INTERACTIVE TRAINING IN SPC IN INJECTION MOLDING

FACT SHEET and Training Options

Abstract

Even though statistical process control, SPC, has been around for over half a century, many injection molding companies still do not use it effectively, if at all. A major barrier to the implementation of SPC is unfamiliarity with basic SPC tools and how to apply those tools to injection molding operations. Successful implementation of SPC requires effective training not only in SPC, but also in injection molding process technology. SPC can identify process problems, but cannot solve them. Operating personnel can only solve process problems effectively if they have a thorough understanding of the injection molding process.

Training continues to be a challenge for many injection molding companies. The traditional method of on-the-job-training is often ineffective, time consuming, and frequently results in less than optimum performance. Another option is sending people to off-site seminars. This is costly in terms of travel and registration as well as time away from the job. Recently, a new option for training in extrusion has become available, Computer Based Training, CBT, using interactive, multi-media programs. Interactive CBT offers several advantages, such as: cost effective, self paced, less time away from the job, better understanding and retention of the material, training test results available to training administrator, etc.

This paper describes a new training program in statistical process control in injection molding that is delivered on CD-ROMs. The program not only shows slides and video with full narration, it also makes extensive use of 2D and 3D animation to show parts of the injection molding process that cannot be observed on actual machines. For instance, the program shows a detailed animation of flow of the plastic in the plasticating unit, the nozzle, and the mold. The program also shows the reciprocating action of the screw in the plasticating unit and the movement of the check valve at the end of the screw.

The program is bundled with an injection molding simulation program, called MiniFlow. This simulation program can be used for the initial design decisions for injection molds and material selection. Designers and engineers can use MiniFlow to rapidly assess the effects of part geometry and material on the filling during injection molding.

Introduction

Companies interested in providing training in injection molding to their employees have had limited options until recently. The most common options are:

1) develop a custom in-house training program and have a company employee teach the program,
2) bring in an outside trainer and have the training conducted on-site or locally,
3) purchase a video training program and use an in-house person to conduct the training, or
4) send employees to off-site seminars or classes.

Recently, another option has become available: computer based training. This paper discusses the advantages and disadvantages of the different training options and provides details on the new interactive training program in SPC in injection molding (SPCIM©). This program was developed by Rauwendaal Extrusion Engineering in cooperation with the Society of Plastics Engineers.

Traditional Training Methods

Developing a custom in-house training program is rather time consuming and expensive. One hour of training requires at least ten hours of preparation. Thus, a one-week training program will take at least 400 man-hours to prepare. At a cost of $50 per hour, it will cost a minimum of $20,000 to put a custom training program together. For small injection molding companies this cost is generally prohibitive. Another problem for small companies is they may not have a technically competent person on staff that can develop and teach the program.

Bringing an outside trainer into a company is another option; this eliminates the development cost of a custom training program. In this case, however, the trainer has to be paid for his/her time and expenses. The cost per day of training will usually vary from about $1,000 to $3,000 per day depending on the experience and reputation of the trainer. Expenses include airfare, hotel, meals, car rental, etc. Expenses for a two-day class typically run about $2,000 with the lion share going to airfare. This means that a two-day training program can run from $4,000 to $8,000.

Video training is a relatively easy method for a company to bring in a training program. A typical video training program on injection molding runs about $6,000. A company employee usually conducts these programs in classroom style. As with all classroom style training, the pace of learning is set by the program and/or the instructor. Self-paced training is possible to a limited extent if a person goes through the program individually and stops the tape to review information.

Sending employees to an off-site seminar or class is a frequently used training option. In this case, the cost per employee is determined by the registration cost for the class and the travel expenses. Typical registration cost is about $1,000, while typical expenses for a trip that requires plane travel run about $2,000. As a result, the cost per employee for an off-site seminar is about $3,000. The drawback of most of these options is that the persons being trained will not be available for several days while the training is being conducted. This, of course, adds substantially to the cost of training.

Computer Based Training (CBT)

CBT has slowly made its way in the plastics industry and is becoming increasingly popular as training programs improve in quality and more people become computer literate. There are a number of advantages to CBT:

- Low cost for high volume training
- Instructional consistency
- The student controls the pace of training
- Flexible scheduling
- Work schedules do not need to be disrupted
- Reduced learning time
- Improved retention
- Training material available at all times
- No off-site travel required
- Student not inhibited by presence of other students

There are some disadvantages as well. Some people are not comfortable with computers and may not do well with CBT. The task, therefore, is to make CBT very user friendly, so that even a student inexperienced with computers can use the training program. Another disadvantage is the lack of a group synergy that can exist in a classroom setting.

