Development of a Framework for Web-Based Product Platform Customization

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Product customization is a value-added activity that can significantly increase sales by increasing customer satisfaction. Many companies are using product platforms to increase product variety and customization while reducing development costs and time-to-market. While flooding the market with a variety of products may satisfy some customers by providing a substitute for customization, variety is not customization. This subtle, yet important, distinction between variety and customization motivates the need for investigating technologies to facilitate customer involvement during the product realization process, and our focus in this paper is on web-based platform customization strategies enabled by recent advances in information technology. Towards that end, we describe the development of an interactive web-based platform customization framework as an extension of product family design and present a prototype that has been created as part of on-going research with a company that produces customized refiner plates for pulp and paper processing. While the utility of the proposed web-based framework is demonstrated in the context of customizing a refiner plate design, the proposed framework is applicable to a variety of engineered products and enhances customer interaction during the product realization process while reducing design and manufacturing lead-time for custom orders. [DOI: 10.1115/1.1582881]

Keywords: *Product Platform, Product Variety, Information Technology, Mass Customization*

1 Introduction to Product Platforms

Product customization is a value-added activity that can significantly increase sales by increasing customer satisfaction; however, the time and cost of individual product customization limit all but the most agile manufacturers from providing this service to their customers [1–8]. Many companies are using product families to reduce development costs and time-to-market while increasing product variety and customization. A product family is a group of related products that is derived from a common set of components or subsystems, often referred to as a product platform, to satisfy a variety of market niches. The key to a successful product family is the product platform around which the product family is derived [9]. As Robertson and Ulrich [10] point out, ''By sharing components and production processes across a platform of products, companies can develop differentiated products efficiently, increase the flexibility and responsiveness of their manufacturing processes, and take market share away from competitors that develop only one product at a time.'' Companies like Sony [11], Kodak [12], and Volkswagen [13] have successfully employed product platform strategies to increase product variety while reducing development costs, manufacturing costs, and time-to-market.

Designing a product platform and corresponding family of products is a difficult task. It embodies all of the challenges of product design while adding the complexity of coordinating the design of multiple products in an effort to increase commonality across the set of products without compromising their individual performance. The prominent approach to product family design is to develop a *Module-Based Product Family* where product family members are derived by adding, substituting, and/or removing one or more functional modules from the product platform [14–24]. An alternative approach is to develop a *Scale-Based Product Family* where scaling variables are used to ''stretch'' or ''shrink'' the product in one or more dimensions to satisfy a variety of market niches [25–30]. Scalable platforms are commonly used in the aircraft industry [31,32], and automobile manufacturers are trying to learn how to utilize them [33–35].

In addition to improving economies of scale and scope in the manufacturing process [36], *a product platform also facilitates customization by enabling a variety of products to be quickly and easily developed to satisfy the needs and requirements of distinct market niches* [2]. A platform can be used to create a variety of known derivative products in anticipation of customers' needs, but customer requirements change over time, and some customers may desire products that meet their exact needs. While flooding the market with a variety of products may satisfy some customers by providing a substitute for customization, *variety is not customization*. Offering a wide variety of products has both positive and negative effects [1,37,38], but the proliferation of product variety incurs substantial costs within a company [39–41]. Variety provides choices for customers, too many of which can overwhelm customers [42–44], but it does not enable the customer to specify the desired features of a product. A customized product, on the other hand, is designed to meet the specific needs of a particular customer. This distinction is overlooked in much of the mass customization research as noted by Duray et al. [3] who state that customers must be involved at one or more points in the product realization process in order for the product to be truly customized, see Fig. 1. They classify companies that mass customize products based on the point of customer involvement where customized products can be either made-to-order, tailored-to-order, assembled-to-order, or made-to-stock, each of which has different implications on the product realization process and associated technologies needed to deliver that product. Duray and Milligan [45] state that information technology must be capable of capturing customer specifications and supporting engineering design decisions in order for customers to be involved in the early stages of

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Contributed by the Computer Aided Product Development (CAPD) Committee for publication in the JOURNAL OF COMPUTING AND INFORMATION SCIENCE IN ENGINEERING; Manuscript received Aug. 2002; Revised Apr. 2003. Associate Editor P. Wright.

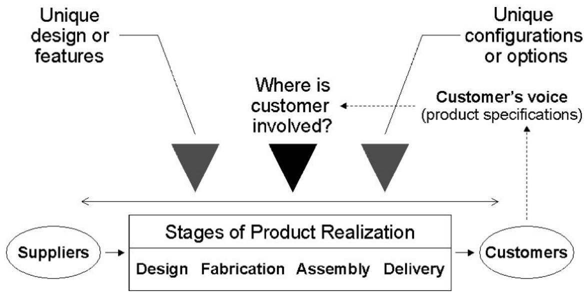

Fig. 1 Customer Involvement for Mass Customization (Adapted from Ref. [45])

the design process. We aim to support customer involvement in the early design stages with the web-based platform customization framework proposed in this paper.

Why a *web-based* framework for platform customization? Efficient information technology for customization is one of several important research directions facing many of today's firms [8,46]. The Internet opens new channels for promoting products, delivering services, and making sales [47], and Choi and Whinston [48] assert that the "computer-mediated market will accelerate the process of customization through its technologies." Electronic commerce is quickly becoming an important new channel for business in a range of industries [47,49–51]. For example, GM recently announced plans to transform itself into a build-to-order manufacturer to sell custom cars over the Internet [52], and Intel created DevelopOnline.com to support mass customization of electronic products on-line [53]. It is still unclear, however, what factors will influence people to buy products over the web, and Shaw [54] argues that "how to capitalize on the full potential of electronic commerce is still an open question."

Considerable research in utilizing the Internet for distributed design and manufacturing exists. For instance, Wright and his colleagues have pioneered a network manufacturing service called CyberCut™ for design and fabrication on the Internet [55,56]. Flores, et al. [57] present a web-based system for customizing coated steel belt sheaves, extending early parametric modeling capability developed in their lab [58]. Chen et al. [59] discuss a web-based system that incorporates fuzzy geometric customization and fuzzy reasoning and use it to customize wineglasses and furniture. A web-based knowledge system to support product family design has been developed by Zha and Lu [60] and tested with a power supply product family. Tseng et al. [61] introduce a framework for virtual design for mass customization while Siddique and Shao [62] are using graph grammars to develop a web-based system for product family reasoning.

