Minimizing mold changover time by standardizing sprue sizes

Mikael Hellman

Degree Thesis
Plastics Technology 2007
2012


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EXAMENSARBETE	
Arcada	
Utbildningsprogram:	Plastteknik 2007 / Plastics Technology 2007
Identifikationsnummer:	7200
Författare:	Mikael Hellman
Arbetets namn:	Hur man kan snabba upp form bytande genom att optimera anpassarens och nosens storlek
Handledare (Arcada):	Marko Voho
Uppdragsgivare:	Suunto Oy

Sammandrag:

Suunto Oy har en ägen avdelning för att tillverka sina plast produkter med form sprutnings maskiner. Syftet med detta slutarbete var att undersöka kan form sprutnings prosessen utföras snabbare genoma att inflöda på tiden som det tar att byta ut en form i maskinen. Detta skulle utföras genom att hitta en standard storlek åt anpassarna i formerna som används på denna ena maskin som utsätt för detta projekt, som betyder att även maskinens nos inte skulle mera behöva bytas i framtiden och där med skulle utbyte av formen gå mycket smidigare i framtiden. Mätande av formernas anpassarens storlek, samt deras bytaden till standard storlek och provkörning av formerna gjordes på Suuntos plastproduktions avdelnin i Vanda. Resultaten visade att projektet var lyckat och inga större problem kom fram.

Nyckelord:	Form sprutning, anpassare, nos, form, Suunto Oy
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DEGREE THESIS	
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Author:	Mikael Hellman
Title:	How to make faster mold changes by optimizing sprue and nozzle size
Supervisor (Arcada):	Marko Voho
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Abstract:

Suunto Oy has an own department to manufacture its plastic products with injection molding machines. The aim of this final thesis was to find out if the injection molding process could be made faster by effecting on the mold changin time. This would be done by finding out a standard size for sprues of the molds used on this one machine that was set to this project, which would lead to that, that the machine nozzle would not need to be changed more in the future so the mold changing would be faster. Measuring the sprue sizes of the molds and the changing them to a standard size and test drive of the molds was done in the Suunto plastic production department in Vantaa. The results of this project shows that the outcome of the project was excellent and no bigger problems was found out.

Keywords:	injection molding, sprue, nozzle, mold, Suunto Oy
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Tiivistelmä:

Suunto Oy:llä on oma muovituotanto osasto jossa käytetään ruiskuvalu koneita. Tämän opinnäyte työn tarkoituksena oli selvittä voitaisiinko ruiskuvalua prosessia nopeuttaa vaikuttamalla muotin vaihto aikaan. Tämä tehtäisiin selvittämällä standardi koko muottien suuttimille jotka ovat käytössä tällä yhdellä tietyllä ruiskuvalu koneella joka oli käytössä tässä projektissa. Tämä johtaisi siihen, että koneen nokkaa ei enää tarvitsisi vaihtaa jatkossa, joka taas tarkottaisi, että muotin vaihto sujuisi nopeampaa tulevaisuudessa. Muottien suuttimien mittaaminen, vaihtaminen uusiin isompiin ja koe ajo tapahtui Vantaalla Suunnon muovituotanto osastolla. Opinnäyte työn tulokset näyttävät, että työ oli onnistunut ja projetki saatiin tehtyä ilman minkäänlaisia ongelmia.

Avainsanat:	Ruiskuvalu, suutin, nokka, muotti, Suunto Oy
Sivumäärä:	
Kieli:	English
Hyväksymispäivämäärä:	

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1 VOCABULARY

Clamping force: The amount in kilo newton`s that keeps the female and male molds together.

Granulates: Shape of plastic raw material

Injection molding cycle: The time it takes for a certain part to be produced with an injection molding machine.

Pre drying: Technique used to remove extra moisture from plastic material before usage.

Reciprocating screw: Screw type used for the injection molding and extrusion machines. Its purpose is to transport the plastic forward inside the machine.

Shot size: The shot size is the amount of plastic material needed to fill the whole mold.

Two-cavity mold: A mold that can make two different or same plastic parts.

Raw material: Is the basic unprocessed material from which the plastic parts are made off. Often refers to plastic granulates

Runner scrap: Plastic that will be as leftover from the runner channel in the mold. Needs often one step more in the injection molding cycle to be taken away.

2 INTRODUCTION

Plastic products are part of our everyday life. Often we do not even realize how much we use them daily or how dependent we are upon products made out of plastic. For example, a lot of food-packages are made out of plastic, cell phones are often made at least partly out of plastics, the small card holder for our bus ticket is made out of plastic, cars have a lot of plastic parts, even our tooth brush is made out of plastic, and so on. Therefore it is easy to imagine how big the plastic industry is worldwide and how it has developed during the twentieth century. The growth of plastics industry is still huge with new materials coming out, especially bio-plastics and biodegradable plastics, and the development of production technology takes big steps forward year by year, making production of plastic parts easier, cheaper and faster, and yet more advanced, precise and with a better quality of products as a result.

One of the most common ways of producing plastic parts nowadays is injection molding. As the need to produce more precise and advanced plastic parts grows, injection molding has to be perpetually developed. New machines are made; they are faster, they can produce products for which earlier two or three machines were needed and they are incredibly precise. Even though the machines get better and better, we also need to speed up everything else in the production cycle besides the injection machine; the whole manufacturing process, from changing the molds to inserting the plastic raw materials, needs to be as fast as the machine or else it will slow down the production.

The main task of this thesis is to develop the injection molding procedure by finding out if the mold changing time can be affected by standardization of the molds' sprue size.

2.1 Suunto and the idea of the project

Suunto was founded in 1936 by Tuomas Vohlonen, an outdoors man and an orienteering enthusiast. Being an engineer with an inventive turn of mind, he discovered and patented a unique method of filling and sealing a light-weight compass housing made entirely of celluloid with liquid to dampen the needle and protect it from shock and wear due to excessive motion for much steadier needle, better readings and a new level of accuracy for the compass [1]

Already in the 1950's *Suunto* became well-known for the quality of its products, and compasses were exported to over 50 countries worldwide. In 1987 *Suunto* took a further step by starting to produce dive computers, which turned out to be the seed of the company's later growth. As the dive computer that fits on the wrist, combined with an electronic compass, proved to be a success, it provided the foundation for *Suunto*'s next market conquest, the Suunto Vector in 1998. The Suunto vector was a wrist-top computer, designed for outdoor leisure; it measured air pressure, altitude and helps in predicting changes in the weather as well as displaying direction and time. It was the first step towards the next-generation wrist computers that *Suunto* is known for today.

In the beginning of this century, *Suunto* started to produce more high-technology products, as, for instance, the D9, the first unit that combines a dive computer and digital compass. They produced *t6* which was followed by a whole series of training products with heart rate monitors which helps you to measure the effect of training upon the users' fitness. In 2007, *Suunto* came out with the outdoor sport instruments Core and Lumi, which provided ABC–altimeter, barometer and compass functions. In 2009, *Suunto* brought the Hel02 dive computer to the markets, It is the first dive computer with full mixed-gas capability, fully designed for technical divers who use multiple gases while diving. In the same year *Suunto*'s first premium sport-watch collection was introduced. Suunto Elementum was designed for active city dwellers with interest in sailing, diving and outdoor activities.

"Today, Suunto is a leading designer and manufacturer of sports instruments for training, diving, mountaineering, hiking, skiing, sailing and golf. Prized for their design, accuracy and dependability, Suunto sports instruments combine the aesthetics and functionality of watches with sport-specific computers that help athletes at all levels analyze and improve performance. Headquartered in Vantaa, Finland, Suunto employs more than 500 people worldwide and distributes its products to over 100 countries. The company is a subsidiary of Helsinki-based Amer Sports Corporation with the sister brands Wilson, Salomon, Atomic, Precor, Arc'teryx and Mavic." [2]

Suunto has its own plastic part manufacturing department with ten injection molding machines and a storage of nearly 300 different molds for different plastic parts. *Suunto* have manufactured their own plastic parts since the 1960's for the compasses, wrist computers and hundreds of other technical components.

I was happy to find a practical training place at *Suunto* in the spring of 2012. I worked at the printing department of *Suunto* during the whole summer, informing about my interest in getting a subject for my final thesis from the plastic manufacturing department. The idea for the present thesis was born in discussions with the staff.

2.2 Aims and objectives

Suunto Oy has set the aim of finding out if it is possible to make the whole process of manufacturing plastic parts faster and more fluent. Would the change of the sprue size for the molds used on a specific machine effect the mold changing time on that injection machine?

The objectives of this study were to find out the sizes of the sprues on the different molds that are used on a specific injection molding machine, and after that, to decide which sizes the sprues should be changed to, so that as many as possible would have the same size or be big enough so that the nozzle of the injection machine also could be changed permanently to one size. As a result the nozzle of the machine would never need to be changed.

The result of the project would then be that if the new sprue sizes of the molds functioned well on the injection machine, the manufacturing process would be faster and more effortless as there would no longer be any need to change the injection molding machine's nozzle.

The following aims and objectives were set up:

- to find one standard sprue size for all molds
- to study how standard sprue size can be used in the existing machines
- to find out if the plastic parts still can be made with the same machine
- to see if the result will have a time-saving effect on the production circle

With my thesis I also want to give some basic understanding to those who are not familiar with the injection molding process of manufacturing plastic parts, show how the nozzle and sprue work and how they effect the whole injection molding cycle.

2.3 Methods

Most of the work was done at the *Suunto* plastics manufacturing department in Vantaa while some work was in the form of research and literature reading. The work with the molds, changing the sprues and after that the test run of the molds on the injection machine was done first, while the analyzes, the reading of literature of the field and the actual writing was done after all the datas had been collected and test runs made.

2.4 Restrictions

Initially, some restrictions have to be taken under consideration.

First of all, if the number of sprues which are to be changed is high, the cost to order new ones will be too high. The amount and the sizes of the sprues which we would like to change will also show, if there is an actual need to fulfill this project or if it is easier to just swap the molds to the injection machines which already have molds with that same-sized sprues in use. It will also show if molds with even a too big sprue size must be changed to a smaller sprue size or to a different injection machine.

Restriction of this project is to be made on one injection molding machine, so that the capability of the machine is set as a restriction for the outcome of the plastic parts. For example, if the clamping force turns out to be insufficient, the mold needs to be changed to an injection machine with a bigger clamping force.

The result of the test runs, that is, the quality and outlook of the plastic part, will mostly be made by visual inspection and by comparing two example pieces. Some of them may need inspection by weight.

3 LITERATURE REVIEW

The manufacturing process of injection molding is explained with the help of a theoretical background. In the following I will give some basic information about the injection molding process, what a mold is and what the nozzle and sprue have to do with the injection molding cycle. The most common parameters of the injection molding machine and their effect on the plastic part that is produced will also be explained.