Interactive Training SPC in Injection Molding (SPCIM©) Catalog #0180

SPCIM© was developed by Rauwendaal Extrusion Engineering in cooperation with the Society of Plastics Engineers to provide a fully interactive training program on SPC in injection molding. It is a complete training program that teaches injection molding and statistical process control in an integrated fashion; it consists of 9 sessions:

Session 1, The Injection Molding Machine and Process.

This session covers the injection molding machine (plasticating unit, clamping unit, and the mold), and the process (the injection molding cycle, flow into the mold, cooling, and ejection).

Session 2, The Injection Molding Machine, the Mold.

Session 2 explains the different types of molds that are used in injection molding and the flow of plastic into the mold. It also covers various defects that can occur in the molding process

Session 3, Plastics and Plastic Properties.

This session discusses different types of plastics and plastic properties important in the injection molding, such as melt flow and thermal properties.

Session 4, Introduction to Statistical Process Control.

Session 4 introduces basic SPC concepts, discusses implementation of SPC, and describes the main SPC tools.

Session 5, Data Collection and Problem Solving.

This session explains the difference between attributes and variables data and discusses important aspects of data collection. It also covers diagrams for problem solving, methods of collecting data, and sampling.

Session 6, Measurements in Injection Molding.

Session 6 introduces basic measurement concepts and explains how to quantify measurement error. Specific measurements important in injection molding are discussed in detail.

Session 7, Control Charts.

This session explains control charts, how to construct control charts, and how to interpret control chart. The main emphasis is on x-bar & R charts; other charts are discussed briefly.

Session 8, Process Capability and Special SPC Techniques for Injection Molding.

Session 8 explains what process capability means, how to determine it, and different measures of process capability. It also covers special SPC techniques for injection molding.

Session 9, Other Statistical Tools to Improve the Process.

This session discusses other tools to improve process control, such as design of experiments, the Shainin approach to process improvement, and precontrol.

The SPCIM© training program combines text, audio, 2- and 3D animations, video clips, tests, graphs, and figures to provide a true multi-media training experience. The cost of the complete program is $2599 SPE member, $2900 nonmember; this includes the 234 page book "Statistical Process Control in Injection Molding and Extrusion" by Chris Rauwendaal.

Smaller Training Programs

The SPCIM program consists of 9 sessions. However, some companies may not need the entire program, so mini programs are available as follows: Sessions 1-2 "Introduction to Injection Molding" (#0181, mem $675/non $750); Sessions 1-3 "Injection Molding and Plastic Properties" (#0182, mem $990/non $1100); Sessions 4-9 "Statistical Process Control" (#0183, mem $1980/non $2200.

Delivery Software

A unique feature of the SPCIM program is the delivery software. SPCIM is the first interactive training program that uses PowerPoint™ (PPT) by Microsoft as the delivery software. The flexibility of PPT allows excellent control of the introduction of text, pictures, video clips, animations, and sound in the training program. Many other interactive training programs require special training delivery software that can cost up to $500. Specialized training delivery software generally does not offer the flexibility that PPT offers.

Nowadays, PPT is ubiquitous in the industry. As a result, companies that have PPT do not have to spend extra money for the delivery software.

The interactive training program is structured to deliver about two minutes of instruction followed by about three to four questions to test the comprehension of the material just covered. If a question is answered incorrectly, the program automatically repeats the information related to the question and then the question is repeated. The program does not continue until the question is answered correctly. This keeps the student engaged all through the training program and maximizes comprehension and retention.

Tracking Capability

A custom tracking capability was developed that allows a training administrator to track how many employees have taken the course, how much of it was finished, and how well each student scored on the test questions. A complete database is developed to help administer the training program. This is a valuable tool in meeting ISO requirements.

Animations

One of the key aspects of this interactive training program is that generous use is made of animations, both 2D and 3D animations are used to explain the inner workings of the injection molding machine. For instance, the program shows a detailed animation of flow of plastic in the plasticating unit, the nozzle, and the mold. Since these processes cannot be shown on actual machines in operation, animation provides a valuable tool to bring these processes to life. If a picture is worth a thousand words, an animation is worth a thousand pictures.