Balakrishnan et al. [63] provide a recent review of Internet-based manufacturing "services" and discuss research opportunities in intelligent information processing for manufacturing. Researchers at NIST are also exploring Internet-based CAD/CAM services [64]; distributed service architecture for Internet-based CAD "services" is also being developed by Han et al. [65]. Meanwhile, Coutinho et al. [66] and Tumkor [67] are exploring the use of Internet-based design catalogs for component design over the Internet while Benami and Jin [68] introduce an Internet-based documentation approach for conceptual design. Gerhard et al. [69] discuss the use of Sandia's Product Realization Environment for distributed product design and realization. Finally Wallace and his co-authors [70–72] are developing a Distributed Object-based Modeling Environment (DOME) to link distributed and heterogeneous design "services" over the Internet to enable tradeoff analysis during product design.

In our research, the Internet is viewed as an enabler to improve customer involvement in the early stages of the product realization process through *interactive web-based platform customization as an extension of product family design*. Toward this end, a framework for web-based platform customization is currently being investigated, and a prototype has been developed as part of on-going research with a company that produces customized refiner plates for pulp and paper processing. The company designs and manufactures refiner plates used in papermaking, specifically refiner plates for mechanical pulping and for low-consistency stock preparation. Customers may choose from an inventory of common plate designs (consisting of about 250 product families each having about 12 plates) or have plates customized to their specific papermaking needs. While the utility of the proposed web-based framework is demonstrated in the context of refiner plate customization, the proposed framework is applicable to a variety of engineered products where the objective is to enhance customer interaction during the product realization process while reducing design and manufacturing lead-time for custom orders. An overview of the refiner plate design and customization process is given in the next section as background for the web-based framework introduced in Section 3. Examples from the prototypical web-based framework are presented in Section 4, and closing remarks and future work are discussed in Section 5.

2 Refiner Plate Design and Production Process

The traditional process of customizing a refiner plate pattern for sand casting is shown in Fig. 2 and is described in detail in Ref. [73]. First, salespeople meet with customers to identify their particular pulp requirements, and then designers develop a new 2-D Computer-Aided Design (CAD) model. Next, craftsmen or production engineers develop prototypes for customer verification. If the product does not satisfy the customer, it is then redesigned, and the process is repeated, adding significant delays in product lead-time. When the customer is finally satisfied with the design, pilot production is used to verify the product performance. If the product does not meet expectations, the entire process is repeated until performance verification is achieved and full-scale production starts.

In this traditional product development and customization process, considerable time is spent translating customer requirements into CAD drawings and prototype development for design verification. To further complicate matters, many companies still use two-dimensional CAD software which can cause delays when the product is complex and subject to miscommunication between the

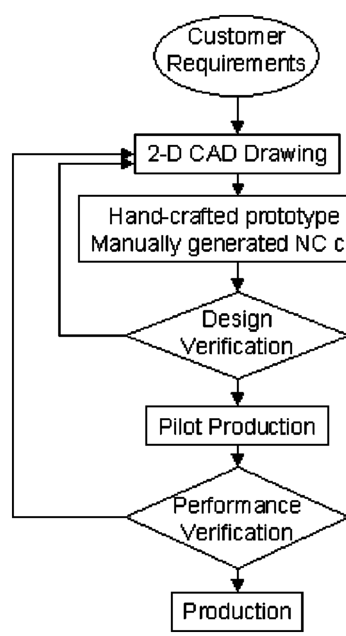

Fig. 2 Traditional Approach to Refiner Plate Design and Production [73]

design engineer and the prototype engineer due to ambiguous design specifications. Furthermore, several prototypes are usually required before all of the customer requirements are met and customers are completely satisfied. The lack of associativity between the two-dimensional model and the manufacturing process can also cause further delays. Every time there is a design change, the numerical control (NC) code for prototyping must be manually developed or edited.

To reduce lead-time and development costs in refiner plate design, we have developed 3-D feature-based parametric modeling capabilities [73] along with mathematical analyses and computer software [74] to allow designers to easily evaluate customer inputs, change parameters, and verify a refiner plate design before going into production. These tools provide the basis for a web-based system to enable refiner plate customization via the Internet. In the case of new specifications given by a customer, the software has the capability to design a newly customized plate that satisfies customer requirements as closely as possible. This expedites the process of placing orders and also improves customer satisfaction. The customer is then provided with a CAD model of the existing/customized plate almost immediately after specifying the requirements. Hence the customer is provided with real-time feedback about the refiner plate design and its specifications, reducing the lead-time for product realization and simplifying the time-consuming, iterative process. Details on the web-based customization framework are presented next.

3 Proposed Web-Based Customization Framework

The web-based framework for refiner plate customization is shown in Fig. 3. The framework consists of four main modules that form the basis for the customization process:

1. Design rules for engineering new custom refiner plates
2. A database of existing refiner plate designs and platforms
3. A feature-based parametric CAD model to generate a model of the customized refiner plate in Pro/Engineer (Pro/E)
4. A web-based interface and portal for product platform customization and ordering

Each module is explained in more detail in the following sections.

3.1 Refiner Plate Design Rules. In the papermaking process, pulp (individual wood fibers in a water/slurry mixture) is formed into a web to make sheets of paper. Before this can occur, it is essential that the fibers be conditioned or worked, either chemically or mechanically. Working or developing the fibers is what determines the type and properties of the paper being produced. This mechanical pulp processing relies on a technique known as *refining*, which is defined as ''a mechanical treatment of pulp fibers to develop their optimum papermaking properties'' [75]. The specific application of the paper predetermines these required qualities and properties, and the degree of pulp refinement can be varied by controlling the refining process parameters as well as the parameters of the refiner plate design.

Mechanical refining takes place in a machine called a *disk refiner*. Figure 4 shows a commonly used low-consistency Twin-flo disk refiner. The refining action occurs when a pulp and water slurry passes between large, metal, rotating disks that are composed of numerous *refiner plates*, which resemble equally sized wedges of a circle—the cut-away view in Fig. 4 shows one refiner plate removed from the nearest disk. Varying parameters such as the consistency of the slurry, flow rate, plate geometry, and power can alter the refining action, but the refiner plates lend themselves to the most cost-effective changes as they are easily replaced.