3.1 Injection molding

"*Injection molding is the most important process used to manufacture plastic products. Today, more than one third of all thermoplastic materials are injection molded and more than half of all polymer-processing equipment is for injection molding. The injection molding process is ideally suited to manufacture mass-production parts of complex shapes that require precise dimensions."* [3]

The first injection molding machine was patented in 1872. It worked like a large hypodermic needle, using a plunger to inject plastic through a heated cylinder into a mold. The industry expanded rapidly in the 1940s , as World War II created a huge demand for inexpensive, mass-produced products. In 1946, the American inventor James Watson Henry built the first screw injection machine, which allowed a more precise control over the speed of injection and the quality of articles produced. This machine also allowed material to be mixed before injection, so that colored or recycled plastic could be added to virgin material and mixed thoroughly before being injected. [4]

The next big development in the history of the injection molding machine took place in 1956, when W.H. Willert patented the reciprocating system. In reciprocating systems the screw moves backwards and forwards during the mould cycle. After mixing, the screw stops turning and the entire screw pushes forward, acting like a plunger for injecting material into a mold. The screw moves backward against the hydraulic back pressure during the

plastication.

The injection molding machines of today are to large extent copies of the machines invented by Watson and Willert, even if they are much more developed. [5]

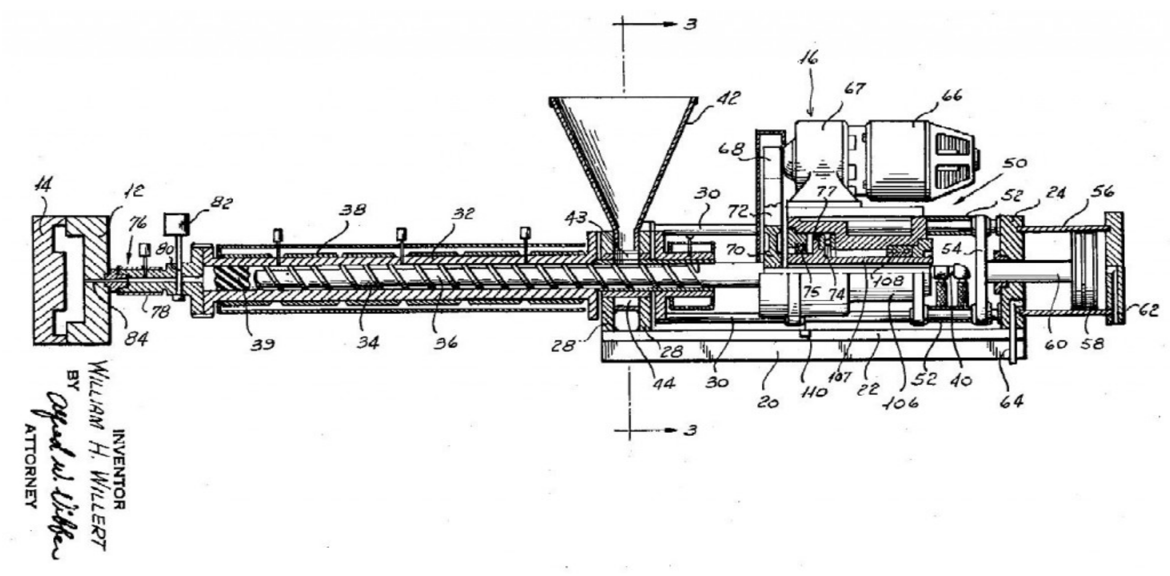

Figure 1 Picture of an old injection machine [12]

3.1.1 The machine

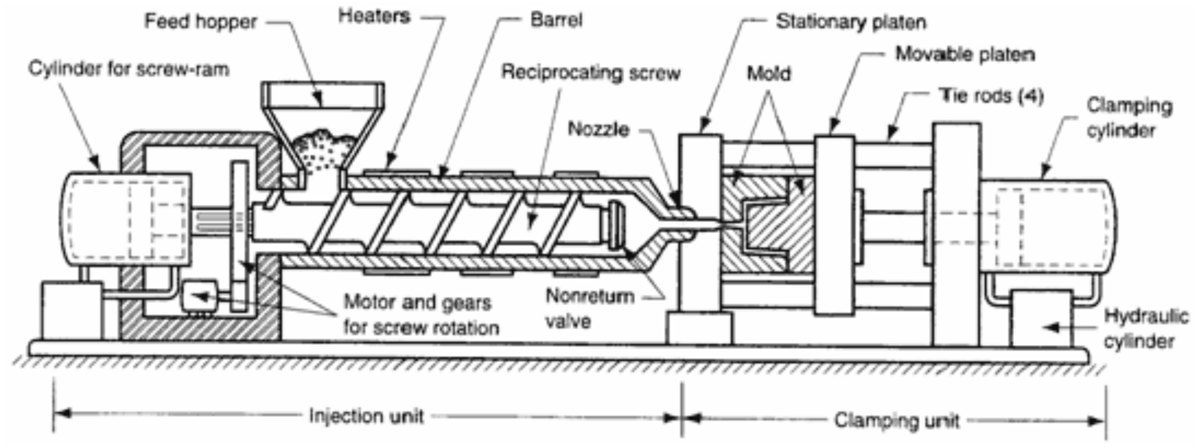

Figure 2 A modern injection machine [13]

Three different kinds of injection molding machine types exist: hydraulic, electric and hybrid. The most common is the hydraulic, which is the type of machine used in this project.

An injection molding machine consists of many different parts, but the injection molding machine can be divided into two main units: the injection unit and the clamping unit. All the other parts, as heaters, screw, feed hopper etc., basically have the same function in all machine types related to injection molding, and will be more precisely explained in the text below.

Parts of a typical injection molding machine

Injection unit:

Hopper is a container, holding a supply of the plastic raw material to be fed to the screw.

The barrel supports the screw, and it is heated by the heating system which is attached on the outside of the barrel.

The screw (sometimes called the reciprocating screw) is used to compress, melt, and convey the plastic material. The screw consists of three zones:

- the feeding zone
- the compressing (or transition) zone
- the metering zone

The nozzle connects the barrel to the sprue of the mold and forms a seal between the barrel and the mold. The nozzle temperature will effect the mold temperature.

The size of the nozzle, that is, the diameter of the nozzle, has to be taken under consideration when changing the mold, because it will influence on how big the sprue size of the mold should be.

The heating system often consists of 3-5 electric heater bands, depending on the length of the barrel, and one in the hopper to gain a unified heating of the barrel. The heating is often lower in the beginning of the barrel and will slightly grow towards the nozzle.

Clamping unit:

The clamping system is used to keep the mold halves tightly closed when the melt is injected into the cavity under high pressure.

The plates are the part of the injection machine where the mold is attached by using clamps. One is stationary and the other is movable, allowing the mold to be opened and closed.

Even though *the cooling system* is not showed in the Figure 2, it is a very important part of the injection molding machine with a vital effect on the outcome of the plastic part produced. It also affects the whole cycle time of making a plastic part. In older machines the cooling is often fixed by a water cooling system that is not attached to the machine in itself, while new machines have the system integrated, something which makes it possible to control the cooling from the input values on the machine. The water cooling is often attached to the mold on the core and the cavity side of the mold, so that you get a precise cooling according to the demands of the plastic material. [6]

Without a *mold* it is not possible to produce plastic parts with an injection machine. In a way the mold is as important or even more important than the machine in itself. It gives the shape to the plastic part that is to be made. A standard mold consists of two sides. One of them is the mold cavity side, which is stationary and where the sprue, runners, gates and one part of the cooling system is placed. The locating ring, too, is placed on the outside of the mold cavity, so that you align the mold with the injection machines nozzle. The other half is called mold core and it is movable because it is attached to the clamping unit, and in the core you can locate the ejector system and some of the cooling system. The line between the mold cavity and the mold core is called the parting line. [7]

Figure 3 A mold that was used in this project. (Photograph Mikael Hellman, Suunto 2012)

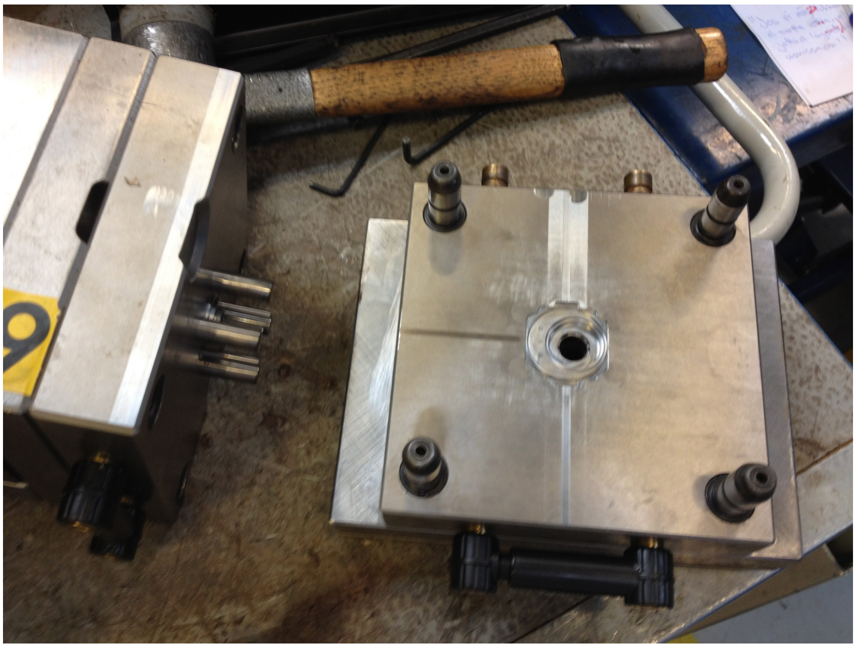

Figure 4 A picture of an open mold where you can see the cavity and a part of sprue. . (Photograph Mikael Hellman, Suunto 2012)

