CHAPTER 9

RESULTS AND DISCUSSION

9.1 INTRODUCTION

This chapter presents the results of the work carried out as planned in chapters 5, 6, 7 and 8. The results are presented in four sections, they are:

a) results of design of reflector and lens for any car body profiles
b) results of multiple view product modelling for assembly and manufacture; and finished assembly of headlamp with identification of parts and assembly
c) results of manufacturing phase with development of product line for manufacture of the components and related tooling and
d) results of development of a framework for PDM system supporting integration of design and downstream phases in the development of headlamp.

9.2 RESULTS OF DESIGN OF LENS AND REFLECTOR OF HEADLAMP

The design methodology proposed in this work enables the designer to practise high level of aesthetics and to include regulatory norms in design of headlamps. The critical components in headlamp, namely, reflector and lens are developed from the profiles of car body which are the inputs to the design module. Lens surface is evaluated with visual considerations while the reflector surface was evaluated by optical principles.
This methodology provides a generic design model from which various design variants can be derived. The results of evaluation of surface of lens may be extended to analyse its optical behaviour. The design procedure was implemented in CATIA V5®. The information required for the lens design was the boundary curve of headlamp and a set of associated front fender surfaces of car. The surface can be interrogated at the early stages itself and discontinuities can be evaluated.

The design procedure for reflector involves the creation of paraboloidal surface whose basic dimensions were decided by the boundary curve of headlamp. Cloud data required for the paraboloidal surface is obtained from Equation (4.1). It was implemented in Microsoft Excel. Paraboloidal surface developed in CAD is tailored according to the standards of illumination. The tailored reflector surface is analysed for intensity value at test point of standard using equation (5.15). The data required for design of reflector is the boundary curve of headlamp, value of the constant of parabola, ‘K’ which is a user defined parameter and the standard of illumination. For a given body profile of car, geometry of lens and reflector can be obtained as shown in Figure 9.1.
Figure 9.1  Lens and reflector surfaces modelled for three sets of car body profiles

Bezel and casing of headlamp were designed according to the design of reflector and lens. Design of casing requires data of the boundary curve, reference plane for mounting the bulb holder and edge profile of rib of the lens. Design of bezel needs the boundary curve and the edge of reflector.. The surfaces generated for lens and reflector at the conceptual stage provides information for process planning and manufacturing phases of product development. Detailed design of these parts is interactively performed.

The proposed design enables the designer to carry out the following tasks:

a) To develop exterior surface for lens from the front fender surfaces
b) To analyse the surface for smoothness

c) To develop paraboloidal segmented reflector in compliance with standards for the front fender surface and
d) Conceptual modelling of other parts of headlamp

9.3 RESULTS OF MULTIPLE VIEW PRODUCT MODELLING FOR DEVELOPMENT OF HEADLAMP

Multiple view product model for the design of headlamp discussed in this thesis has two dimensions. First dimension supports the co-designers by providing information required for each part in the assembly and enables horizontal integration of design participants. Customer’s requirements trigger changes in design of individual components by the parameters. Figure 6.1 and table 6.1 have already shown the association of parameters among the components of headlamp. The product modelling module propagate changes in customer requirements via the design inputs to the various part designers. Figure 9.2 shows the exploded view of assembly of headlamp unit, the result

![](image)

**Figure 9.2** Exploded view of headlamp assembly showing automatically generated part numbers
of the multiple view product modelling applied to the design methodology discussed in the chapter 5. The design methodology proposed in this work also provides a mechanism for identification of parts and products. Part number for the each part in the assembly structure is automatically generated by the design module. The year, month and serial number are used for specifying part/product numbers. The specification tree of CATIA V5 shows the part and product numbers for the lens, reflector, bezel and lens of the headlamp assembly.

The second dimension of multiple view product model supports the vertical integration of downstream phases, namely, assembly and manufacturing. For the reflector and lens, the influence of decision at the early phases of design was analysed. Conceptual design of reflector includes decision on the basic shape and dimensions of reflector. The parameters which are dependent on the design decision on each phase were identified. Table 6.2 shows the influence of the values of parameters in the design of reflector on the various downstream phases, namely, detailed design, analysis, process planning, manufacture and recycle. The development phases of lens also include the same phases as that of reflector. The design information relevant to various lifecycle phases in the design of lens is given in Table 6.3.

9.4 RESULTS ON THE USE OF MANUFACTURING VIEW

Design for manufacture (DFM) has become an area of research during the last few decades. Producibility is an offspring of DFM, where attention is made on improvements of manufacturing technology. The results of manufacturing view address producibility aspects in the development of headlamps.
Skin models are the basis for the geometric modelling of lens and reflector of the headlamp. The basic reflector model is paraboloidal which is governed by a mathematical formula. The surface is then tailored for illumination distribution according to the optical principles. Hence it is grouped as ideal class of products. Manufacturing process is closely related to the surface models. Figure 9.3 shows the tooling for injection moulding.

![Figure 9.3 Tooling for injection moulding of reflector](image)

It consists of two parallel fixed frames with a fixed pattern of holes. The holes are arranged exactly as the XY grid configuration for surface representation. The holes in both planes are aligned so that pins of constant length are passed through these holes. The orientation of mould takes care of two coordinate axes (X and Y) and pins are positioned along the third axis (Z axis). Figure 9.4 shows the arrangement of discrete pins in a reconfigurable mould for manufacturing of lens for headlamp.
Lens model is governed by curvature continuity conditions only. It is classified as non-ideal item of products. For each of the classification, product lines are specified. Process for each product line also defined. For the

![Drape forming arrangement](image)

**Figure 9.4 Reconfigurable moulds for manufacture of lens for headlamp**

manufacturing of lens RMS is suggested, for which reconfigurable mould is proposed. However, the technique is not recommended for manufacture of lens unless the resolution is improved.