In low-consistency refining (less than 6% solid fibers by density in the liquid slurry), the refiner plate pattern and geometry are the

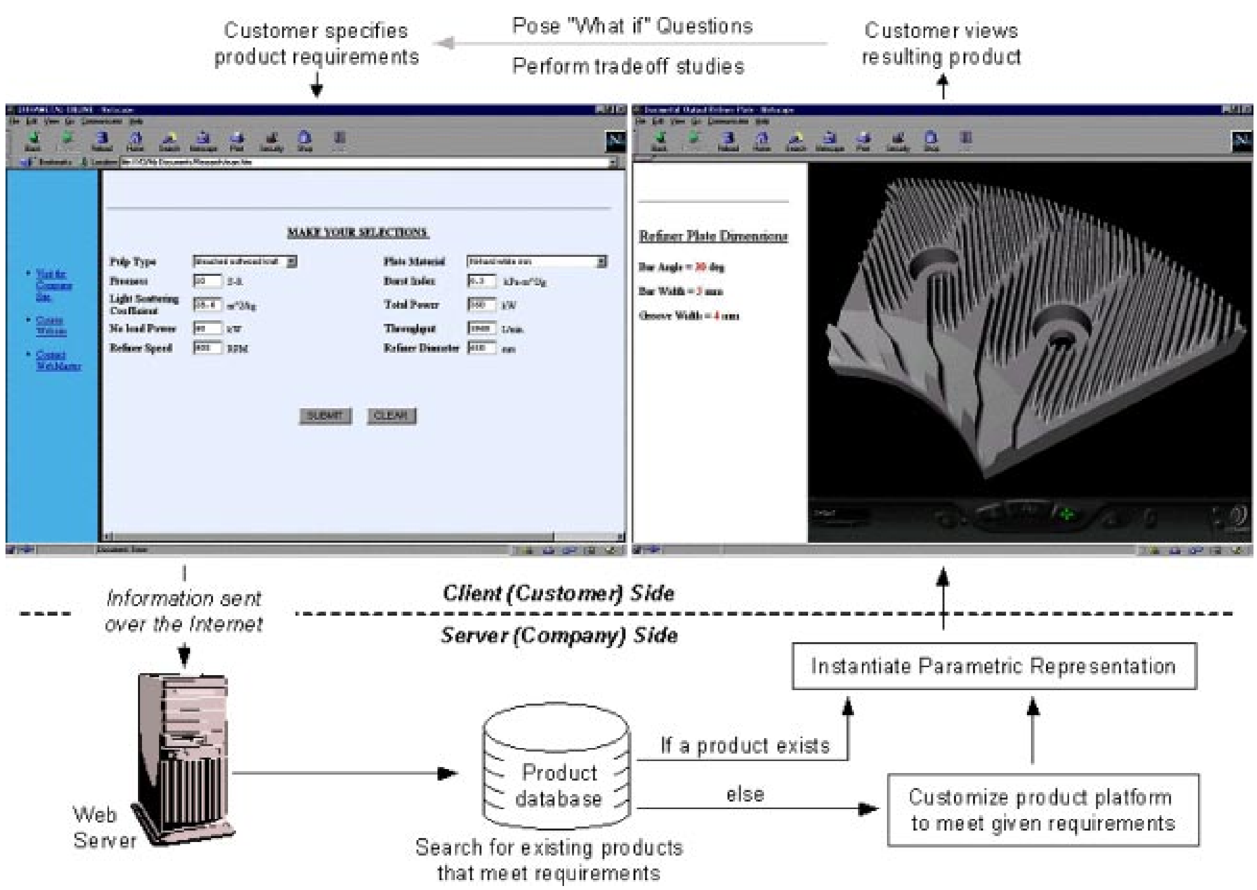

Fig. 3 Proposed Web-Based Platform Customization Framework

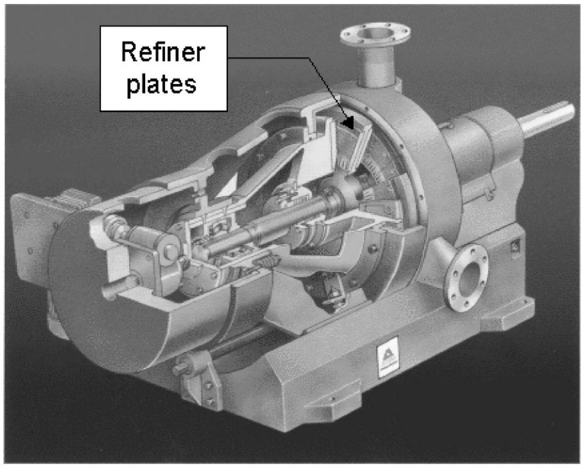

Fig. 4 A Low-Consistency Twin-Flo Disk Refiner

biggest influences on pulp characteristics [76]. There is an infinite variety of plate designs, depending on the paper properties desired, although manufacturing processes do limit some dimensions. Paper mills use specific plate patterns depending on their operating conditions and requirements, and these patterns can be grouped into families based on the pulp characteristics they develop. For example, refiner plate families may include severe cutting, cutting, strength development, high development, and maximum development where the geometric parameters vary between these families.

Bar configuration is probably the most important factor to achieve pulp properties. Analyses performed by Sharpe and Rodarmel [76] have determined the following plate design parameters are the key components of a refiner plate:

- *Bar edge:* Major working point of *fibrillation* (peeling action or pulling back of the primary wall along the fiber length) that increases fiber flexibility
- *Bar width:* Narrower bars yield more bars for a given size plate which increases the total available bar edges and frequency of bar crossings, leading to a higher degree of fiber development while minimizing fiber shortening.
- *Groove width and depth:* Groove width determines flow through the refiner. Decreased groove width and depth brings the fibers to the bar edges, promoting refining action, restricting flow rate, and reducing hydraulic capacity. Excessive groove depth results in more stock passing through the refiner untreated.
- *Bar angle:* Increased bar angle gives more bar edge length, leading to enhanced refining and fiber development. This also increases pumping action, yielding more throughput capacity and higher pressure build-up, which uses more energy and lowers efficiency.
- *Dams:* Prevents the water-slurry mixture from channeling through the plate without being passed over the bar edges, but dams reduce throughput capacity. They are seldom used in low consistency refiners.
- *Plate clearance:* Distance between the refiner plates determines the amount of fiber cutting, as well as affects plate wear.