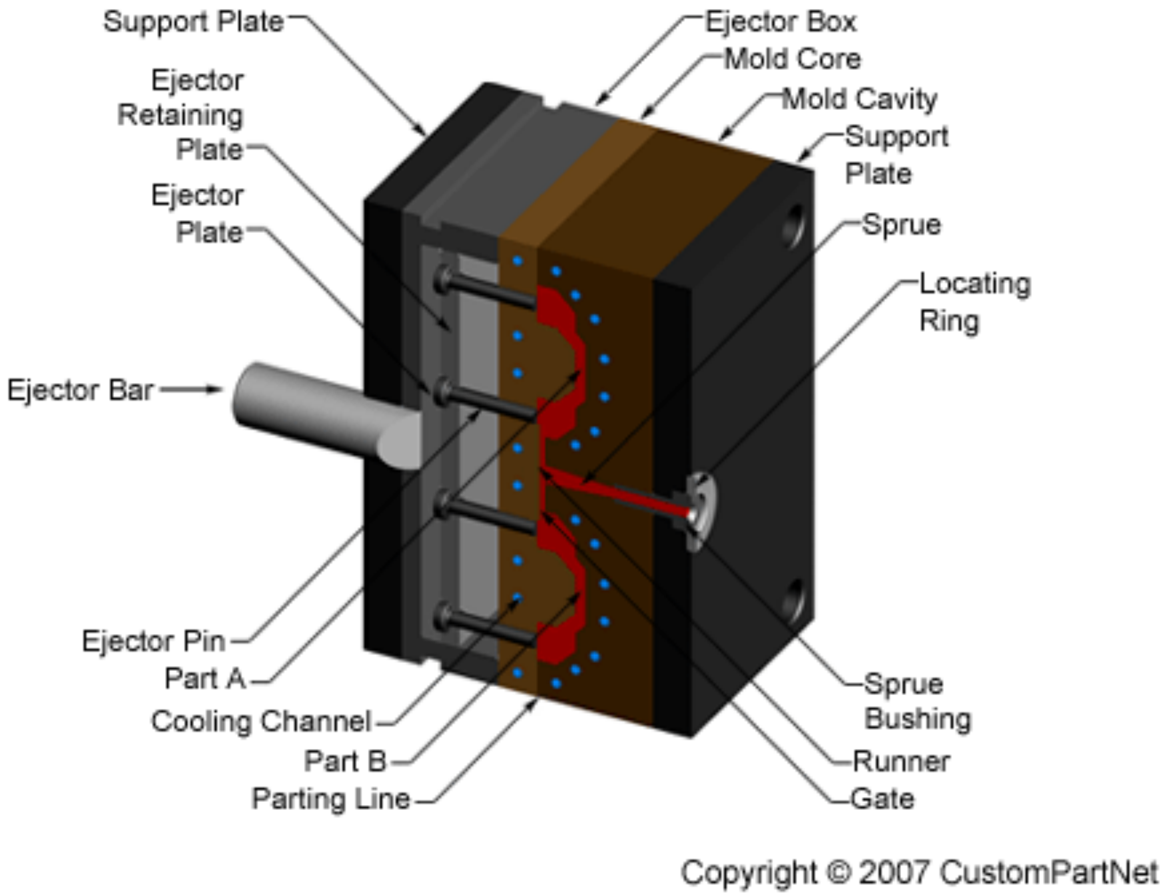

Figure 5 Picture of the different parts of a mold. [14]

The most typical molds have a hot runner system or a cold runner system. The differences between these two systems are explained below:

Cold runner. It works without any additional heat in the sprue, runners or the gate. Only the heat of the injected plastic and the temperature of the cooling system will affect the mold. The biggest disadvantage with the cold runner system is that it generates much plastic waste that has to be taken care of in some sort of a way. This means "a step more" in the manufacturing process. Molds with cold runner system are much cheaper and much easier to maintain and operate than molds with hot runner system.

Hot runner. The hot runner system means that the runners (or the system that works like runners, heated nozzles and heated gates/ melt passage), which are connected to the sprue, are heated. Hot runners form a fairly complicated system; they have to maintain the plastic material within them uniformly heated, while the rest of the mold is being cooled in order to solidify the product quickly. There are two main types of hot runner systems: the externally heated and the internally heated.

Internally heated runner systems require higher molding pressures, and color changes are very difficult. There are many places for the material to get stuck and degrade in the runner channels, melt passages or the nozzle, so thermally sensitive materials should not be used. Internally heated systems better separate runner heat from the mold, as an insulating frozen layer is formed against the steel wall on the inside of the flow channels.

Externally heated hot runner channels have the lowest pressure drop of all runner system (because there is no heater obstructing flow and all the plastic is molten), and they are better for color changes, as none of the plastic in the runner system freezes. There are no places for material to hang up and degrade, so externally heated systems are good for thermally sensitive materials. [8]

Molds with hot runner system are much more expensive than molds with cold runners and more skill is required to maintain and operate it. The production of plastic parts with different colors can be difficult, since it is hard to remove all plastic from an internal runner system. The most important advantage among many others with the hot runner system is that it reduces the plastic waste by completely eliminating the runner scrap. It also shortens the injection molding cycle time.

The molds need high precision engineering manufactured to very close tolerances by skilled craftsmen. Therefore the molds are very expensive to make and they are often made only if they will be used in mass production. [3]

3.1.2 Process

The process of injection molding in itself is not very complicated. The process starts by choosing the right raw material, which is often in the form of granulates, for the plastic part that is to be made. Some of the raw materials need to be pre-dried, and if that is the case you need to dry the raw material in an oven before it is fed into the hopper. After the raw material has been fed into the hopper the process of the machine is ready to start.

The different steps of the injection molding cycle are explained below:

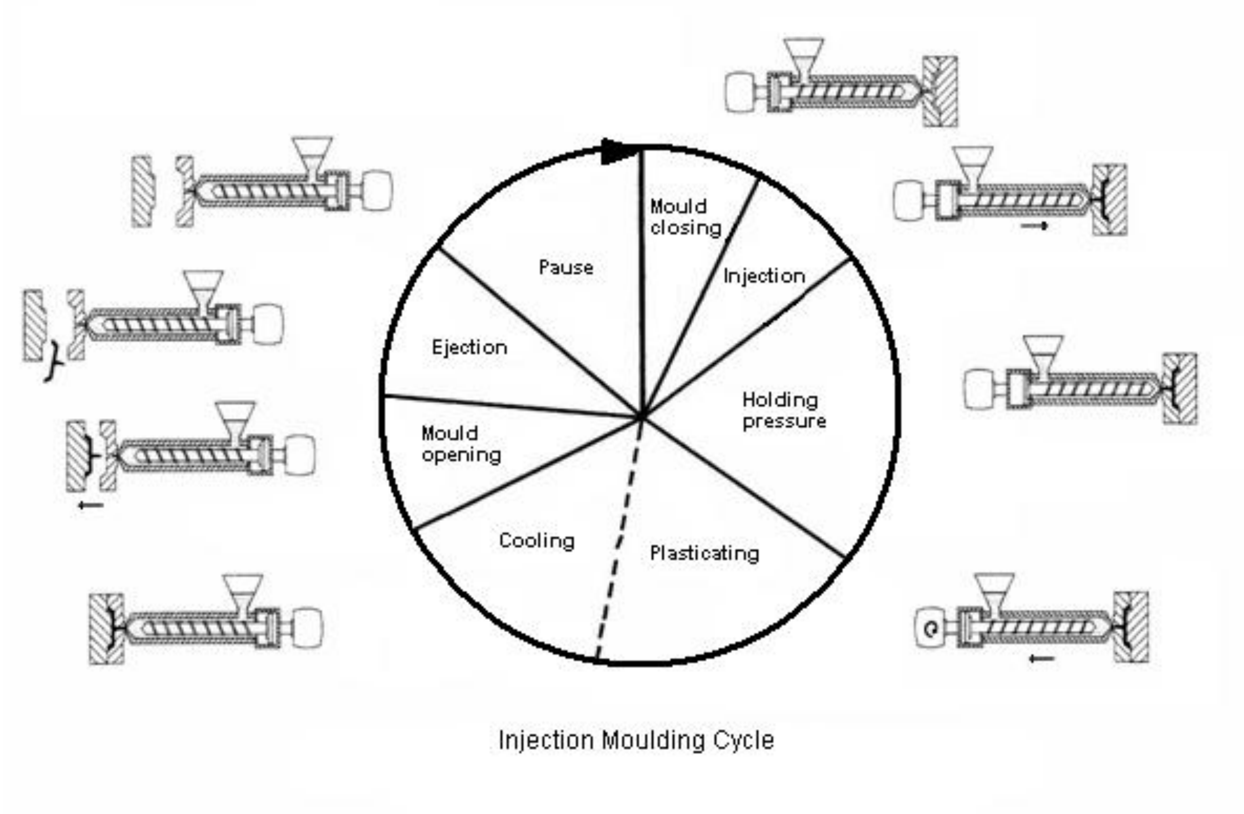

Figure 6 The cycle of injection molding and the time taken for each step [15]

1) The first step is the mold closing; the hydraulically powered clamping unit pushes the mold halves together and exerts sufficient force to keep the mold securely closed, while the material is injected.

2) The second step is the injection, when the melted plastic is pushed by the reciprocating screw into the mold. The air within the mold will be pushed out through small vents and holes.

3) The third step is the holding pressure, when the screw keeps pushing forward to maintain a holding pressure. This motion creates the effect of squeezing extra melt into the cavity to compensate for the shrinkage of the part when it cools down. [3]

4) The fourth step is the plasticating and cooling. No more melt can enter the mold when the gates start to freeze, and so the screw can pull back. At this point, the screw starts to rotate and draw in new plastic from the hopper. This operation prepares the next shot by applying the desirable amount of plastic in front of the screw. When the preset amount of the shot size is reached, the screw stops rotating, and the machine waits for the next injection to start. The cooling time ends as soon as the part achieves a certain temperature which allows the ejection without distortion. This stage of the cycle is just an operation of the heat dissipation transported by the material, depending on the molding thickness and on the mold cooling system.

5) The fifth step is the mold opening and ejection of the plastic part. After a sufficient time, when the part is enough cooled, it may be ejected from the mold. The mold is opened by the clamping unit and the plastic piece is ejected by a mechanism that is attached to the rear half of the mold and is used to push the part out of the mold.

6) The sixth and the last step is the pause. The pause step is the period of time from the moment when the part is ready to be removed from the mold and the start of a new cycle. If the machine is working in automatic mode, it is almost instantaneous, but it can be extended if the part is being manually removed or if it is necessary to put in inserts. [9]

The process cycle for injection molding is very short, typically between 2 seconds and 2 minutes.

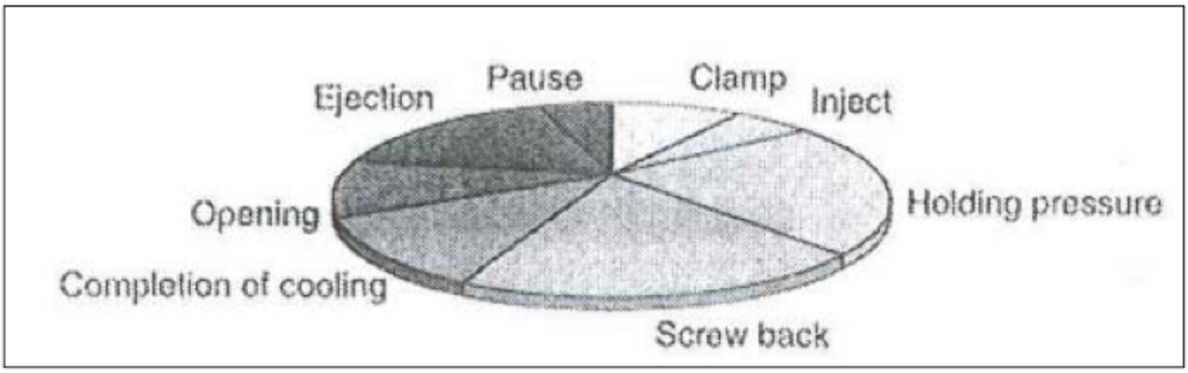

Figure 7 Another picture of the stages during injection molding cycle (R.J.Crawford, page 281, 1998)

3.1.3 Injection machine input parameters

The input values for the machine are chosen according to the kind of plastic piece produced and the material used. The size of the piece will affect many different values, like the clamping force, shot size and the cooling time. Different plastic materials have different properties that will affect, for example, the heating and cooling time.

The properties of the plastic material are often provided by the manufacturer on a datasheet for that specific material. There you can see whether the material needs to be pre-dried or not and what temperatures are needed for the heating system to process the material. If not provided, then there are many web pages where you can find up-to-date datasheets for different materials

Like, for example, www.matweb.com.

