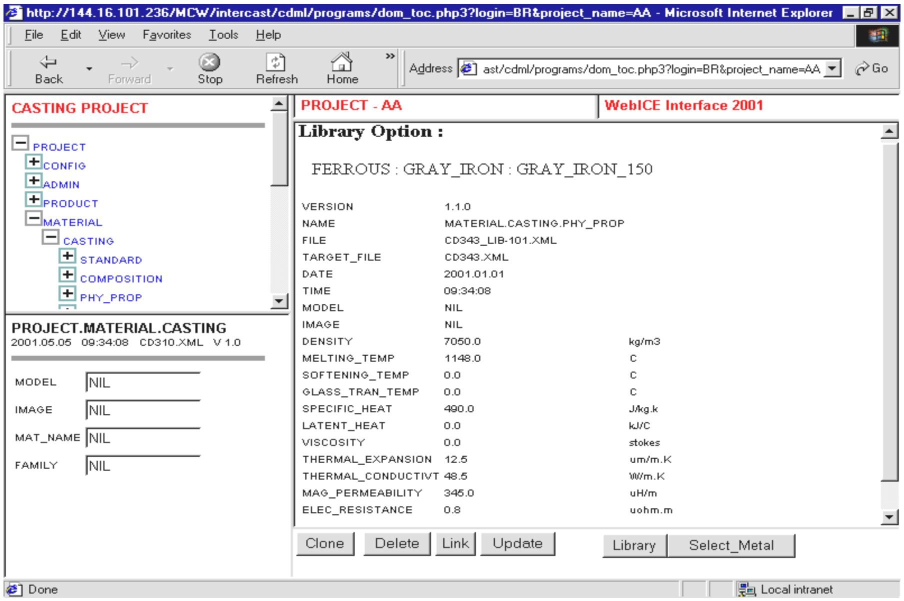
2001.05.05 09:34:08
CD310.XML V 1.0

MODEL	NIL
IMAGE	NIL
MAT_NAME	NIL
FAMILY	NIL

Suitability of Individual Properties

Property	Suitability
Density	62
Melting Temperature	80
Thermal Conductivity	76
Tensile Strength	66
Poissons Ratio	100
Brinnel Hardness	75

Fig 5.9 Suitability indexes of chosen metal



PROJECT.MATERIAL.CASTING
2001.05.05 09:34:08 CD310.XML V 1.0

MODEL	NIL
IMAGE	NIL
MAT_NAME	NIL
FAMILY	NIL

Library Option :

FERROUS : GRAY_IRON : GRAY_IRON_150

VERSION	1.1.0	
NAME	MATERIAL.CASTING.PHY_PROP	
FILE	CD343_LIB-101.XML	
TARGET_FILE	CD343.XML	
DATE	2001.01.01	
TIME	09:34:08	
MODEL	NIL	
IMAGE	NIL	
DENSITY	7050.0	kg/m3
MELTING_TEMP	1148.0	C
SOFTENING_TEMP	0.0	C
GLASS_TRAN_TEMP	0.0	C
SPECIFIC_HEAT	490.0	J/kg.k
LATENT_HEAT	0.0	kJ/C
VISCOSITY	0.0	stokes
THERMAL_EXPANSION	12.5	um/m.K
THERMAL_CONDUCTIVT	48.5	W/m.K
MAG_PERMEABILITY	345.0	uH/m
ELEC_RESISTANCE	0.8	uohm.m

Fig 5.10 User browsing through the database

The material selection program within the WebICE framework, was first implemented in local server in the Department of Mechanical Engineering at IIT Bombay. This has also been mirrored at the casting portal ‘metalcastingworld.com’ running on a Unix server. The speed at which the results of different functions of the material selection program are displayed depends on the network speed.

CHAPTER 6

CONCLUSIONS

6.1 Contributions

- Database of the following families of metals have been created based on a study of relevant handbooks and technical literature.
  1) Aluminium Alloys
  2) Cast Irons
  3) Copper Alloys
  4) Ductile Irons
  5) Gray Ions
  6) Magnesium Alloys
  7) Malleable Irons
  8) Steels
  9) Zinc Alloys
- Important criteria for the cast metals have been identified. Physical, mechanical and casting properties are the most important for cast metals. Important physical properties are density, melting temperature, thermal conductivity etc and the important casting properties are liquidus temperature, solidus temperature and pouring temperature
- The overall hierarchy of the material database has been designed to be compatible with the Casting Data Markup Language (CDML). A four level hierarchy (metal, category, family, option) has been maintained in the database. The database is designed to minimize the file size, for easy information transfer across the web.
- Five international standards are included in the database: ASTM, BS, IS, ISO and JIS.
- Indexing mechanism for the database has been done keeping in mind the future requirements. For each family of metals, a separate number series has been

identified. The present indexing mechanism accommodates hundred metals per family.

- The tool used in building the database is XML, widely used for information transfer across the web. The tools used for this system and design of the database files is so done, so as to make maximum utilization of the web
- The system developed will allow the user to browse through the database. He can view properties like physical properties, mechanical properties etc of any metal available in the database. The most important function of the system is that, it will allow the user to select the metals based on property given by him. The program will find out the optimum metals available in the database and display it in descending order of suitability. Another function helps the user to find the equivalent standards of a particular option.

In summary, this project has demonstrated the feasibility of maintaining the material database on the web, and providing access to it to any user irrespective of location. The functions for browsing, equivalent standards, criteria-based search and suitability index are expected to be very useful to product designers. The database can be modified (by adding new property fields or materials or correcting the property values). Only a standard web browser is required by the users; no specialized programs need to be installed, eliminating the need for training.

6.2 Limitations and Future Work

The database and selection program developed is limited to the field of casting metals only. Some of the property values may need to be improved. The speed at which the functions of this system work is dependent on the network speed. The execution time for some of the functions may be high in networks with low bandwidths.

The tools used in this system, has to be upgraded when new versions of the same are released in future. The system can be modified to an expert system, by building an appropriate database by consulting with various experts in foundries

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