By changing the size and configuration of these elements, the degree of fiber development can be adjusted, and unique values of these parameters represent a unique refiner plate. The design of these refiner plates involves the knowledge of various refiner theories, which are influenced by a number of factors such as pulp type, consistency, customer requirements, pulp fiber impact, etc. For this work, a simple and well-known method, the *Modified Edge Load* (MEL) theory, is used [77]. The MEL theory does not take every refining variable into account, but it is easier to use than many other theories. In combination with plate material properties and optimization models, the important parameters of bar width, groove width, bar angle, and number of bars can be determined using MEL theory.

In order to simplify the calculations needed to customize a refiner plate, the following assumptions are made to demonstrate the proposed framework.

- Only Twin-Flo model refiners are considered for low-consistency pulp processing.
- All plates have a similar layout: a single zone with diagonally running bars and grooves.
- Fillets and rounds on refiner plates are neglected and constant values are assumed for detailed refiner plate features such as segment gaps, breaker bars, dams, etc.

The customer is required to specify the following inputs:

— Average MEL (Modified Edge Load of the plate)

— Total Power (HP) and No Load Power (HP) of the refiner

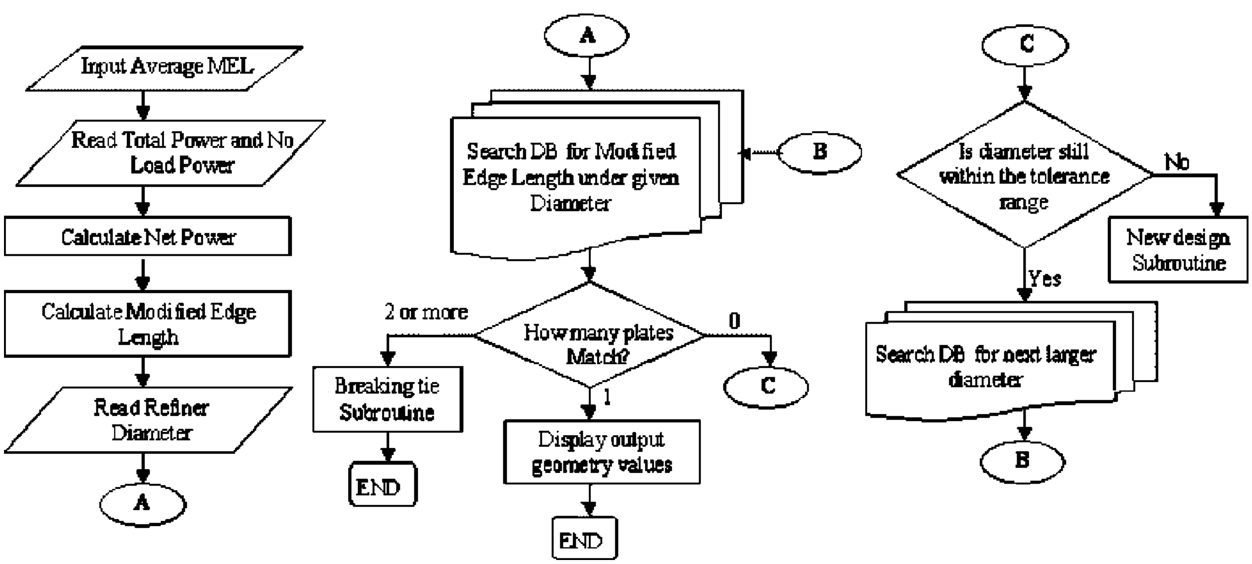

Fig. 5 Flowchart for Customizing a Refiner Plate

— Refiner Diameter (in)

— Number of Bolts (default is 2)

The flowchart in Fig. 5 illustrates the logic used for the design of the refiner plates after collecting the necessary customer input. The full set of equations used to compute net power, modified edge length, and plate geometry based on the customer inputs are summarized in Ref. [74]. The resulting outputs include:

— Bar Width

— Groove Width

— Bar Height

— Average Bar Angle

— Refiner Plate Diameter

This information is then used to search the refiner plate database (DB) to determine if an existing refiner plate satisfies the customer specifications; details about the database are given in the next section. If multiple plates exist which satisfy the specifications, then the analyses given in the Appendix are used to "break the tie" and suggest an appropriate refiner plate to the customer.

3.2 Product Database. The product database contains the information and configuration of *existing* refiner plates. The web-based interface dynamically compares the calculated configuration with that of each plate in the database. The best match is obtained by comparing customer requirements to existing refiner plate designs. If an existing refiner plate does not satisfy the customer requirements, a new customized plate is designed and presented to the customer. The web-based interface also provides capabilities for dynamically generating a text file that acts as an input to a feature-based parametric plate generation module created in Pro/Engineer (Pro/E), which is described in Section 3.3.

We have used the Entity-Relationship (ER) model, which is a popular high-level conceptual data model, to design our database. This model and its variations are frequently used for the conceptual design of database applications, and many database design tools employ its concepts. The ER model describes data as entities, relationships and attributes. The basic object that the ER model represents is an entity, which is a thing in the real world with an independent existence. Each entity has attributes, namely, the particular properties that describe it. A particular entity will have a value for each of its attributes. The attribute values that describe each entity become a major part of the data stored in the database. A relationship type R among n entity types $E_1, E_2, \ldots E_n$ defines set of associations or a relationship set among entites from these types. As entity types and entity sets, a relationship type and its corresponding relationship set are customarily referred to by the same name R. Mathematically, the relationship set R is a set of relationship instances r_i, where each r_i associates n individual entities $(e_1, e_2, \ldots e_n)$ and each entity e_j in r_i is a member of entity type E_j, $1 \leqslant j \leqslant n$. Each of the entity types $E_1, E_2, \ldots E_n$ is said to participate in the relationship type R; similarly, each of the individual entities $e_1, e_2, \ldots e_n$ is said to participate in the relationship instance $r_i = (e_1, e_2, \ldots e_n)$.