The input values for the machine are something that varies from every plastic piece produced. The perfect values can often be found through a sufficient number of test runs. Because of this, input values, like injection pressure, holding pressure, shot size and changing point between holding pressure and injection pressure, will affect each other in so many different ways that the outcome of the plastic part cannot immediately be seen.

The most common input values of injection molding are listed below. Some of them can be calculated in beforehand:

Clamping force: *(V.Poliakova, 2012)*

F = Clamping force (N), p =mean affective pressure (bar), A = total projected area (mm2)

Cooling time: *(V.Poliakova, 2012)*

T = cooling time (s), c = 2 to 3 (s/mm2), s = wall thickness (mm)

Shot size (required to determine the plasticizing stroke) *(V.Poliakova, 2012)*

$V = \pi r2*d$

V=Volume of the material plasticized (mm3) = Volume of the part, r = screw diameter (mm), π = 3,14

Melting temperature

Barrel temperature

Nozzle temperature

Mould temperature

Injection pressure

Injection speed

Holding pressure

Holding pressure time

Cushion

Changing point between holding pressure and injection pressure

3.2 Sprue

A sprue, also called sprue bush, is a channel through which a molten plastic material is being injected. The molten plastic is injected from the nozzle of the injection machine into the sprue, from where it passes on to the runners and finally into the mold cavities. The sprue has a smooth, round, tapered wall to allow smooth material flow. [10]

The sprue size actually stands for the diameter of the sprue. The diameter of the sprue is determined when the mold is designed, so that you will have a good plastic flow into the cavity of the mold. Here you will have help of software programs like Mold flow, that will give you accurate calculations, analysis and simulations of the phases of injection molding.

Figure 8 Different kind of sprues [17]

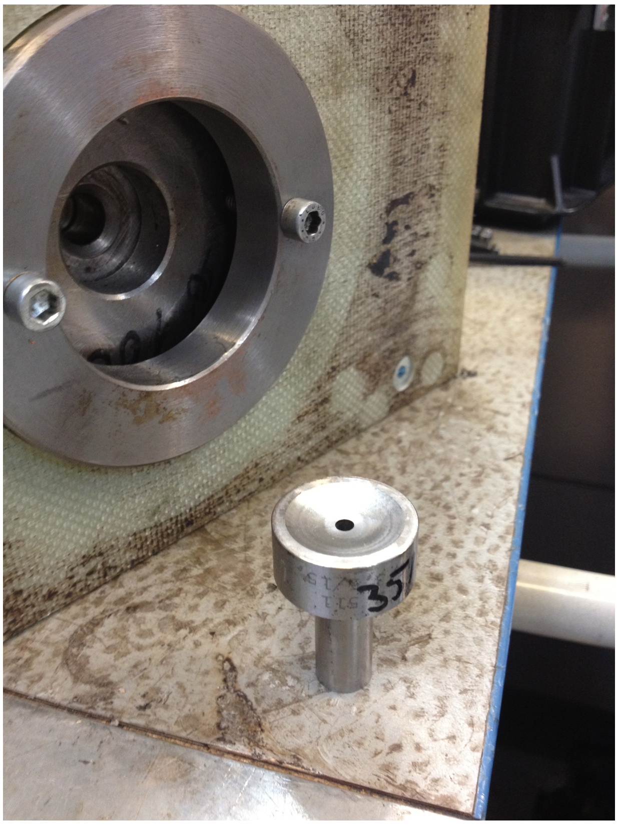

Figure 9 A typical sprue taken out of the mold. (Photograph Mikael Hellman, Suunto 2012)

3.3 The relevance between nozzle and sprue

The sprue and the nozzle will determine whether the plastic flow into the mold cavities will be good or not. The placement of the nozzle and the sprue has to be linear and the shapes need to be the same so that they will fit and no leakage or holding pressure drop will occur.

The size (diameter) of the nozzle should be slightly smaller than the diameter of the sprue in order to allow a good flow of the plastic. [11]

Thus a thumb rule can be made:

The sprue diameter ≥ the nozzle diameter

The sprue and nozzle relevance has to do with basic rules of physics that can be learned in a course called Fluid mechanism, how the melt plastic will flow and how the sprue and nozzle size will have an effect on the flow. Also in this project you can see how the flow of the melt plastic can effect on the different input values of the machine or that some of the bigger molds had to be changed to a machine where you can use a bigger nozzle for the bigger sprues and the machine has more clamping force and power to handle the faster and more powerful injection of the melt plastic.

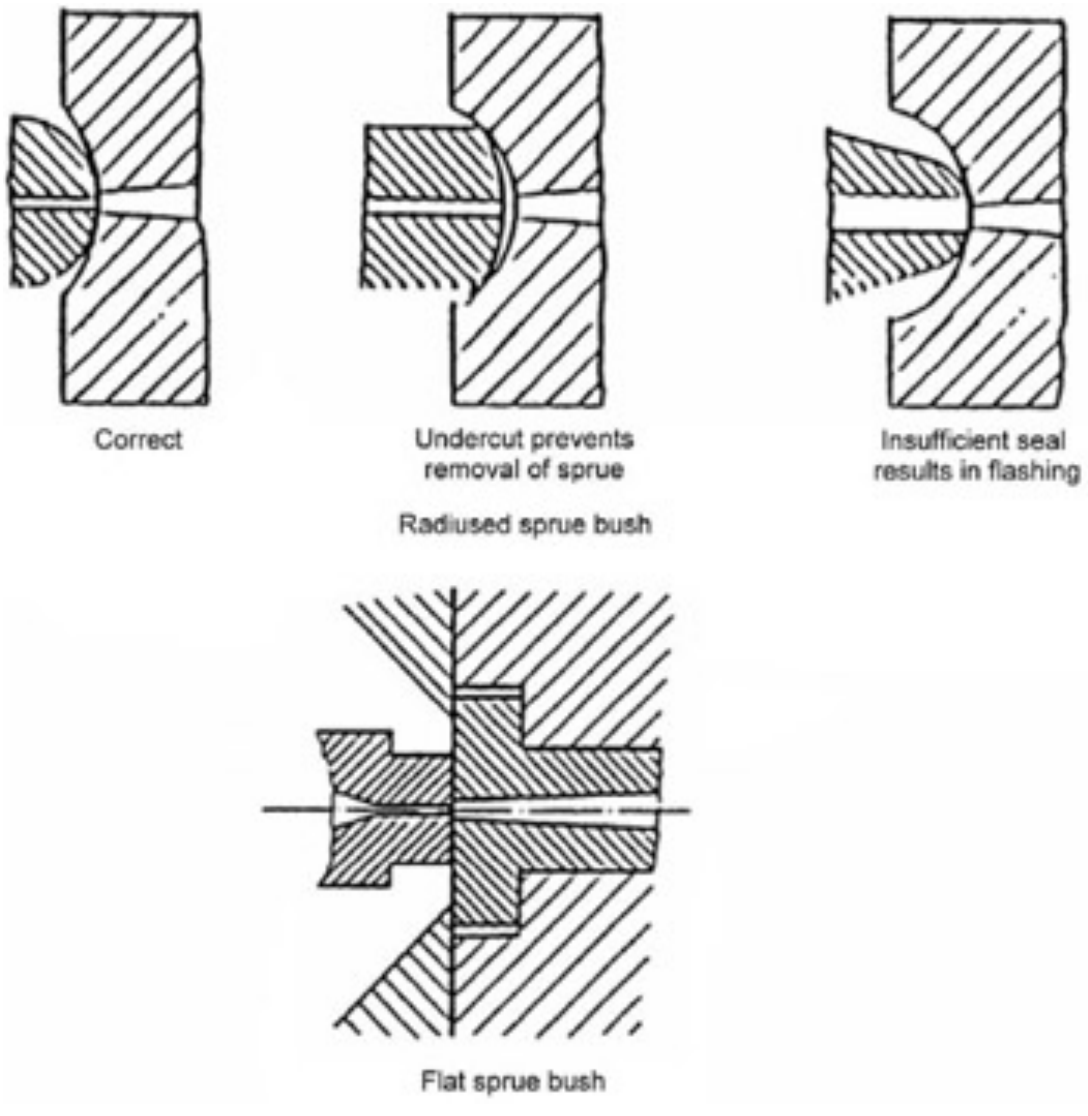

Figure 10 How the machines nozzle should be located with a sprue. [18]

3.4 The machine used in this project

The injection machine used in this project is a Demag ergotech viva 25-80. Demag Viva is a typical machine for the injection molding industry today, and it works in a similar way to the processes explained in previous chapters and have the same parts.

Figure 11 The machine used in this project. . (Photograph Mikael Hellman, Suunto 2012)

DEMAG 25-80 VIVA

Producer:		**DEMAG**
Type:		**D 25-80 Viva**
Year:		**1999**
	Clamping unit	
clamping force	**ton**	**25**
opening Stroke	**mm**	**350**
distance between tie bars	**mm**	**280 x 280**
mold height min/max	**mm**	**55 / 105**
size of mould plates	**mm**	**455 x 475**
	Injection unit	
screw diameter	**mm**	**22**
injection volume	**cm³**	**42**
shot capacity	**gr**	**37**
injection pressure	**bar**	**2061**
	Machine dimensions and weights	
dimensions LxWxH	**m**	**3,8 x 1,05 x 1,94**
net weight	**Kg**	**1550**

Table 1 Technical datasheet of the machine used in this project. (Mikael Hellman 2012) [16]

4 RESEACH METHODS

In this chapter the methods for fulfilling the demands of this project are explained. They can be divided into two sections: the preparation of the molds and the test running.

4.1 Executing the experiment

The aim of the project was to find out if the sprues to the molds used on one specific injection machine can be changed so that they would all have the same sprue size or that it at least would be big enough so that they could all work with one nozzle size on the injection machine.

The initial step of the project was to go trough the molds in order to find out how many sprues will be changed. After that new sprues were ordered and the old sprues in the molds were replaced with new ones. Then the nozzle size of the injection machine was changed, and finally the test running could be started.

The injection machine, molds, sprues and the nozzles used and changed in this project are similar to those which are explained in the previous chapters. In the following the steps of the project are described more in detail.

4.1.2 Preparation of the molds

For the machine that was chosen for this project Suunto has 56 molds in use. They all are rather small with a weight varying from 15 to 40 kg. Some of them are two-cavity molds, allowing two different plastic parts to be made (this can be seen from the mold numbers in the table beneath). None of the molds in this project has a hot runner system, but *Suunto* has hot runner systems in many other molds that are in use on other injection machines. Except those molds which are used to produce colored plastic parts or those which uses acrylic raw material, because with those you will have problems with plastic waste inside the hot runner system channels.