Selected Portions from the SPCIM Program

Figure 1 shows an illustration of screw recovery. This picture is one of the frames of an animation that shows a three-dimensional view of a plasticating unit with the barrel cut open to show the screw and the plastic melt. Such an animation provides a level of insight into the injection molding process that cannot be achieved any other way.

Figure 2 shows a 3D illustration of a double toggle system. This picture is also a single frame from an animation that dynamically shows the movement of the toggle mechanism. The animation explains the workings of the toggle system better than many diagrams.

Figure 3 shows an illustration of fountain flow in a mold. It shows the stretching that occurs of elements at the flow front and the cooling that occurs at the walls. The SPCIM program also contains an animation of the fountain flow process.

Figure 4 shows the six main factors that can affect a process. They are man, machine, method, measurement, material, and milieu or environment. These are the main categories of possible causes of variation in any process.

Figure 5 shows the main components of measurement error: precision, accuracy, and stability. Precision is determined by the repeatability and the reproducibility. Accuracy is determined by the bias, either constant or variable. Stability can be evaluated by short-term and long-term measurement variation.

Figure 6 shows the green, yellow, and red zones are used in pre-control. Pre-control is a method of SPC that is significantly easier to use than the conventional Shewhart SPC method. The differences between the two methods are explained in the program.

SPCIM© comes with a companion book that contains all the material covered in the interactive training program. This book (1) provides convenient reference material, particularly for those wanting to review certain parts of the course without going back to the computer. It is recommended that the book is used together with the interactive training program to maximize retention and comprehension of the material.

SPCIM© can be bundled with the injection molding simulation program Miniflow; this will be discussed next.

Simulation Program MiniFlow (#0184)

Another feature of interactive training program is the simulation program MiniFlow. This icon driven program can optimize the injection molding process in a matter of minutes. The simulation program is useful at two levels. Primarily, it allows the students to explore important injection molding calculations without needing to master complicated equations. Additionally, experienced molding personnel can use the software to aid in the design and analysis of molding systems.

The main screen of MiniFlow is shown in figure 7. To use the program, the user first selects the injection molding machine. A large number of machines are incorporated in the databank, see figure 8. Machines can be sorted by manufacturer, model, or specification. New machines can also be entered into the machine databank. Second, the user selects the material. Again, a large number of materials are incorporated in the databank, see figure 9. Materials can be sorted by manufacturer, grade, and resin family. New materials can also be entered into the material databank.

Next, the user sets the operating conditions by opening the molding conditions window, see figure 10. The molding conditions that can be set are injection temperature, mold temperature, part thickness, part width, percent maximum pressure, and percent maximum flow rate. The program provides reasonable default values for all the molding conditions. The user can select between English (American) and S.I. units.

The user is now ready to calculate the flow length and temperatures. The results of the calculations are presented in graphical form, see figure 11. Three graphs show how flow length, flow rate, and pressure vary with time. It is also possible to choose multipoint data and obtain a graph that can be used to determine the processing window for the current polymer-machine-mold combination. Figure 12 shows such a plot with flow length along the y-axis, thickness along the x-axis, and pressure along the z-axis. The user can choose to plot the following parameters along the y-axis: flow length, maximum bulk temperature, or fill time. For the x- and z-axis the user can choose the parameters shown in figure 12.
These features allow the user to quickly scan a large number of operating conditions to optimize the injection molding process. As such, MiniFlow is a valuable tool not only for training but also for actual analysis of molding operations. MiniFlow comes with a complete tutorial. (#0184-purchased with SPCIM, mem $265.

Conclusions

Various options are available for companies wanting to train employees in SPC and injection molding. Computer based training offers a number of advantages over traditional training methods. Most importantly, computer based, interactive training improves learning effectiveness and retention. A further advantage of interactive training is that it provides flexible, self-paced learning. Production schedules do not have to be disrupted to conduct training because employees do not have to miss time from work.

SPCIM© is a new, fully interactive training program on SPC and injection molding. This Windows based program provides a cost-effective solution to training; the cost of the program is about the same as the cost of sending one employee to an off-site seminar. Thus, this training program provides a cost advantage when two or more employees are trained; the cost advantage becomes greater as more people are trained.

SPCIM© not only teaches the basics of SPC, it also teaches the fundamentals of injection molding process technology and can be used at any level. This combination allows for the most effective implementation of SPC in injection molding operations.

The interactive training program can be bundled with the simulation program MiniFlow. It allows students to determine the flow length, pressures, and temperatures. This simulation package is not only useful for training, but also in analyzing real injection molding problems.

