CAUSES OF MOLDINGS DEFECTS FROM INJECTION FORMS AND THEIR ELIMINATION

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Abstract

In every manufacturing company the maintenance of machinery and equipment is one of the most important components of the manufacturing process. Acquisition of machinery and equipment is a major investment for a company and the company expects it would return in the form of incomes. It is necessary to ensure both the functionality and the smooth and trouble-free operation of the acquired machine. Any defects that may occur in the plant bring about many complications, time delay and related costs. The stability of the production system thus depends on maintenance. The article deals with injection molding, analyzing the costs of maintenance and analysis of the causes of injection molds scrap.

Keywords: Injection molding process, maintenance, defects, costs

1. INTRODUCTION

At present, plastic materials play an important part in the innovation of the products and equipment. The products previously manufactured of wood, metal or other materials are now made from plastic. The reasons for this development for example include the production of complex shapes, low weight, corrosion resistance and the desired appearance. And thanks to their properties plastics have their place in almost every industry sector.

Nowadays a considerable amount of processing technologies exists in the market and the most widespread methods of processing plastics include injection. It is a complex thermo-mechanical process that is performed on the injection molding machine.

2. PLASTIC INJECTION

2.1. Basic principle of injection molding

Injection molding is used to produce such products, which either have the nature of a final product and/or are the semi-finished products or parts for further completion of a separate unit. Injection molded products have very good shape and dimensional accuracy and high reproducibility of mechanical and physical properties. The injection molding technology is the most widely used technology for plastics processing; it is the discontinuous and cyclical process. Injection molding can be used for processing almost all types of thermoplastics. To a limited extent also some thermosets and rubbers are injected. [1]

Injection molding is a method of forming plastic, wherein the dose of the processed material is injected from an auxiliary pressure chamber at high speed into a closed metal mild cavity, where it solidifies into the final product. The pressure chamber is a part of the injection molding machine and the supply of injected material in it continues to be replenished throughout the cycle. Benefits of the injection include the short cycle time, the ability to produce complex parts with good dimensional tolerances and a very good finish, but also structural flexibility, which allows for the elimination of surface finishing and assembly operations. The main drawbacks in comparison with other methods of processing of plastics include high investment costs, long time required

for the production of molds and the need to use equipment, which is disproportionately big in comparison with the produced work piece. [1]

The injection procedure is as follows: a plastic in the form of granules is put into the hopper, from which it is taken by the working part of the injection molding machine (screw, piston), which transports the mass into the melting chamber, wherein the processes of friction and heating melt the plastic and the melt formed. The melt is then injected into the mild cavity and fills it completely. Consequently it assumes its shape. The pressure stage follows to reduce shrinkage and dimensional changes. The plastic transfers its heat to the mild and through the process of cooling in solidifies into he the final product. Then the mild is opened and the product is ejected; the whole cycle is repeated again and again. [1], [2]

The injection cycle, see **Fig. 1**, consists of a sequence of precisely specified tasks. It is a non-isothermal process, during which the plastic passes through the temperature cycle. At the description of the injection cycle is necessary to clearly define its beginning. The moment corresponding to a pulse for closing the mild can be considered the beginning of the cycle time. [1]

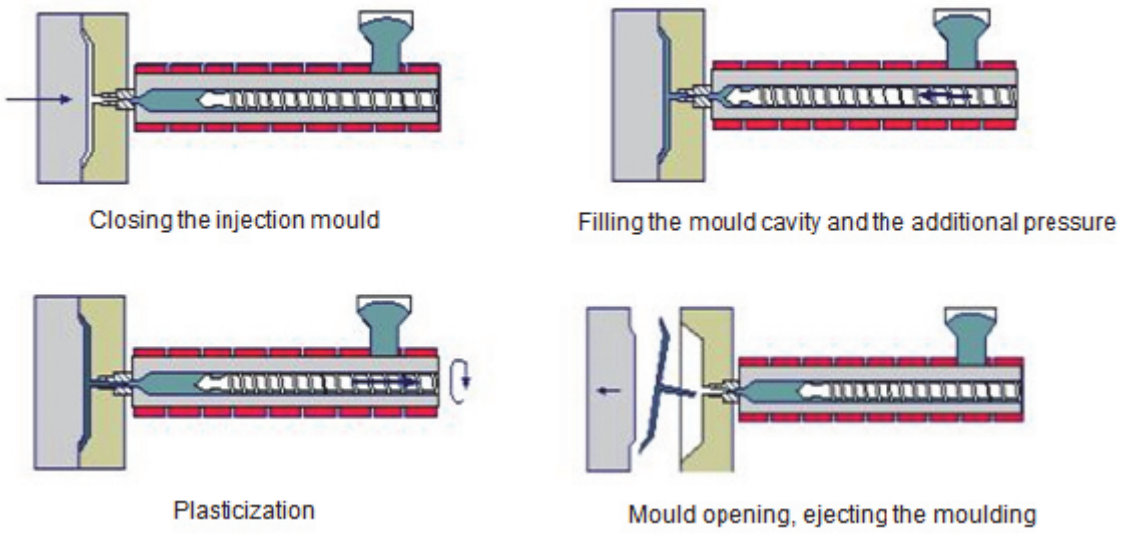

Fig. 1 Inject molding cycle [1]

2.2. Injection molding machine

The fully functional injection molding machine, see **Fig. 2**, with regularly performed maintenance, including cleaning the oil filling, is obviously a prerequisite for optimizing the injection molding process.