The database has ten entities: Technical Information, General Information, ICPM, KMS, Refiner Manufacturer, Bar, User Plates, Users, Company and Zone. The schema for each entity is as follows (primary keys are underlined):

- Technical Information–(<u>Pattern#</u>, KMSCode, ICPMCode, KM/Rev, ModelID, Seg/Circle, Zones, AvgBarAngle)
- General Information–(<u>Pattern#</u>, <u>MftID</u>, DiscDia, CircleDia, Date, BarCode)
- ICPM–(<u>ID</u>, Value, RPM)
- KMS–(<u>ID</u>, Value, RPM)
- Refiner Manufacturer–(<u>ID</u>, Name)
- Bar–(<u>BarCode</u>, BarType)
- User Plates–(<u>CustID</u>, <u>Pattern#</u>, Plate Status)
- Users–(<u>ID</u>, Password, FirstName, LastName, CompanyID, Work Phone, Mobile Phone, e-mail, Access Level)
- Company–(<u>ID</u>, Name, Address, Telephone number, Url, comments)
- Zone–(<u>Pattern#</u>, BarWidth, GrooveWidth, BarHeight, DamType)

The database is constructed using Microsoft Access 2000. Meanwhile, Component Object Model (COM) components are used for database connectivity from Active Server Pages (ASP) used in the web-based interface. COM components give ease and flexibility of implementation in multiple webpages. Since most of the database handling is done using COM components, the system could easily be upgraded to a SQL Server database if required.

3.3 Feature-Based Parametric CAD Module. The feature-based parametric CAD module is developed to present customers with snap shots of the refiner plate so that they get an idea about the final product. Text files are used to generate the required models within the Pro/Engineer (Pro/E) environment. Thus a statically obtained input is fed manually to the feature-based parametric model, which modifies an existing template to obtain the required 3D solid model. Templates can be modified using programs such as J-Link and .pls in Pro/E. When using J-Link, .jar files have to be created, which will be given as input to J-Link manually; hence, the .pls file option was chosen to take full advantage of the feature-based parametric model developed by Kulvatunyou et al. [73]. We note that Siddique and Yanjiang [78] are investigating alternative template-based approaches that automatically generate CAD models for each member in a product family. For commercial software applications, Parametric Technology Corporation, the makers of Pro/E, recently introduced Windchill® DynamicDesignLink™, which allows customers to create custom products via the web by guided product selection and configuration, automated product and process selection and generation, and integration with enterprise business systems [79]. Dynamic linking of the web-based interface with the feature-based parametric model-generating module is currently not available within the proposed framework; it is part of our ongoing work.

Generation of .pls files is dependent on model details. Input required for generation of the file is taken in two stages and is dependent upon numerous design parameters. In the first stage, the pattern number of the plate is obtained, to calculate the dependent variables using independent variables in the database and pattern allowance rules provided by the company. In the second stage, the remaining independent variables are obtained from the company representative. As part of future work, these variables can be included in the database itself to generate the .pls files in a singe stage. A .pls file has been generated by first creating a .HTML file which can then be saved as a .pls file. We found that the file object of ASP could not handle a large .pls file of more than 17,000 lines due to software constraints.

Creation of a sample refiner plate is shown in Figure 6 starting from a plate feature (Fig. 6a) and bar feature (Fig. 6b). The parameters are divided into four main blocks—plate plate, bolt hole, machine stock, and bar—as defined in Ref. [73]. The necessary values are obtained from the refiner plate customization output (Section 3.1) and the database (Section 3.2). Values that remain constant across all plate designs (e.g., bolt hole diameter) are hard-coded into the .pls file. The resulting Pro/E model is then used to generate a .VRML file, which can be viewed directly in the web-based interface and manipulated by the customer. Details about the web-based interface are given next.

3.4 Web Architecture for Interface and Portal. The architecture for the web-based interface is shown in Fig. 7. As shown in the figure, the architecture uses Active Server Pages running on Internet Information Server (IIS), which invoke Component Object Model (COM) components to interact with the database (see Section 3.2) and send email using W3 Jmail, which uses POP3 as its email gateway.

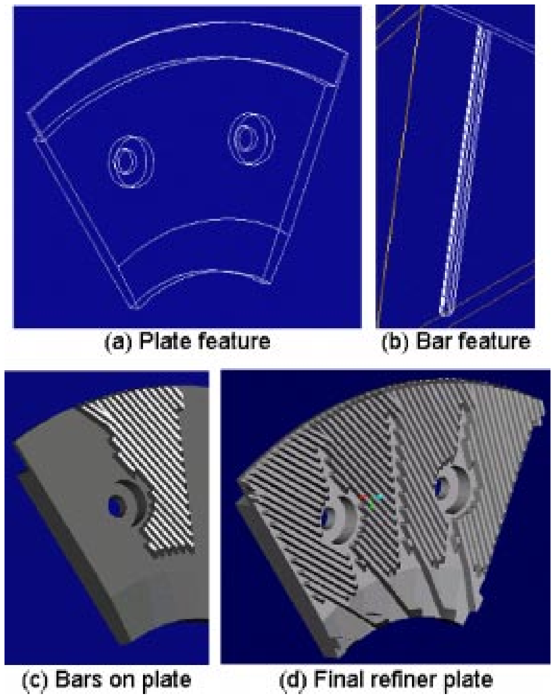

Fig. 6 Refiner Plate Model Generation in Pro/E

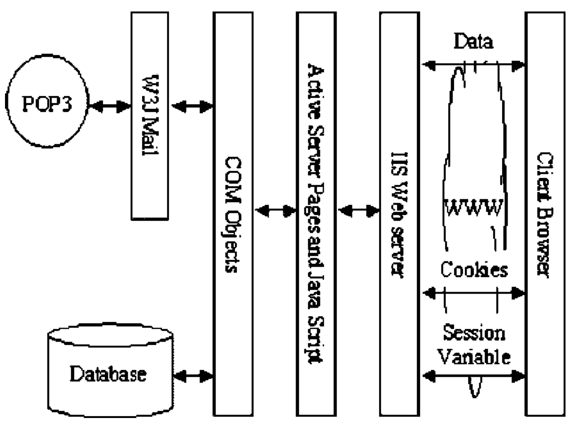

Fig. 7 Architecture of Web-based Interface

Active Server Pages. Active Server Pages (ASP) is a mix of HTML, scripts, and ASP code that can be used to build dynamic and database-driven websites. Microsoft describes ASP as an ‘‘open, compile-free application environment in which you can combine HTML, scripts, and reusable ActiveX server components to create dynamic and powerful Web-based business solutions. Active Server Pages enables server-side scripting for IIS with native support for both VBScript and Jscript’’ on their webpage. While standard HTML is only a display language, ASP allows you to tailor the information displayed on the page based on user interaction. ASP also supports Microsoft’s Component Object Model (COM), which allow common scripts, such as those used for database access or content generation, to be encapsulated into reusable components accessible from any .asp file or program as described next.