References

C. Rauwendaal, "Statistical Process Control in Injection Molding and Extrusion," Hanser Verlag, Munich, (2000)

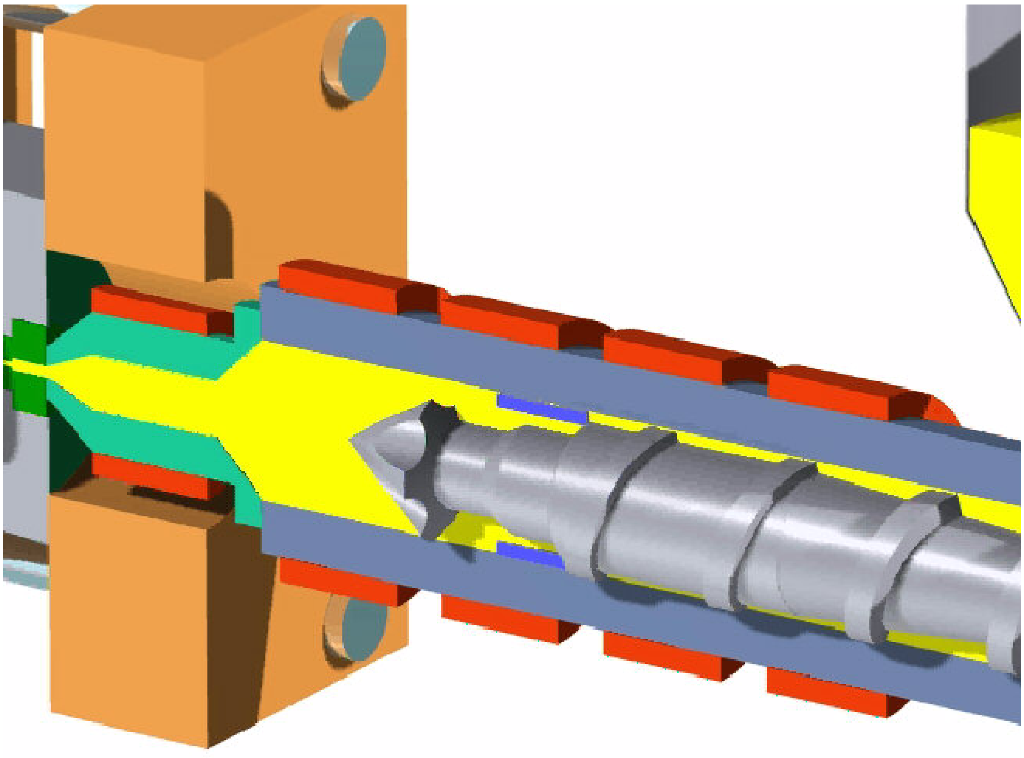


Figure 1, Illustration of screw recovery

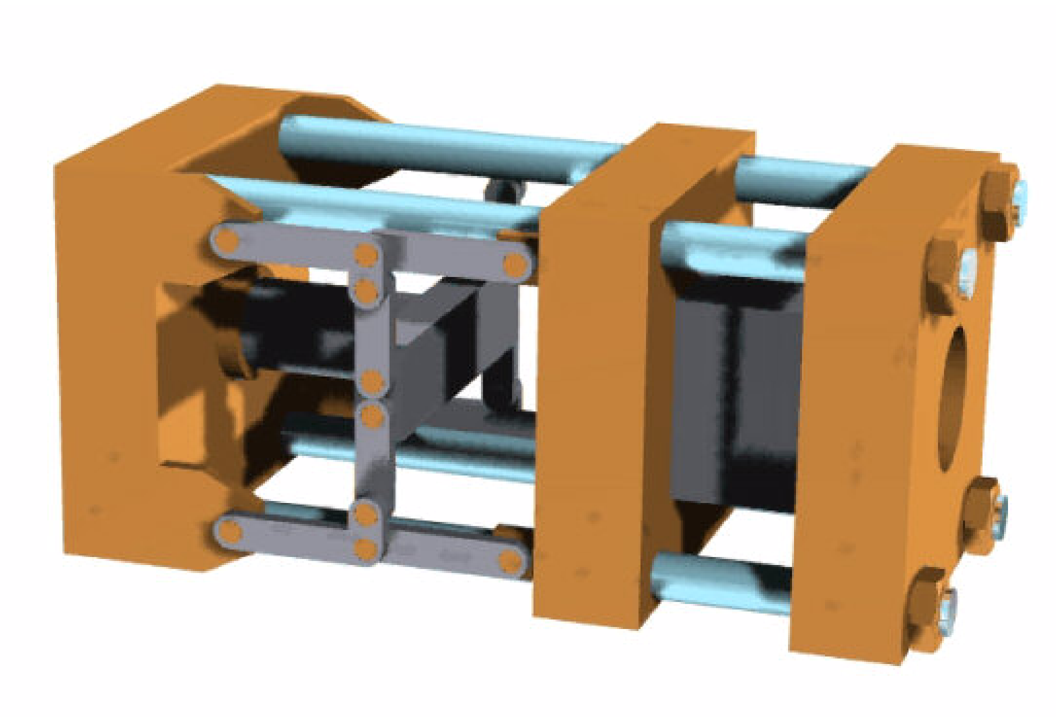


