CHAPTER-6

SCOPE OF THE PRESENT WORK

Injection Moulding is an industrial production technology first used in the 1920’s. From that date onwards, many companies have adopted this technology using it for parts ranging from automotive parts to everyday items such as a plastic fork. Plastic Injection Moulding (PIM) is one of the most important plastic production methods. Even though many people regard it as simple and common manufacturing process, PIM is one of the most complex processes due to the many delicate adjustments required. Product quality depends on material selection, mould design, and process parameter settings. The injection moulding process includes four phases: plasticization, injection, packing and cooling. Previously, engineers’ used trial and error approach, which depend on the engineers’ experience and intuition, to determine initial process parameter settings for the injection moulding process. However, trial and error processes were costly and time consuming, not optimal for complex parts. In research it was urged that with a trial and error process, it is impossible to verify actual optimal parameter settings. Subsequently, Taguchi’s parameter design method was successfully employed to determine the initial process parameter settings in industrial applications. However, Taguchi’s parameter design method can only find the best set of specified process parameter level combinations, which included the discrete setting values of the process parameters. The application of a conventional Taguchi’s parameter design method is unreasonable when the variable of a process parameter is continuous, and cannot help engineers obtain
initial process parameter setting results. An unsuitable process parameter setting can cause many defective products and unstable product quality during injection moulding process, therefore efficient analytical methodologies and tools are necessary to efficiently and rapidly analyze process parameters and control the product quality.

In PIM nylon profiles are characterized by a combination of high strength, toughness and abrasion resistance. Other advantages are low weight, non corrosive, low co-efficient of friction, true self lubricating effect, vibration and noise damping etc. Parts fabricated out of Nylon replaces metal parts such as bushes, bearings, slide plates, gears, gear racks, wear plates, washers, gaskets, seals, sleeper pads for rolling mills, liners, wheels, sleeves, pulleys, ropeway tires, rollers etc. which were originally fabricated out of Phosphor-Bronze, Gun Metal, Brass, White Metal, Steel and other expensive metals.

Nylon injection moulding is used in a wide range of parts and components including:

- Consumer products – footwear, clothing, toothbrush bristles, pantyhose, windbreakers, wind pants, hair combs
- Recreation - musical instrument strings, tennis racket strings, climbing rope, climbing slings, fishing line, basketball netting, rope
- Industrial – bearings, gears, flexible tubing, bushings, pulley components, washers
- Medical – sutures
- Automotive – gas tanks, intake manifolds, seat belts, tire cords, fuel system parts
- Military applications – parachutes,
Electronics – electrical insulators, electronic components

Because of the following advantages Nylon products are preferred over products from other materials. [Bluemay Limited web site (80)]

- Excellent machining characteristics
- Resistant to abrasion
- High impact resistance
- Toughness
- Extremely low coefficient of friction
- Good resistance against ultraviolet (UV) radiations
- Highly resistant to chemicals, fungi, insects
- Very durable
- Melts instead of burning

Plastic bushes are essential to many industries such as mechanical engineering and building industries. Plastic bushes are also used by electrical manufacturers and various other manufacturing companies, it is vital to the success of a project’s outcome that all of the materials used are of an excellent standard. Plastic bushes eliminate the need for lubricants, due to an inner lubricious surface which aids improved sliding properties, and plastic bushes also help to reduce the wear on shaft and mating surfaces. Plastic bushes also have properties which combine good vibrational dampening with a low component weight.

The main objective of this study was to develop a methodology for quality improvement as per the requirements of SMEs. In case study part of this work the quality of injection-moulded nylon-6 bush (KAMANI BUSH) was
improved with the proposed Six Sigma cycle called DAURR (Diagnose, Analyze, Upgrade, Regulate and Review) and its usefulness for small scale plastic injection moulding industries was proved.

This research proposes an effective approach (Based on Six Sigma methodology) for process parameter design and prediction, to help manufacturers in the achievement of competitive advantage on product quality and product cost. The proposed approach that integrates Taguchi’s parameter design, Artificial Neural Network and Regression Analysis can effectively help engineers in the determination of optimal initial parameter settings in injection moulding.

The approach proposed here has three main phases. First Taguchi’s parameter design method is applied to determine the initial process parameter settings and then regression model is applied to build the prediction model then artificial neural network method is applied to search out final optimal process parameter settings. Third a confirmation experiments is performed to verify the effectiveness of the final optimal process parameter setting. The final optimal process parameter settings are not limited to discrete values as in Taguchi’s parameter design method, and can determine settings for production that not only approaches the target value of the selected quality characteristic more closely, but with less variation.

This work presents the process parameter optimization model, for multiple inputs multiple output (MIMO) plastic injection moulding process, under eight process control factors and two responses to demonstrate the effectiveness and implementation of the proposed approach.

The procedure of the proposed approach used a modified six sigma methodology called DAURR (Diagnose, Analyze, Upgrade, Regulate and
Review), which has been designed especially for small and medium enterprises, in combination with various statistical tools.

The procedural steps and tools used in each phase of the above proposed cycle are as follows:

**Phase 1.**
To know the reasons of rejection or failure of the product with the help of voice of customer and production line brainstorming, to find out factors that are critical to quality (CTQ).

**Phase 2.**
Step 1.
Collect appropriate number of samples from existing production line to determine sigma level, process mean and the values of CPU, CPL ($C_{pk}$) for the selected quality characteristics.
Step 2.
Identify feasible responses (quality characteristics) as the target requirements of the experiment. The responses must be confirmed which have significant influence on final product quality. Moreover, engineers need to decide a most major response from all responses just identified via expert opinion or experience.

**Phase 3.**
Step 1.
Determine the feasible and tractable process control factors and levels that influence the performance of responses. How many control factors should be included in the experiment at how many levels can be decided using experience, preliminary studies, or brainstorming.
Step 2.
Select an appropriate orthogonal array for arranging the experiment and acquiring the experimental treatments.

Step 3.
Select an appropriate formulation for the S/N ratio and calculate the S/N ratio for each response under different treatments of the orthogonal array. The S/N ratio is of three types: nominal the best, larger the better, and smaller the better. Engineers can select an appropriate S/N ratio for their experiment by considering the goal requirement of each response.

Step 4.
Select the highest S/N ratio treatment of both responses as the initial process parameter settings (initial population).

Phase 4.
Step 1.
Recognize the important process parameters affecting the quality characteristics the most, with the help of Taguchi’s orthogonal experiment.

Step 2.
Formulate the fitness function for both the quality characteristics using the above selected process parameters.

Step 3.
To further validate fitness function an artificial neural network model for both the quality characteristics has been formulated.

Phase 5.
Step 1.
Determine the final process parameter settings via the predictions made by both regression analysis and artificial neural network model and perform confirmation experiment.

Step 2.
Perform a confirmation experiment to verify the effectiveness of final optimal process parameter settings and implement these settings in the production line.

Step 3.
Taking appropriate number of samples from the production line calculate the value of CPU, CPL (C_{pk}) as well as process mean for both the characteristics.

Step 4.
Go in Review phase of the proposed cycle to see whether the six sigma standard has been achieved or not, if not, again apply the proposed cycle, keep applying the proposed cycle until six sigma standard is achieved.