First the diameter of the 56 mold sprues where measured by using different sized sticks. These were made out of a soft metal, so that they would not scratch the surface of the sprue. They were measured with a micro meter. The molds were listed with the plastic part name, mold number, placement code in the mold storage and the sprue size in diameter. In the list below you can see the outcome:

Name	Mold nr.	Placement	Sprue ⌀
1. SM-16 Hammaspyörä	64	D3	3,5 mm
2. MC-1 Narulukot	110	A6	3 mm
3. MCA Saranapalat	139	A6	3,5 mm
4. M-9 Ruusu Valoväri	141	D5	3,2 mm
5. KB/PM Hila	142	D6	3 mm
6. M-9 Runko	144	D2	-
7. M-89 tausta	147	D5	-
8. Sol/Comp tausta	151	F2	3,5 mm
9. Comp. Paristo.kot.kansi	151	F2	3,5 mm
10. SK Valovärinastat	180	D6	2,5 mm
11. SK Suunto rengas	179	E6	3,5mm
12. M-5 kiin. Rengas (type B)	199	D2	-
13. M-5 Asteikkorengas	200	D2	3,5 mm
14. SK-5 Valovärirengas	205	E6	3,5 mm

15. MC-1 Kilometriosoitin	210	A6	2,5 mm
16. KB/PM Säätösat	211	E5	3,5 mm
17. M-18 Napa	219	A5	3,7 mm
18. M-18 Asteikkorengas	221	A5	3,7 mm
19. M-18 Clipper runko	230	A5	-
20. Arrow napa+mang.pidin.	231	D6	2,5 mm
21. Arrow-1 kiin. Rengas	233	B4	2,5 mm
22. Narun pikalukko (A-10)	243	E4	3,2 mm
23. Vector näppäin	255	B2	3,7 mm
24. MC-2 kiin. Rengas	263	B6	3,5 mm
25. MC-2 valoväri tapit	266	A6	3,5 mm
26. MC-2 kiertokehä	267	A6	3,5 mm
27. MC-2 asteikko reng. Valo väri	268	B6	3,5 mm
28. X-lander kiertokehä insertti	281	B4	3,2 mm
29. X-lander kylkiosat	282	B4	3,5 mm
30. Cobra anturin suoja	289	C1	2,5 mm
31. MCB - Pillinpääty	292	D6	3,5 mm
32. MCB - Pillinrunko	293	E6	3,7 mm
33. Observer valosihti	294	A2	3,5 mm
34. Vector tuki holk.+ tiiviste putki	294	A2	3,5 mm
35. CB-71 lenkki	300	D5	3 mm
36. Daine anturin tukirengas	312	A3	3,5 mm
37. X6/M9 paineanturin tukirengas	312	A3	3,5 mm
38. X6 Salpa	313	A3	2,5 mm

39. X6 Kehys B	313 A3	2,5 mm
40. X6 Kehys C	314 A3	2,5 mm
41. (RV2) D9/6/04 Kehys B	322 A3	3,5 mm
42. (RV2) D9/6/04 Kehys C	322 A3	3,5 mm
43. D9 Kehys A	323 B3	2,5 mm
44. T-6 Kehys A	324 A3	2,5 mm
45. Observer Kehys C	326 A3	3,2 mm
46. Observer salpa	327 A2	3,2 mm
47. Observer Kehys B	327 A2	3,2 mm
48. D-6 Välipohja	329 A3	2,5 mm
49. D4 Valosihti	345 B3	3,5 mm
50. D4 Salpa	346 B3	3,5 mm
51. D4 Välipohja	348 B3	3,5 mm
52. Clino osoitin DS-50	351 D1	2,5 mm
53. D-10 Kiertokehä	354 E1	3,7 mm
54. DP-10/6/5/2 Pohjalevy	356 D1	3,5 mm
55. DP-10 Kiertokehä	370 E1	3 mm
56. Vyper 2 anturisuojus	371 B1	2,5 mm
57. (vesikontaktori)	397 E2	2,5 mm

Table 2 List of all molds. (Mikael Hellman 2012)

Name	Mold nr.	Placement	Sprue ⌀
15. MC-1 Kilometriosoitin	210	A6	2,5 mm
30. Cobra anturin suoja	289	C1	2,5 mm
40. X6 Kehys C	314	A3	2,5 mm
43. D9 Kehys A	323	B3	2,5 mm
48. D-6 Välipohja	329	A3	2,5 mm
52. Clino osoitin DS-50	351	D1	2,5 mm
56. Vyper 2 anturisuojus	371	B1	2,5 mm
57. (vesikontaktori)	397	E2	2,5 mm

Table 3 List of molds which's sprues will be changed. (Mikael Hellman 2012)

As can be seen from the table, most of the sprues are 3.5 mm in diameter. This was the size that was planned that the rest of the sprues would have. We also had to decide what the size of the injection machine's nozzle in use would be. It was set to be 3 mm in diameter. As we explained in chapter 3.3, the sprue diameter can be the same as the nozzle diameter of the injection machine, and thus we decided not to change the sprues of the molds with the diameter of 3 and 3.2 mm.

Figure 12 Picture of the old sprue with a locking mechanism compared to the new bigger sprue. . (Photograph Mikael Hellman, Suunto 2012)

The sprues to be changed had the diameter of 2.5 mm and they were changed to 3.5 mm. The sprues had to be taken out of the molds, something which turned out to be a more challenging operation than foreseen, as some of the sprues were jammed after many years of usage or had an old locking mechanism. The best tool to pop out the jammed sprues was a hammer with a plastic face and a thick copper stick. They were both soft as to damp the force of the strike against the metal of the sprue. No marks were to be left on the sprue. As for the ones with an old locking mechanism, we had to take a part the mold bit by bit, until the locking mechanism was found and the sprue could be taken from the mold. After that, the sprues were marked with the mold number and they were sent to a company that made new ones with a bigger diameter. The new, bigger sprues arrived in less than one week and they fitted perfectly to the molds. (As there is no real need for a locking mechanism on the sprues, the new sprues could easily be put in, without the molds being taken a part.)

In the results we will explain more in detail that some of the molds were set to be no more in use. You can also see from the tables that some sprues are bigger than the 3.5mm, which was set to be the ideal size for the sprues, and also found out what was done to these molds.

4.2 Test run of the molds

First the nozzle of the injection machine had to be changed. The diameter of the nozzle was decided to be 3 mm, as most of the sprues would be bigger or at least have the same size diameter.

All the molds have ready programs, or, should we say, specific input values for the injection molding machine, saved on a floppy disk. Here the main task was to try all these molds with their saved input values and see if the plastic product was good. If not, the input values had to be changed until we got a product of good quality.

Changing the molds to the injection machine went fluently.

Most of the plastic parts use different plastics, so for every test run of a mold the plastic raw material had to be changed. Therefore the temperature of the screw and nozzle was changed, too. The hopper was cleaned in between every test run with an air pressure pistol and ABS plastic was fed trough the screw to get it clean and ready for the next test run.

Most of the plastic parts were affected by the bigger sprue size due to the higher flow of the molten plastic into the mold with the result that the plastic part did not come out as good as we wanted. Mostly because of this two input values, the changing point between injection pressure and holding pressure and the holding pressure, the input values were changed and saved on the floppy disk, so that the next time the mold was used, we just had to put the mold in the injection machine, load the input values of the floppy disk and start the production of that particular plastic part.

5 RESULTS

The result of the molds will be explained more precisely and the results of the test runs will be shown with the help of pictures of the old input values of the machine, compared to the new ones and explained.

5.1 Molds

In the tables beneath you can see that some of the molds will not be in use anymore. Some of them have to be moved to another injection molding machine because of a too big sprue, which would not work on the machine used in this project after the standardization of the nozzle size as explained in chapter 3.3.

Name	Mold nr.	Placement	Sprue ⌀
17. M-18 Napa	219	A5	3,7 mm
18. M-18 Asteikkorengas	221	A5	3,7 mm
23. Vector näppäin	255	B2	3,7 mm
32. MCB - Pillinrunko	293	E6	3,7 mm
53. D-10 Kiertokehä	354	E1	3,7 mm

Table 4 Molds that will change machine. (Mikael Hellman 2012)

Name	Mold nr.	Placement	Sprue ⌀
6. M-9 Runko	144	D2	-
7. M-89 tausta	147	D5	-
10. SK Valovärinastat	180	D6	2,5 mm
12. M-5 kiin. Rengas (type B)	199	D2	-
19. M-18 Clipper runko	230	A5	-
20. Arrow napa+mang.pidin.	231	D6	2,5 mm
21. Arrow-1 kiin. Rengas	233	B4	2,5 mm
38. X6 Salpa	313	A3	2,5 mm
39. X6 Kehys B	313	A3	2,5 mm
44. T-6 Kehys A	324	A3	2,5 mm

Table 5 Molds that are not in use anymore. (Mikael Hellman 2012)

5.2 Results of the test runs

The goal of the test runs was to find out if it is possible to make the plastic part with a bigger sprue, and, if not, change the input values to make it work. The goal was not to shorten the cycle time. All molds have ready input values for the injection machine saved on a floppy disc and because of this the changes can be very small.

The test runs of the molds with the new sprues worked out well. Beneath I will show what kind of changes was made for each mold and how the molds worked after the change of sprue size.

In the results you will also notice that even if you would think that the size of the sprue would effect on the input values of the machine or on the quality of the plastic part that is made, it is not always like that, as you can see in the results some of the plastic parts came out good without any changes in the input values. Why it did not effect on some molds is because of that, that the new sprue size didn't vary so much of the original and the plastic parts made with these molds are very small so that the effects of the injection of melt plastic is also small.

Mold nr. 329, part name "D-9 välipohja"

Plastic raw material used: M219, Sebs nat DF67820

The plastic part that was made by this mold had some shrinkage. Therefore changes were made in the input values:

Holding pressure (jälkipaine), changed to smaller

Holding pressure time (jälkipaine aika), changed to shorter

Injection speed (ruiskutus nopeus), made faster.

Changing point between the injection pressure and the holding pressure (Jp), was set to be a little bit bigger.