Figure 2, Illustration of a double toggle system

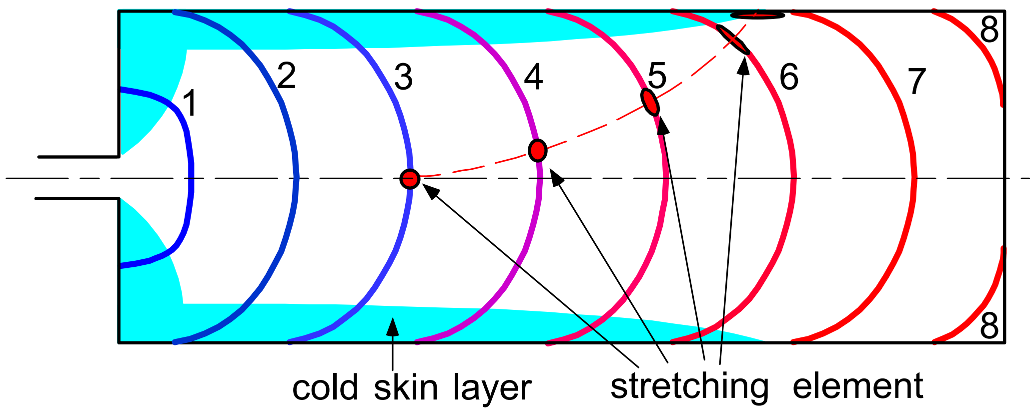


Figure 3, Illustration of fountain flow in a mold

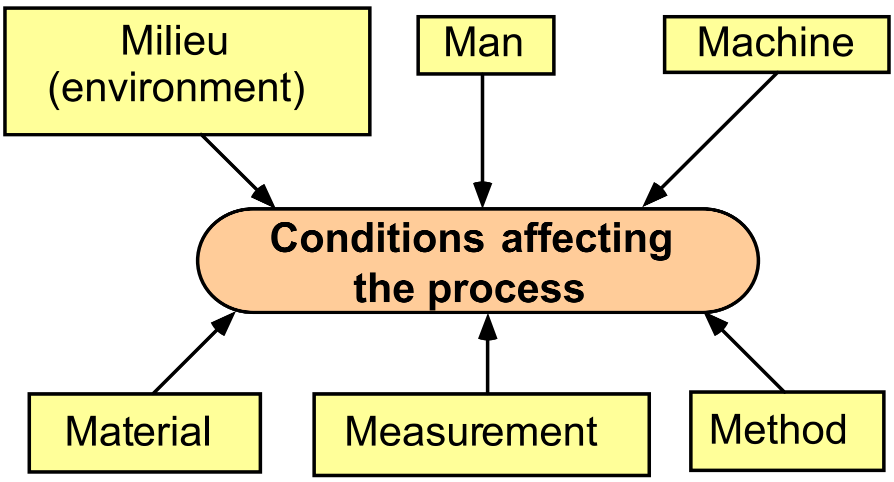


Figure 4, Six main factors that can affect a process