Component Object Model. A Component Object Model (COM) component is a reusable, programmatic building block that contains code for performing a task or set of tasks. COM components can be combined with other components (even across networks) to create web applications. COM components execute common tasks so that you do not have to create your own code to perform these tasks, reducing programming time and enabling robust applications based on tested and standardized components.

COM components contain one or more objects (i.e., self-contained units of code) that perform specific functions within the component. Each object has methods (programmed procedures) and properties (behavioral attributes). To use an object provided by a component, an instance of the object is created and assigned a variable name. ASP’s Server.CreateObject method is used to create object instances, which then send the required parameters to the subroutines or functions as needed to display information within the web-based interface. One of these COM components is W3 JMail, which is used to send email, receive email, and encrypt messages. JavaScript is used to take on-line comments and send them via W3 JMail; this provides the communication medium between customers and the company. Other COM components are used to exchange information with the database.

Security. The security of the website is maintained through session variables. There are two session variables that maintain the access level and login status of each user. All other user information is maintained with cookies on the user’s machine. For instance, registered users belonging to a particular company are given greater access to the website, allowing them to track their orders, save refiner plate designs, or browse through all of the refiner plates previously purchased by their company. The cookies and the session variables are removed the moment the user logs off the website.

4 Refiner Plate Design via the Web: An Example

The following example demonstrates the use of the prototype web-based framework for refiner plate customization, which can be accessed at ⟨http://edog.mne.psu.edu/refiner/⟩. Customers can log in as a guest to browse the site or using a Login Id and Password after registering with the site. Contact information, email, and online chat capabilities are also available to customers. Online chat allows customers to speak directly with a company representative if they wish to get more information about their order or any other information.

After logging into the webpage, customers begin designing a new refiner plate using the webpage shown in Fig. 8. Customers select from a set of refiner plate diameters via a pull–down menu and input the total power and no load power (in HP) for the new refiner plate. To simplify the calculations, a MEL of 5.0 is used in this example. Future inputs such as pulp type (measured by Canadian standard freeness), low/high consistency, and % water content, could be included to expand the list of customer requirements and increase the flexibility of the system.

After the customer submits the input specifications, the best plate match is provided to the customer with output parameters for Part ID, KM/S, ICPM, Throughput, and refiner plate diameter as shown in Fig. 9. The customer can then click on the hyperlink for the matching refiner plate (20601/20602 in Fig. 9) to view more detailed specifications about the existing refiner plate design as illustrated in Fig. 10.

If the input specifications cannot be satisfied by an existing refiner plate(s), then a new customized refiner plate is generated for the customer as shown in Fig. 11. The best refiner plate design is displayed on this webpage with important dimensional and functional specifications (e.g., mean bar length, diameter, groove width, and bar width). Even without the presence of a company representative or salesperson, customers can obtain satisfactory refiner plate designs based on their specified requirements.

Registered users have the option of saving different plate configurations so that they can be viewed later, which eliminates the burden of redesigning the plate or remembering the plate ID. In the future, registered users can also order/buy a specific refiner plate by clicking on the plate ID and then navigating through subsequent links. The customer can also email the customized plate specifications to a technical expert at the company who

Fig. 8 Customer Input Page

would evaluate the feasibility of manufacturing the plate with the existing set up. The company expert would then respond to the customer if the requirements could be met and might also send a Pro/E copy of the plate for the customer to view before approving an order.

Administrators for the website have additional privileges such as modifying or adding existing plates to the database and adding users along with pertinent company information. Administrators can also modify existing refiner plate geometry by inputting new values into the form in Fig. 12 to generate a new .pls file to create a Pro/E model. The following is an example of the data used to generate a Pro/E model for the customer.