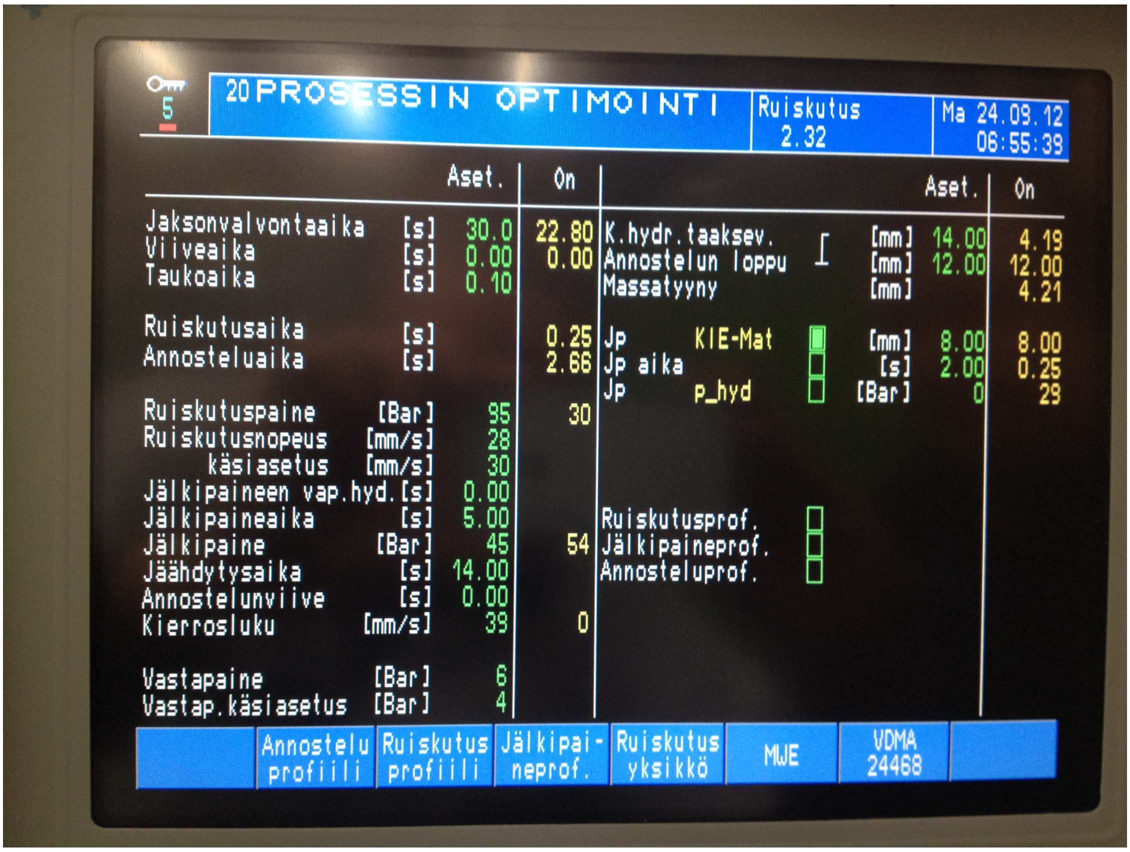

Figure 13 Picture of the input values be for changes. Mold nr. 329 . (Photograph Mikael Hellman, Suunto 2012)

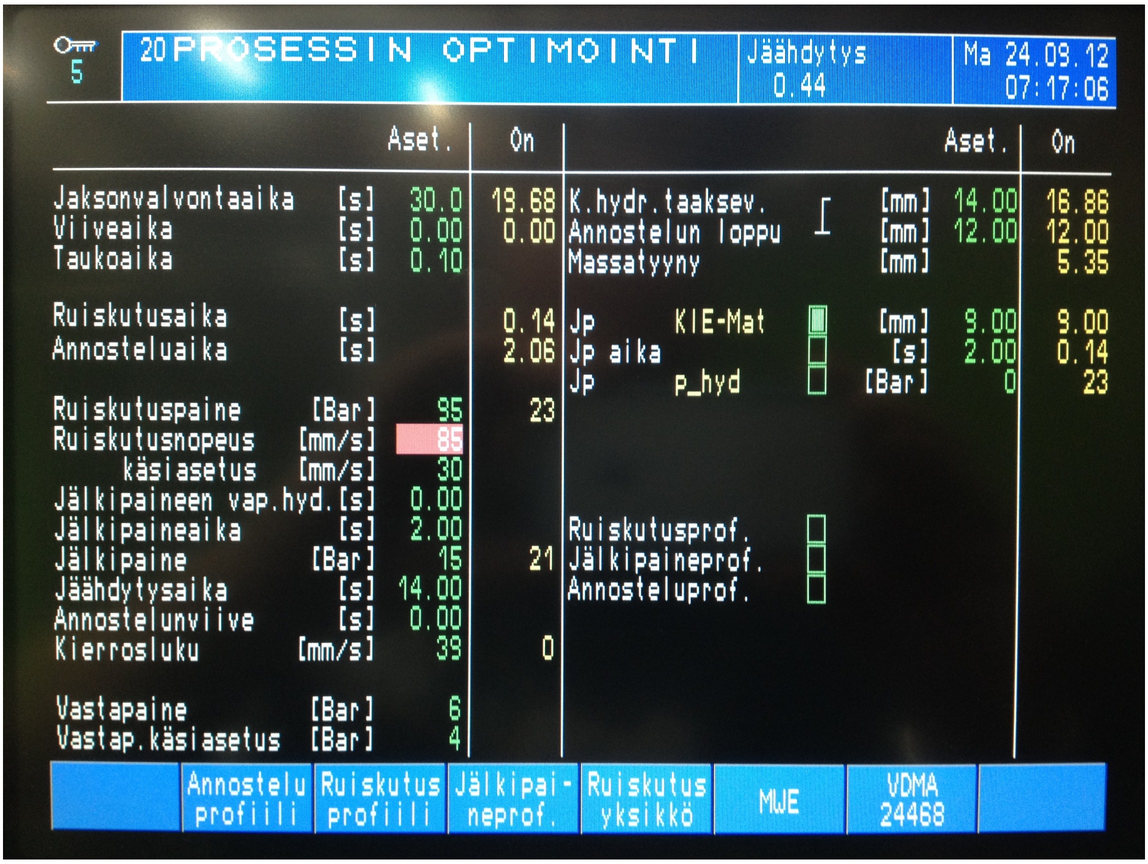

Figure 14 Picture of the input values after the changes has been made, Mold nr. 329. (Photograph Mikael Hellman, Suunto 2012)

Figure 15 In the picture, you can se some shrinkage in the plastic piece on the left side that needed to be prevented by changing the input values. (Photograph Mikael Hellman, Suunto 2012)

Mold nr. 371, part name "Vyper 2 anturisuoja"

Plastic raw material used: M-241, Grilamid LV-3H Black

The plastic part that was made by this mold had some shrinkage. Therefore changes were made in the input values through -

End of dosage (annostelun loppu), was made shorter so that the cushion would be smaller.

Holding pressure (jälkipaine), a little bit more pressure

Holding pressure time (jälkipaine aika), a little bit longer

The final result was found to be good by visual inspection and compared to an example piece.

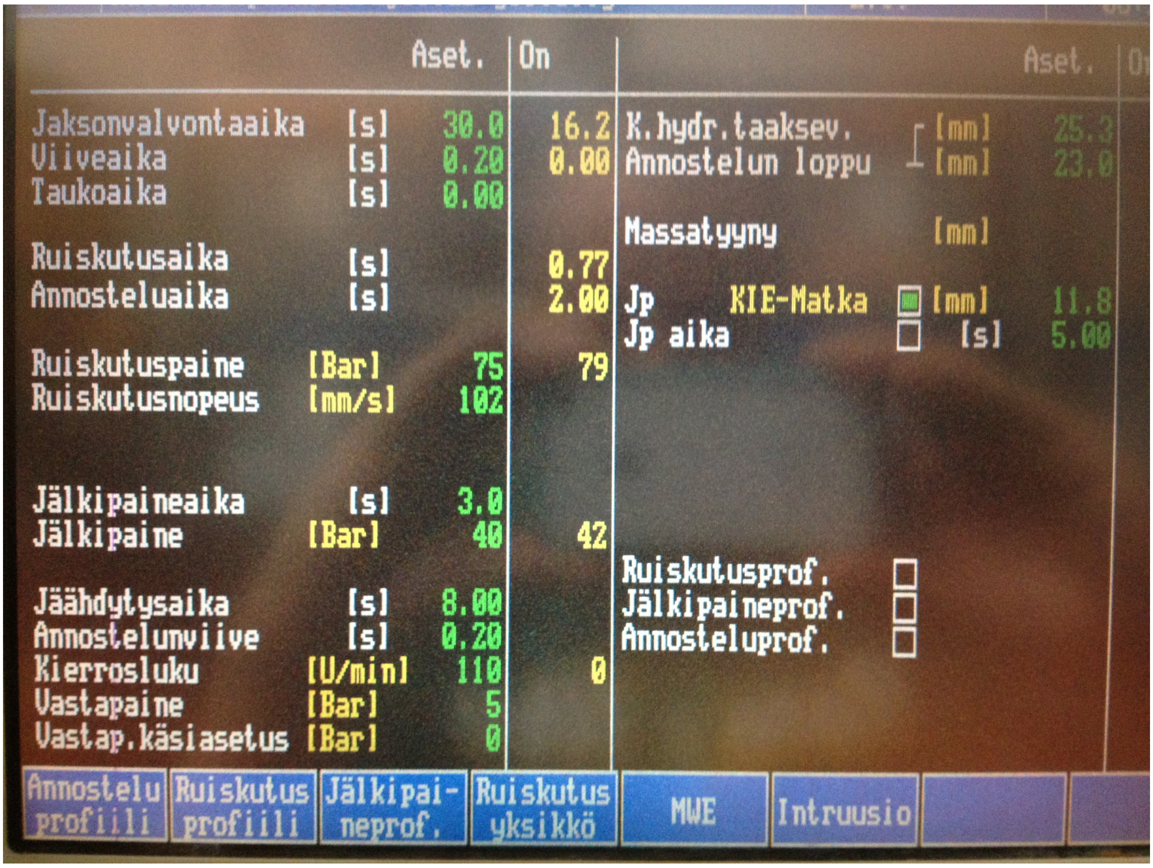

Figure 16 Picture of the input values be for changes. Mold nr. 371. (Photograph Mikael Hellman, Suunto 2012)

Figure 17 Picture of the input values after the changes has been made, Mold nr. 371. (Photograph Mikael Hellman, Suunto 2012)

Figure 18 In the picture below you can see some shrinkage in the plastic piece to the right that needed to be prevented. (Photograph Mikael Hellman, Suunto 2012)

Mold nr. 314, part name "X6 kehys C"

Plastic raw material used: M-241, Grilamid LV-3H Black

The mold is a two cavity mold, but only one cavity, that is, the "Kehys A" cavity, turned out to work. This was found out by the fact that the change of the input values did not give the visual result expected. The water cooling system seemed to be bad because of a low input temperature, but still the mold was very hot. The hose had to be extended in order to improve the water flow.

The mold temperature was changed by setting it down from 70°C to 40°C. Some changes were made in the input values, too, by:

Changing point between the injection pressure and the holding pressure (Jp), was set to be a little bit longer.

Holding pressure (jälkipaine), was changed by making the pressure higher.

Injection speed (ruiskutusnopeus), lowering the speed

Figure 19 Picture of the input values be for changes. Mold nr. 314. (Photograph Mikael Hellman, Suunto 2012)

Figure 20 Picture of the input values after the changes has been made, Mold nr. 314. (Photograph Mikael Hellman, Suunto 2012)

Figure 21 In the picture beneath you can see that the plastic piece was not complete, but needed to be fixed. (Photograph Mikael Hellman, Suunto 2012)

Mold nr. 210, part name "MC-1 klinometri osoitin"

Plastic raw material used: M160, Hostaform C9021 GV 3/20 Glass

This mold worked out fine after a small change in the size of the cushion. It was set to be smaller.