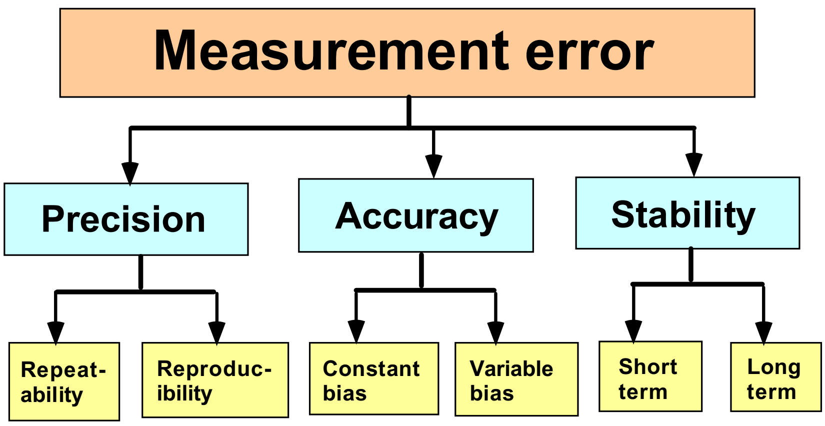


Figure 5, The main components of measurement error

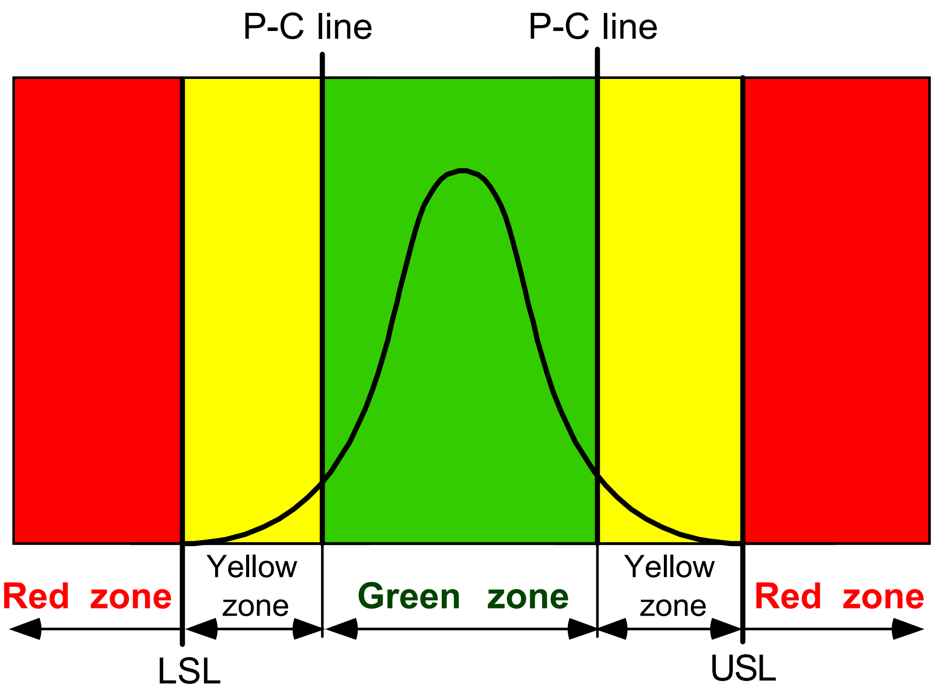


Figure 6, The green, yellow, and red zone in pre-control