RMS is relatively cheaper than FMS. RMS allows implementation of changes in shapes easily. Vacuum forming process is easily integrated with reconfigurable tooling. The mould pressure is less than atmospheric pressure. Process time is only a few seconds in continuous production. The aforesaid characteristics of reconfigurable tooling and advantages of vacuum forming process are the motives behind proposing these technologies for production of lens, one of the critical components in headlamp assembly.

This chapter discusses the relationship among the components of headlamp. Changes in value of one parameter may affect other parameters in associated parts. Thus, the propagation of change in a parameter perspective
is analyzed. This information is critical for co-designers in the product development team. Moreover, this information is used in analysis of assembly relationships among the parts.

The assembly graph is specified based on features used in the stage. As mentioned in section 1.1, the features can be used for exchange of information across the domains effectively. The relevance of features specified on each part and its implication in downstream phases are also studied. This information is critical for developing domain specific knowledge base.

9.5 RESULTS OF FRAMEWORK FOR PDM SYSTEM

PDM framework proposed in this work includes EJB components that are the deployable software modules built in a three tier architecture of J2EE technologies. The client tier of EJB allows the users to interact with the system via web pages. The various user pages are discussed below.

The user login in page is shown in Figure 9.5. User is directed to the concerned pages if the authentication of the user is correct (user Id, role and password). The different roles are also shown in the Figure.
Designer can create, update and delete objects through this page. The objects include part, product and document. The designer can map parts to the concerned products and can relate documents with part. The designer can also specify product and part versions. Figure 9.6 shows the designer’s page which allows him to create and use product information.
Figure 9.6  Designer’s page of the PDM system

Figure 9.7 shows the page for creating part by the designer. Information related to the part is manually entered into the system via this page. Designer enters the part number which is automatically generated by the design module as discussed in section 9.3.
Figure 9.7 Page for creation of part

Figure 9.8 shows the page for creating documents by the designer. The document number is generated automatically by the PDM system.

Figure 9.8 Page for creation of documents
Customer’s pages is shown in Figurers 9.9. The details in this page refer to query status of the product, comments by text editor, addition of new related documents of the product and visualisation of assembly.

Figure 9.9 Customer’s page of the PDM system

The OEM’s page allows the user to put important information like the type of drive and details of standards for illumination. Figure 9.10 shows the page

Figure 9.10 Customer page for placing order
for placing the order. Visualisation is an important capability of PDM system. User can visualise CAD files by using the viewing software installed at the client.

CAD files are translated to STEP file format so that neutral format was used. Non-geometric data were directly stored in the database. CAD file visualisation for different users of the PDM system was done by using a STEP – VRML converter. VRML files could be embedded in HTML codes. Using Autovue software at the client, CAD files in VRML format can be visualised via web pages as shown in Figure 9.11.

![User page for visualization](image)

**Figure 9.11 User page for visualization**

The application server of PDM system generates the HTML pages as shown above. JSP programs within the web container generate the dynamic web contents. The EJB container of the application server acts as an intermediary between the user defined business logic and rest of the server environment. The EJB components are shown in Table 9.1.
### Table 9.1  Details of EJB components created for data management system

<table>
<thead>
<tr>
<th>Package</th>
<th>EJB Reference Name</th>
<th>Type of EJB</th>
<th>Type of Interference</th>
<th>Home Interface</th>
<th>Remote Interface</th>
<th>Linked EJB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organization</td>
<td>ejb/ TheLogin</td>
<td>Session</td>
<td>Remote</td>
<td>organisation. LoginRH</td>
<td>organisation. LoginRemote</td>
<td>Pdm_ejb.jar# LoginBean</td>
</tr>
<tr>
<td></td>
<td>ejb/ ProfileBean</td>
<td>Entity</td>
<td>Remote</td>
<td>organisation. ProfileRH</td>
<td>organisation. ProfileRemote</td>
<td>Pdm_ejb.jar# ProfileBean</td>
</tr>
<tr>
<td>Vault</td>
<td>ejb/ PartBean</td>
<td>Entity</td>
<td>Remote</td>
<td>vault. PartRH</td>
<td>vault. PartRemote</td>
<td>Pdm_ejb.jar# PartBean</td>
</tr>
<tr>
<td></td>
<td>ejb/ ProductBean</td>
<td>Entity</td>
<td>Remote</td>
<td>vault. ProductRH</td>
<td>vault. ProductRemote</td>
<td>Pdm_ejb.jar# ProductBean</td>
</tr>
</tbody>
</table>
The PDM system developed here is a component based system. EJB components were modelled in UML diagram and codes for the structure of the system were generated automatically using Rational Rose®. The codes for the methods were developed using Netbeans® editor. The database tier is created using relational tables implemented in Oracle 9i®. Java programs access the database by using java database connectivity (JDBC) APIs.

9.6 SUMMARY

This chapter presented the results of the design methodology for the design of reflector and lens for headlamps, results of multiple view product modelling for assembly and manufacture and a PDM framework which may be extended as a PDM system supporting the development of headlamps for passenger cars. Next chapter presents the conclusions that can be highlighted from this study.