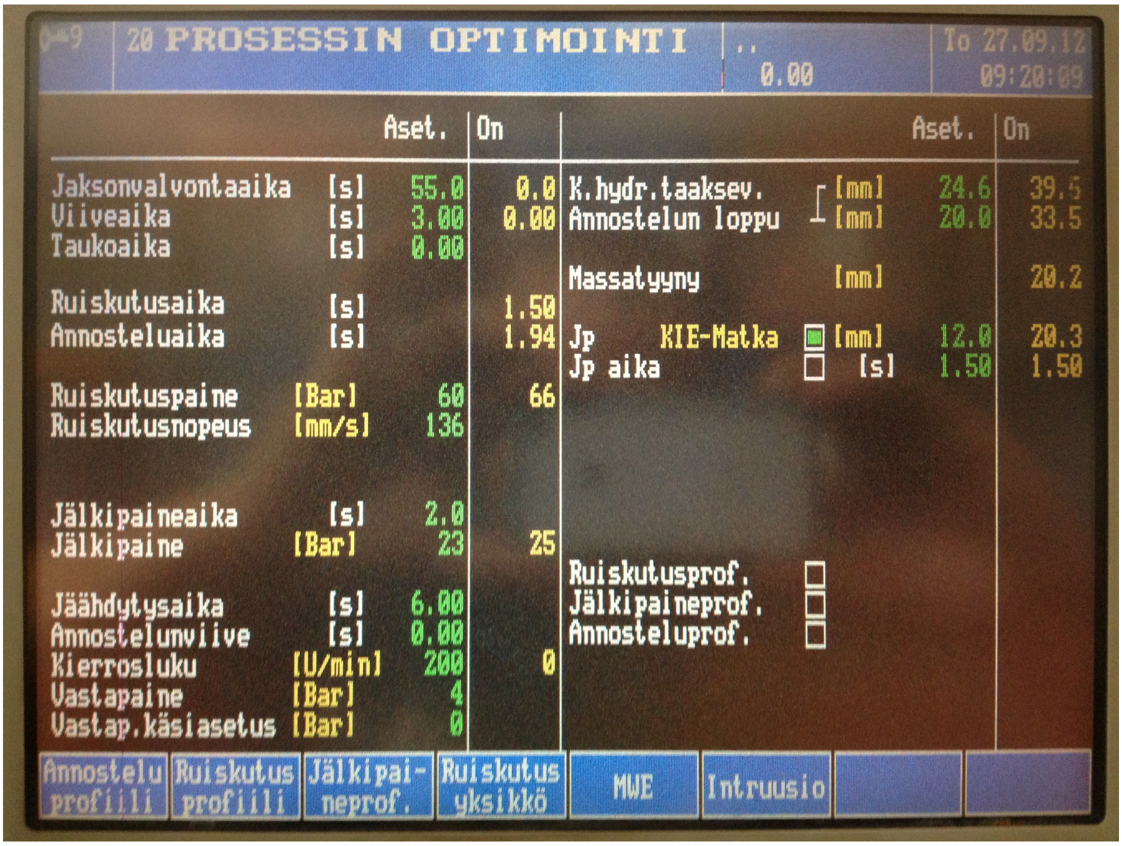

Figure 22 Picture of the input values be for changes. Mold nr. 210. (Photograph Mikael Hellman, Suunto 2012)

Figure 23 Picture of the input values after the changes has been made, Mold nr. 210. (Photograph Mikael Hellman, Suunto 2012)

Mold nr. 289, part name "Cobra anturin suoja"

Plastic raw material used: M016 ABS Black Novodur P2H-AT

The plastic part made by this mold was not complete so changes had to be done in:

Holding pressure time (jälkipaine aika), by making it longer

Holding pressure (jälkipaine), by putting more pressure

Cushion (massatyyny), by making it smaller

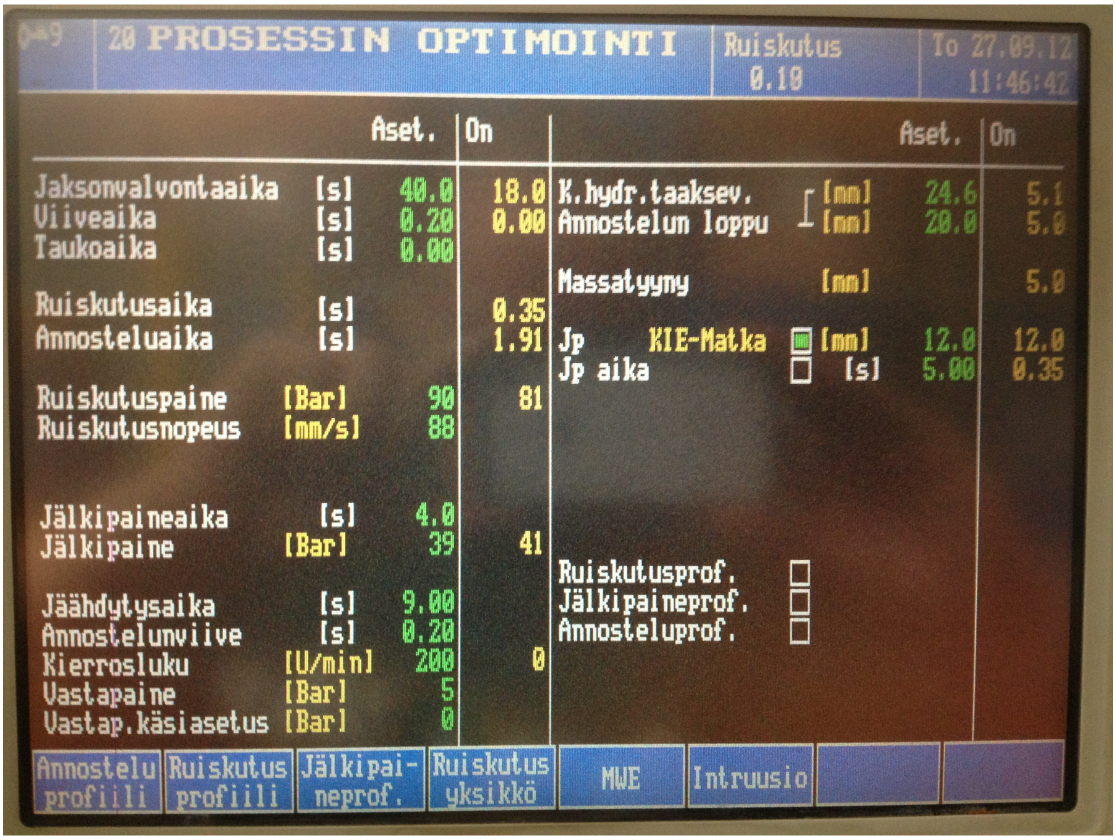

Figure 24 Picture of the input values before changes. Mold nr. 289. (Photograph Mikael Hellman, Suunto 2012)

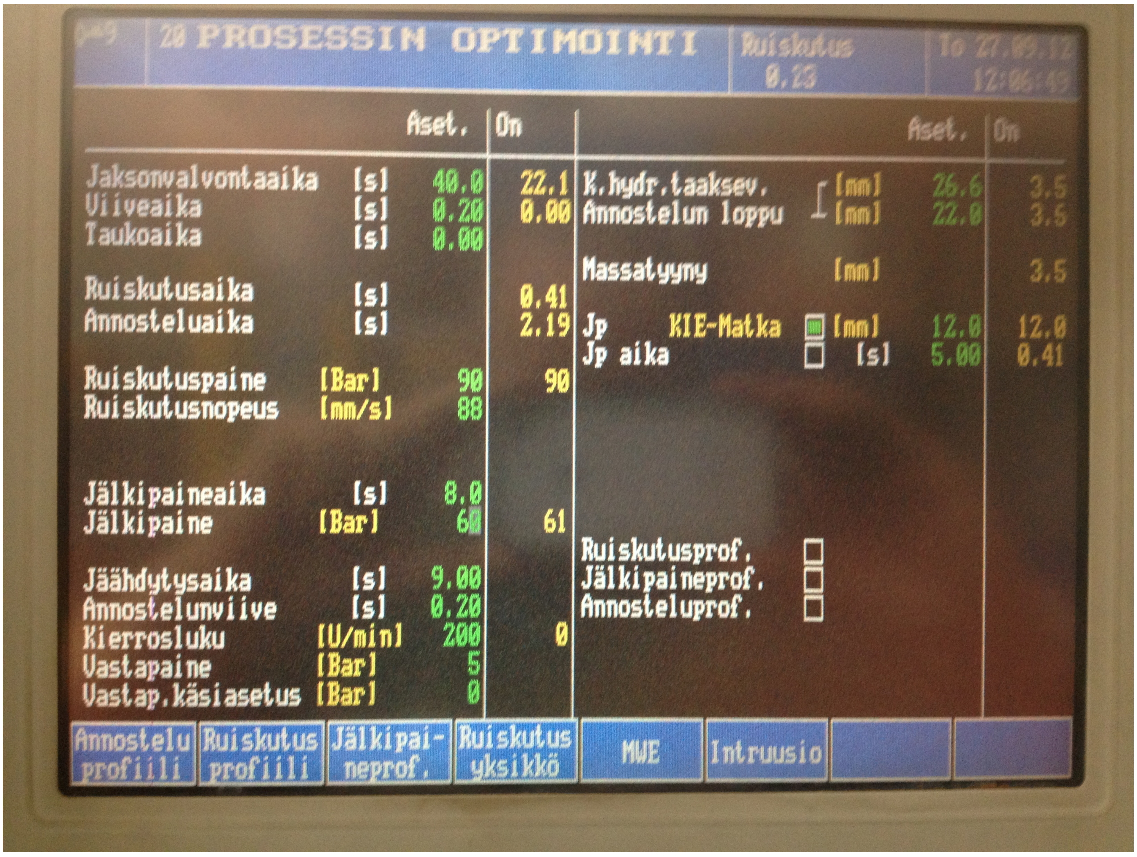

Figure 25 Picture of the input values after the changes has been made, Mold nr. 289. (Photograph Mikael Hellman, Suunto 2012)

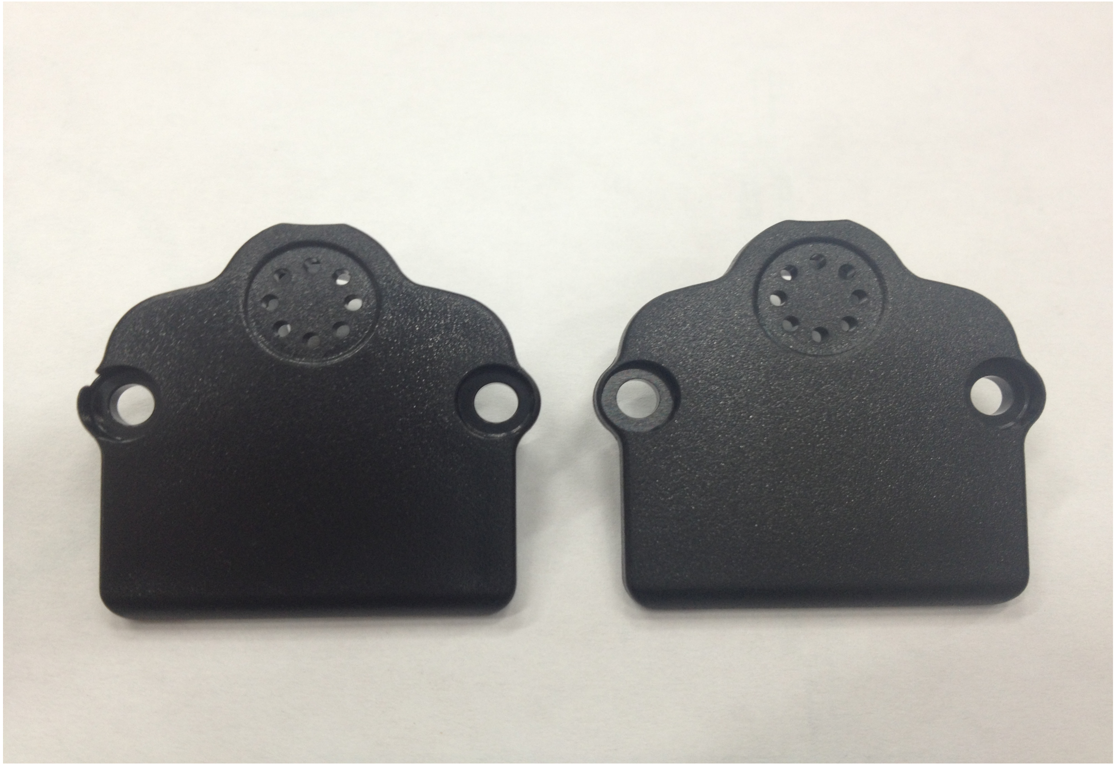

Figure 26 In the picture you can see that the plastic piece to the left is not complete but needed to be fixed. (Photograph Mikael Hellman, Suunto 2012)

Mold nr. 397, part name “Vesikontaktori”

Plastic raw material: M-179 Grivory GV-5H Black, needs to be pre-dried in an oven in 80°C for approximately 4h.