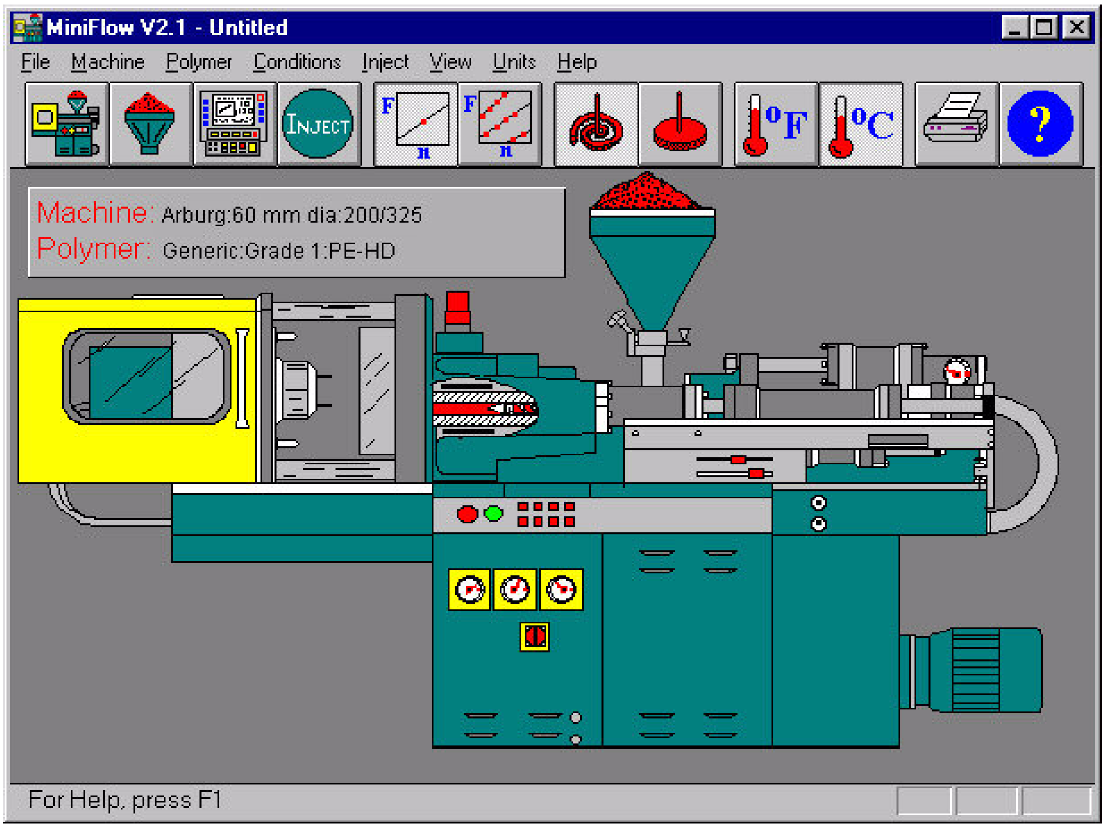


Figure 7, The main screen of MiniFlow

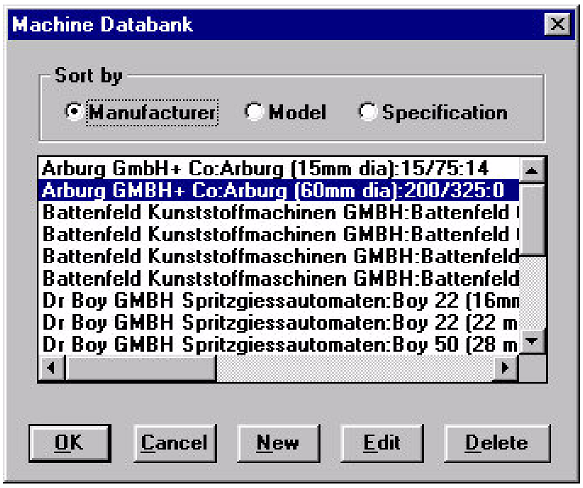


Figure 8, The machine databank window

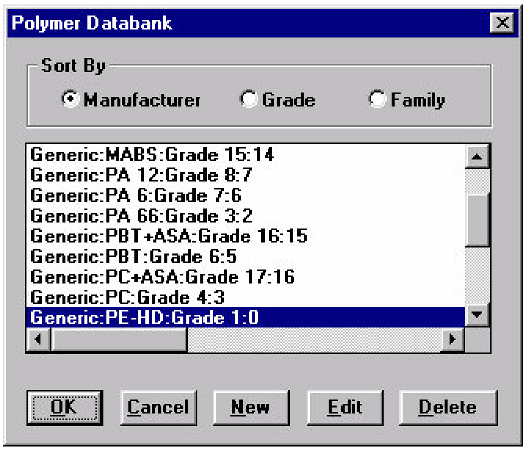
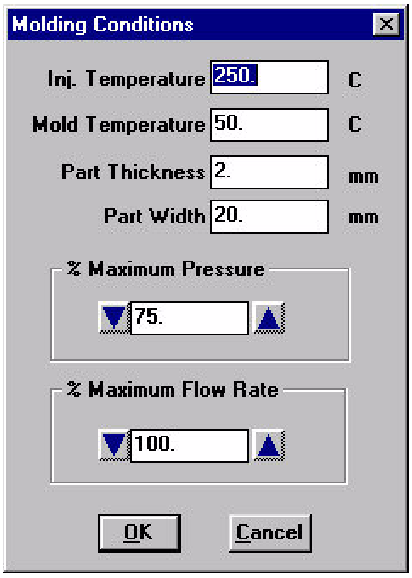


