CHAPTER 7
MANUFACTURING VIEW FOR HEADLAMPS TO SUPPORT TOOL DEVELOPMENT

7.1 INTRODUCTION

Integration of design and manufacturing has been acquiring interest from researchers and industries for the past few decades. In parallel with the product design process, lot of automation efforts is being introduced in various aspects of product development. Producibility is the one activity where industries focus on continuous improvements. It is the measure of relative ease of manufacturing a product in terms of cost, lead time, quality and technical risk. This chapter tries to propose a model for implementing producibility aspects in headlamp manufacturing. Products are classified according to their functions. The common features are used to model different streams of manufacturing called product lines.

Reflector and lens are grouped as ideal and non-ideal groups respectively as mentioned in chapter 4. For each item, product lines are proposed. The concept of reconfigurable manufacturing tooling for lens is discussed. A manufacturing information system for headlamps also has been modelled.
7.2 MANUFACTURING VIEW MODEL FOR THE DEVELOPMENT OF HEADLAMP

Chapter 5 discussed in detail the design of reflector and lens for headlamps. The functional topology of these items is different, that is the surface model of reflector is constrained by formula of paraboloid and is tailored according to other formula. In the case of lens, ‘a visually pleasant shape’ is the higher level requirement and is refined to a condition that the surface continuity or order of the mathematical equation is fixed. This type of product characteristics such as aesthetic or functional can be used for criterion of mapping to manufacturing process domain. Conventional method like process capability mapping is done from detailed design stage. This thesis proposes classification of products based on the features, like ideal features or non-ideal features, and mapping to manufacturing domain as shown in Figure 7.1

![Diagram of Function to Form to Domain Mapping]

**LEGEND**
- RMS: Reconfigurable Manufacturing System
- FMS: Flexible Manufacturing System
- DMS: Dedicated Machining System

Figure 7.1  Mapping of function to form and form to domain
Mass customized market condition forces industries to switch over towards flexible or reconfigurable production systems. Rapid tooling and quick changes in product lines are features of RMS. Conventional NC manufacturing is grouped under flexible manufacturing. The information flow across design and manufacturing is detailed in figure 7.2.

![Diagram of information flow across design and manufacturing phases of development of headlamp]

**Figure 7.2** Information flow across design and manufacturing phases of development of headlamp

### 7.3 MANUFACTURE OF REFLECTOR

Product line for the manufacture of reflector has been discussed in previous section. The ideal product stream for manufacture of reflector
involves the use of die and accessories for injection moulding process. The surface development is based on mathematical equation of paraboloidal surface. Hence reflector is an ‘ideal’ item. Numerical control (NC) machines are suited for manufacturing for moderate shape variation. Manufacture of dies for reflector is carried out in NC machines.

Use of early design information like the basic dimensions of reflector is important in process planning phase. Basic tooling for core and cavity halves of die mostly depends on the outer dimensions. The design information from conceptual stage generally includes external features of car body. Information system supporting conceptual design is proposed in this thesis.

7.4 MANUFACTURING OF LENS

Frequent changes in shapes of lens in headlamps demand flexible and easily adaptable manufacturing and tooling support. Conventionally, lens is manufactured by injection moulding or compression moulding of plastics. As discussed in manufacture of reflector, lot of time and cost are incurred in setting up tools for injection moulding.

Lens is being grouped as non-ideal item; flexible tooling can be practiced in manufacturing of lens. This thesis proposes the concept of re-configurable tooling for manufacture of lens. The proposed methodology is discussed in subsequent section.

7.5 RECONFIGURABLE MANUFACTURING SYSTEM (RMS)

A manufacturing system can be created by incorporating basic process modules - both hardware and software - that can be rearranged or
replaced quickly and reliably. Reconfiguration will allow adding, removing, or modifying specific process capabilities, controls, software, or machine structure to adjust production capacity in response to changing market demands or technologies. This type of system will provide customized flexibility for a particular part family, and will be open-ended, so that it can be improved, upgraded, and reconfigured, rather than replaced (Mehrabi, et al. 2000). All these features of RMS immensely support the manufacturing system requirements of manufacture of lens. This thesis presents a conceptual implementation of the system.

First, the variation in free form shapes and its implementation is discussed. Second, manufacturing process for implementing the tooling is proposed and finally the advantages of the concept are discussed.

### 7.5.1 Surface modelling and implementation

Surfaces can be described mathematically in three dimensional spaces by the equation,

\[ P = [x, y, f(x, y)] \]  

(7.1)

where ‘P’ is the position vector of a point on the surface. The natural form of the function \( f(x, y) \) for a surface to pass through all the given data points is a polynomial, that is

\[ z = f(x, y) = \sum_{m=0}^{p} \sum_{n=0}^{q} a_{mn} x^m y^n \]  

(7.2)

where the surface is described by an XY grid of size \((p+1) \times (q+1)\) points. The physical implementation of this mathematical model was carried out by using discrete pins arranged in XY plane. Each discrete pin axially moved so that its position indicates the Z coordinate value. This concept is the physical implementation of non-parametric representation of surfaces. Figure
7.3 shows a free form surface and its approximation with a set of discrete pins (Kelkar, 2005). This principle is used for development of reconfigurable tooling for the manufacture of lens.

![Figure 7.3](image)

**Figure 7.3** A free form surface and its approximation with a set of discrete pins

Manufacturing of lens involves setting up of reconfigurable mould for the surface model and the mould is used in vacuum forming machine. Development of reconfigurable tooling for the manufacturing of lens involves the following steps:

1. Obtain the point data from the CAD model of the surface – the method is implemented in CATIA V5®.

2. The point data are fed to an actuator for positioning discrete pins. The actuator includes an NC controlled three axes table. For the input cloud data three axes controlled actuator keeps discrete pins in position. Instead of the NC controlled table, a coordinate measuring machine (CMM) could be used. Menq and Chen, (1996) have reported approximation of surfaces using CMM.

3. The set of discrete pins are locked in position. Discrete pins are held by a collet mechanism arranged on a frame.
4. A sheet of rubber (elastomer) was draped over the discrete pins which act as an interpolation layer for approximating the surface. A geometric algorithm for similar reconfigurable surfaces has been reported by Kelkar et al (2005).

The mould is used in vacuum forming process which is discussed in the next sun section.

7.5.2 Vacuum forming process

Vacuum forming is a thermoforming process in which thermoplastic sheets are heated to a temperature near to its glass transition temperature (Tg). The thermoplastic sheet is draped over a wooden or metallic mould and vacuum is applied below the sheet. Heat is absorbed on the mould and sheet takes the shape of mould. The process has the following stages, namely, sheet fixing, heating, draping over the mould, unclamping and ejecting. The vacuum forming process is a competent low cost alternative for injection moulding. However, the vacuum forming process poses difficulties like uneven thickness distribution, need of post processing and difficult to mould slots, holes etc. Almost all thermoplastic materials can be successfully moulded by this process.

7.6 SUMMARY

This chapter presented the manufacturing of lens and reflector. Product line engineering concept was used to select product family for the components. Reflector and lens were classified as ideal and non-ideal, for which product lines were planned. The results of the manufacturing phase of the development of headlamp have been discussed in chapter 9.