In this mold we found out that the nozzle temperature was too high and needed to be changed to smaller due to some leakage in the nozzle. Otherwise it worked fine without any changes in the input values.

Original nozzle temperature was 345°C. It was changed to 310°C.

Mold nr. 351, part name "Clino osoitin DS-50"

Plastic raw material used: 12603 Grilamid LV-5H Black, needs to be pre-dried in a oven in 80°C for approximately 4h.

Worked out perfectly, without any changes.

Mold nr. 323, part name "D9 Kehys A"

Plastic raw material used: 12603 Grilamid LV-5H Black, needs to be pre-dried in a oven in 80°C for approximately 4h.

This mold needed a more changes in the input values than the others, as the plastic part was totally incomplete. Changes were made in:

Injection pressure (ruiskupaine),

Injection speed (ruiskunopeus),

Changing point between the injection pressure and the holding pressure (Jp),

Holding pressure (jälkipaine),

Holding pressure time (jälkipaineen aika),

None of this changes in the input values had any significant visual effect on the plastic part, so we made the conclusion that the barrel and nozzle temperatures needed to be higher. All temperatures were lifted by 10-15°C and the nozzle temperature were set to be 330°C (recommendation 265°C on www.matweb.com).

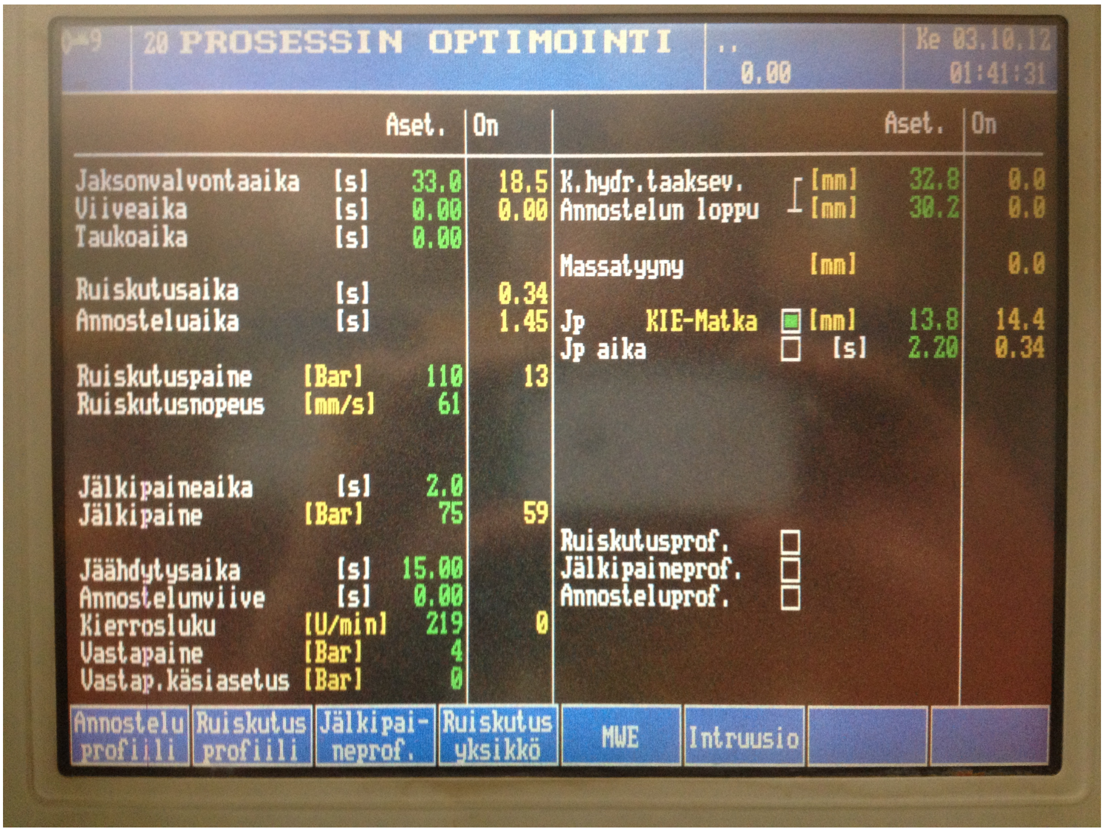

Figure 27 Picture of the input values be for changes. Mold nr. 323. (Photograph Mikael Hellman, Suunto 2012)

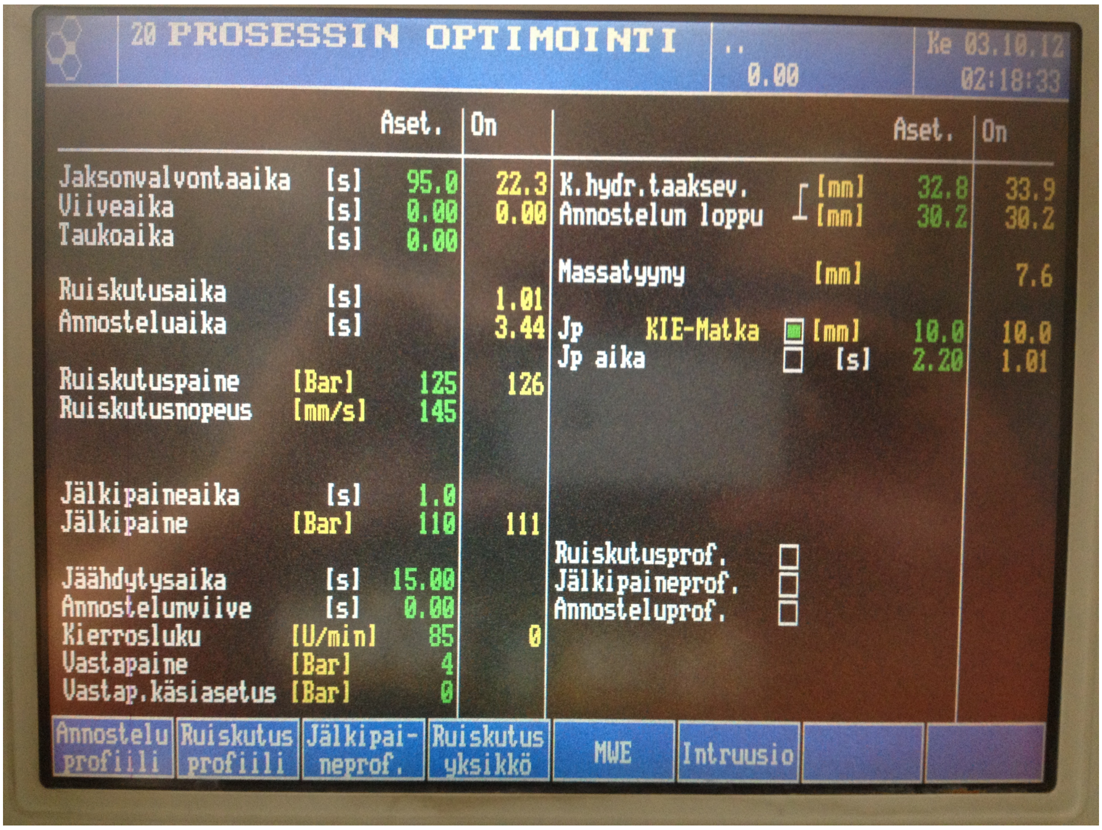

Figure 28 Picture of the input values after the changes has been made, Mold nr. 323. *(Photograph Mikael Hellman, Suunto 2012)*

Figure 29 In this picture you can se that the part was not complete. (Photograph Mikael Hellman, Suunto 2012)

6 CONCLUSION

The outcome of this project was excellent. All the molds worked without any bigger problems or just with some small changes in the input values. As the aim of this project was to find out if time can be saved by standardization of the sprue and the nozzle sizes, the conclusion is that from now on time will be saved at this specific machine as the injection machines nozzle does not need to be changed anymore.

6.1 Calculation of savings in cost by work time

A new nozzle had the price of 150€/sprue and a working hour at *Suunto* has the price of 30€/h. Before the project the calculated time for mold changing was 30min for one mechanic and as the idea of the project was to make it faster, the time after the project was calculated to be 15min to change the mold. Therefore the conclusion can be made for one mold with a new sprue:

When the mold has been changed for 20 times, there have been savings in work cost for a value of 150€, which means that the new sprue has been paid off. After that Suunto will save 7,5€ on each time the mold is changed on the injection machine that was used in this project.

1h of work = 30€

15min of work = 7,5€

20 mold changes will save each time 15min of work cost (7,5€), which equals 150€.

20 x 7,5€ = 150€

7 DISCUSSION

I found the project to be perfect for a thesis, and I learned a lot about injection molding and the functions around the process and not only in theory but also in practice.

To my mind it would be worth to do the same procedure to other injection machines at *Suunto*. It would be worth going trough the molds, see how they are divided to the other machines and find out which ones are not in use anymore. By making similar sprue and nozzle changes in the other injection machines it would speed up the mold changing.

I also think that this could be something that a lot of different companies could think off doing as a project, because over the years of getting new molds and machines, things can start to go too complicated or disorganized and you easily forget about the easy and small ways to keep the manufacturing process as fast as possible. I also understand why projects like this isn't always first on the "things to do" list in companies, because often they don't have the time, interests, man power or money to maintain or develop the manufacturing process that is already running "good enough". Or as *Suunto* have their own manufacturing department, which means that they produced quality over quantity. They produced plastic parts by demand of the other factory departments whit considerable small production volumes, they did not have needs to save in costs of work as an outsourced company would need to do where time is money.

7.1 The end

I am grateful to *Suunto* for the opportunity to do this project and write the thesis. I am especially grateful to Anssi Hämäläinen who has worked for *Suunto* as a mechanic for the plastics manufacturing department for many years and he was of great help to me during the project.

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