Click Here for the Pro/E Diagram

```
VERSION I-03-02
REVNUM 33253
LISTING FOR PART 20603/20604

INPUT
CHANGE_PLATE_SIZE YES_NO
DO YOU WANT TO CHANGE THE PLATE SIZE?
IF CHANGE_PLATE_SIZE
BPAD_THICKNESS=1
IR=1
OR=20
INNER_GRIP=0.25
HOLE_ID=1
HOLD_OD=1
NUM_OF_HOLES=2
IF NUM_OF_HOLES==1|NUM_OF_HOLES==3
  INNER_HOLD_LOC=1
END IF
IF NUM_OF_HOLES==2|NUM_OF_HOLES==3
  INNER_HOLD_LOC=2
END IF
 . . .
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5 Closing Remarks and Future Work

By creating a web-based interface for customers to input specifications and view the corresponding product, information flow between customers and companies can be simplified greatly, allowing business to be done anywhere via the web. Customers can enter their specifications on the website and obtain nearly instant feedback on whether or not a design meets their requirements. The software generates the refiner plate parameters necessary for creating a solid model that can directly be given as input to instantiate a feature-based parametric model in Pro/E. The automation of

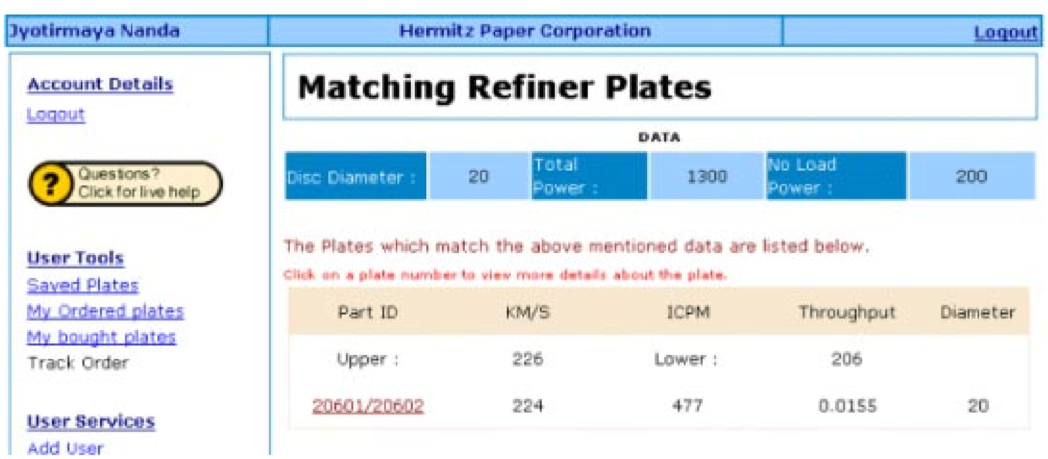

Fig. 9 Display Matching Plate(s)

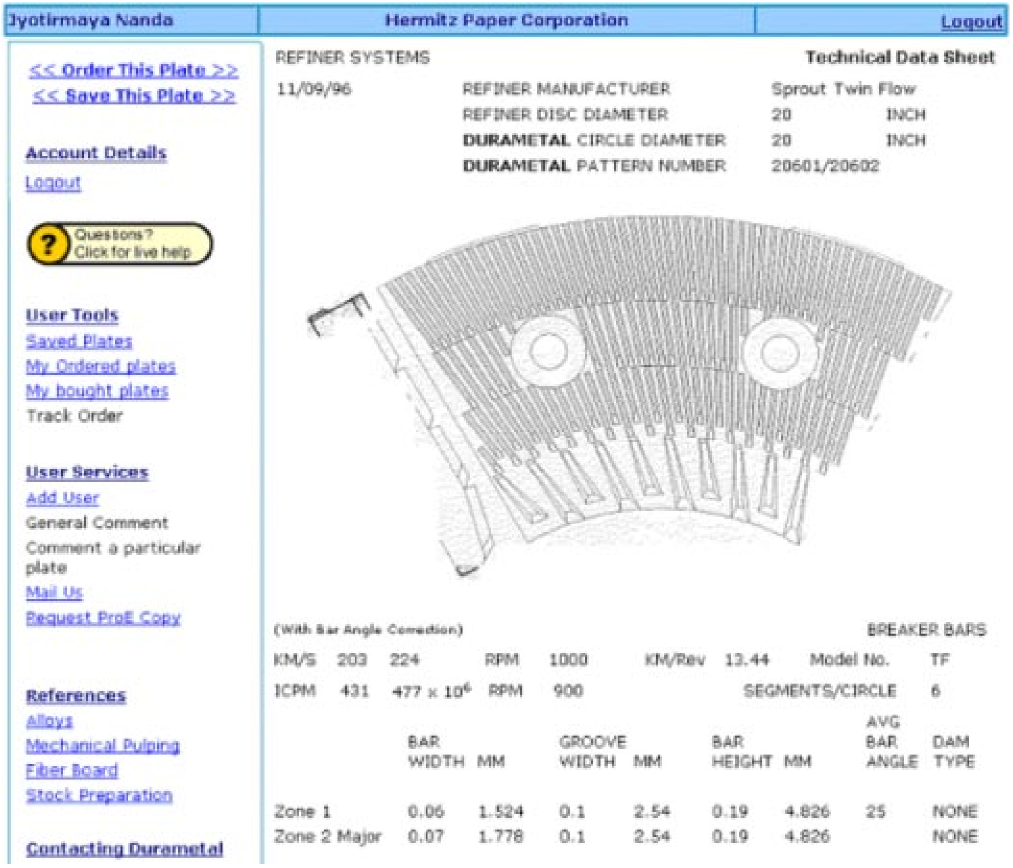

Fig. 10 Refiner Plate Diagram and Details

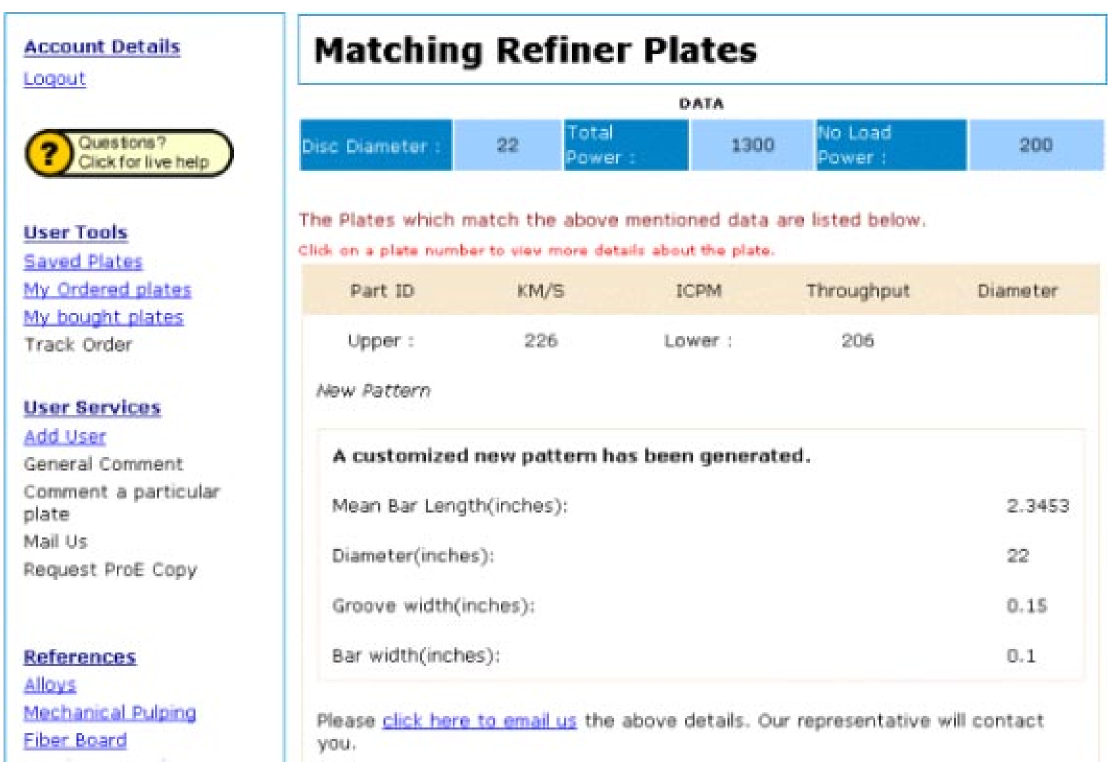

Fig. 11 Details of Customized Refiner Plate

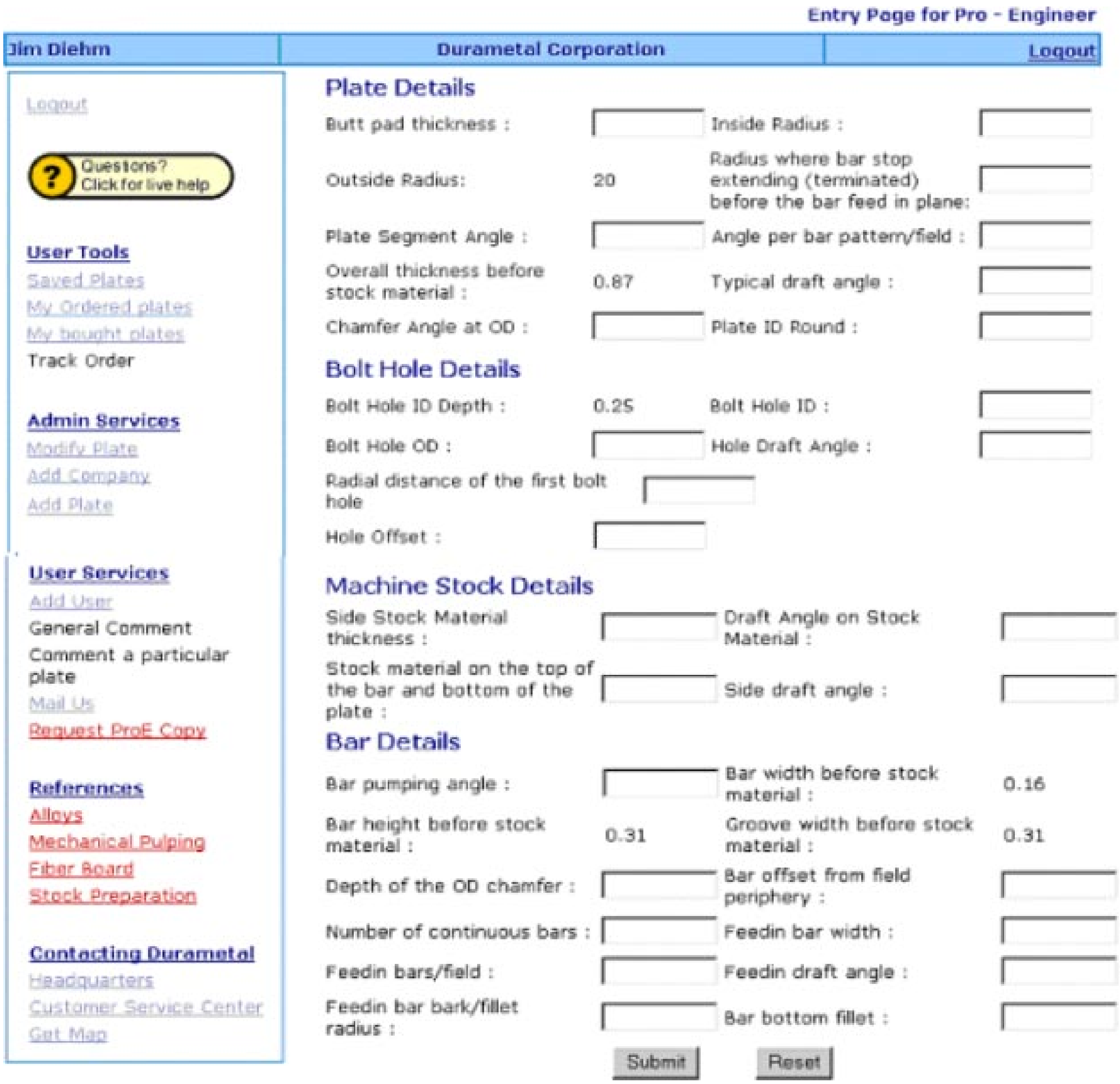

Fig. 12 Generating a .pls File through the Web-Based Interface

the design process gives customers the freedom to change or modify their specifications according to their individual requirements without a significant increase in design lead-time. Also, by making existing sales data available on the web, customers can browse through available refiner plates and their design parameters, which will expedite the reordering process. By targeting the early design stages of the product realization process, information technology enables customers to create refiner plates that meet their exact specifications without the company having to design a wide variety of plates prior to receiving customer orders, reducing design and manufacturing related costs. While our proposed web-based interface has been demonstrated for refiner plate design in this paper, the framework is applicable to a wide variety of engineered products, especially those that can benefit from customer input during the early stages of the product realization process.