Figure 9, The material databank window



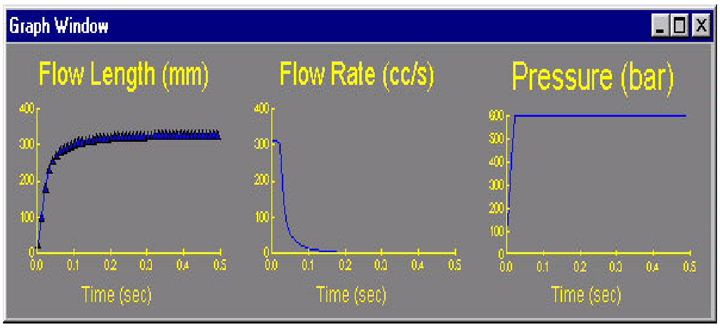


Figure 10, The molding conditions window Figure 11, Flow length, flow rate, and pressure vs. time

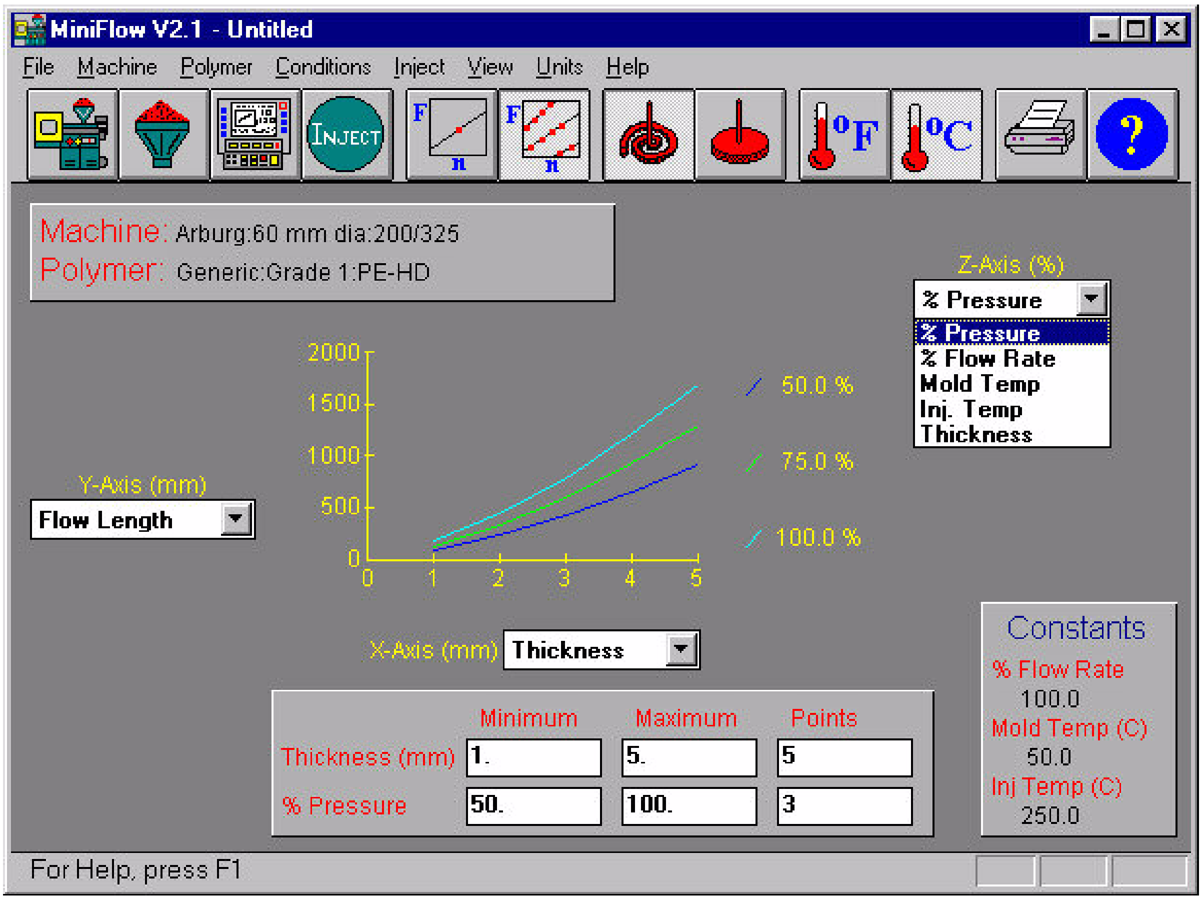


Figure 12, Graph of Flow length against thickness for three values of pressure