At present the website configures a refiner plate for customers based on the specified requirements; there is no provision for cost analysis of the design. In the future, customers could be provided with information about the cost of different refiner plates along with detailed invoices once they place an order. Payment and shipping options could also be made available through the website. It would also be interesting to allow multiple customers to access the website at the same time, allowing them to collaboratively optimize the product and resolve design tradeoffs; multiple users can log onto the website and customize their own individual products, but there is currently no coordination between them. Another area for improvement is the dynamic integration of the feature-based parametric model within the website. At present a text file is generated for Pro/E, enlisting the output parameters of the plate designed by the 'plate geometry generation' software; however, this text file has to be entered manually into Pro/E in order to modify an existing refiner plate design. In the future, this could be automated by having Pro/E read these values automatically and regenerate the drawing for the new refiner plate design. These regenerated models could also be converted into pattern drawings by incorporating the necessary pattern allowances (e.g., tooling, shrinkage, etc.) that would further reduce manufacturing lead-time.

Acknowledgments

This work was supported in part by the National Science Foundation under Career Grant No. DMI-0133923.

Appendix

The different formulas used for the engineering of the plates using MEL theory:

1. For the '*Tie Breaker Subroutine*'

   Throughput = Open Area × Flow Velocity(Q = A×V) ....m^3/sec

   V = rω…………(m/sec)

   $\omega = 2\pi N/60$ (N rpm is obtained from the database)

   $A = Z_g(hg + h^2 \tan\theta)$...........($m^2$)

   Z_g = Number of grooves (number of grooves = number of bars)

   h = bar height

   g = groove width

   θ = Draft angle (assumed as 3°)

   r = plate radius

(Bar width + Groove width) $*Z_g$ = r* angle subtended by the pie at the center

The underlying assumption over here is that a customer will always prefer a plate with the maximum throughput for better performance and higher output.

2. For the '*New Design Subroutine*':

$$\text{MEL/sec} = Z_r Z_s L_m \left(\frac{N}{60}\right)^{*} 2 \tan\alpha \left(\frac{b}{b+g}\right)$$

Where,

Z_r = Number of bars on rotor
Z_s = Number of bars on stator
L_m = Mean bar length (m)
N = refiner speed (rpm)
α = Bar Angle (°)
b = Bar Width
g = Groove Width

Here we assume that $Z_r = Z_s = Z_g$

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