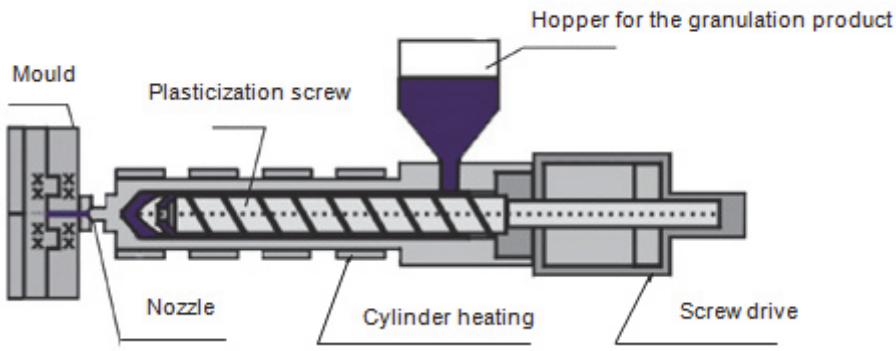

Fig. 2 Inject molding machine [2]

In terms of results, i.e. the production of moldings with defined quality, the design of the used injection molding machine is not important. What matters, is the reproducibility of set manufacturing parameters, which is especially checked in automotive parts. For further work with the injection mild it is necessary - in addition to the reproducibility of parameters - to ensure proper selection of the machine with respect to the closing force and the capacity of the plastification unit. Last but not least, it is necessary to pay the utmost attention to the reverse closure on the plastification and the injection screw. [3]

2.3. Injection mild

An injection mild is a tool that is clamped to the injection molding machine. During the injection cycle it is filled with molten plastic. After cooling, the molding is made with the required shape and functional properties. The mild during its service life must resist high pressures, ensure the desired dimensions and quality of the molding, easy removal of the molding, easy operation and automatic operation, easy and quick production and high utilization of the processed plastic. [4]

At the production of molds high quality steel tools are used, which are mostly thermally processed. A suitably chosen design of the mound may significantly affect the whole economy of the production. Currently there are lots of specialized companies in the market supplying standard parts of the injection mild to the market; these parts are consequently adjusted for the needs of a customer. These are mainly finishing operations done by machining (turning, milling, drilling, grinding, EDM machining, lapping etc.). Materials used for the production of the injection molds are selected according to the kind of the processed plastic, production technology, product shape (complexity, size), heat resistance, resistance against wear and tear, etc. [1], [4], [5]

2.4. Adjustment and optimization of injection molding process

The main output in the production of thermoplastic molding is a part fulfilling all required qualitative and quantitative criteria. This condition can only be achieved with a stable production process. In case of thermoplastic injection the debugging means putting the injection mild into operation, which will produce moldings identical with customer requirements and the adjustment of the injection mild on the injection molding machine with the subsequent optimization of the injection molding process used to find the most favorable, respectively "perfect" conditions for the production of moldings with defined quality. After the optimization process only monitoring of the process parameters should theoretically occur during the production. Thermoplastic injection, however, is a very complex process influenced by many parameters (mild, injection molding machine operator - setting production parameters, injection material and other process conditions). [3]

When commissioning a new injection mild defects may occur that cannot be removed by the variations of technological parameters. Usually these are design flaws or defects in the design and manufacturing defects of molds. Thus, the technicians responsible for the mound adjustment should know at least the basic description of the major design errors to be able to competently decide whether it is possible to correct the defect through changes and variations in production parameters or through repair and correction of the mild, possibly molding or the material from which the relevant part is to be manufactured. Individual parts of the molds have various functions, and therefore have specific requirements for the choice of material, from which they will be produced. Their selection and recommended series should correspond to the required function of the part with regard to wear and durability. [3], [6]

3. INJECTION MOLDS MAINTENANCE EXPENSES

The following data on the maintenance expenses of selected injection molds have been provided by the manufacturing company, which divides the expenses to the scheduled and unscheduled maintenance. The company uses its own maintenance staff and also services of external companies to carry out repairs. For the

maintenance expenses of the three selected injection molds, for 2013, see **Table 1** and for 2014, see the **Table 2**.

Table 1 Maintenance expenses of the selected injection moulds

Year 2013	Injection mild 1	Injection mild 2	Injection mild 3
SCHEDULED MAINTENANCE	42,761.-	11,196.-	28,719.-
- Wages and overhead costs of the maintenance staff	42,671.-	11,196.-	28,719.-
- Materials and services from external companies	-	-	-
UNSCHEDULED MAINTENANCE	435,634.-	28,653.-	9,249.-
- Wages and overhead costs of the maintenance staff	62,629.-	1,135.-	9,249.-
- Materials and services from external companies	373,005.-	27,518.-	-
TOTAL MAINTENANCE EXPENSES	478,395.-	39,849.-	37,968.-

In 2013, the company reported the total maintenance expenses for the maintenance of injection molds (300 pieces) in the amount of CZK 29,021,915.

Table 2 Maintenance expenses of the selected injection molds

Year 2014	Injection mild 1	Injection mild 2	Injection mild 3
SCHEDULED MAINTENANCE	116,308.-	1,292.-	18,890.-
- Wages and overhead costs of the maintenance staff	-	1,292.-	18,890.-
- Materials and services from external companies	116,308.-	-	-
UNSCHEDULED MAINTENANCE	410,691.-	2,745.-	11,464.-
- Wages and overhead costs of the maintenance staff	31,646.-	2,745.-	11,464.-
- Materials and services from external companies	379,045.-	-	-
TOTAL MAINTENANCE EXPENSES	526,999.-	4,037.-	30,354.-

In 2014, the expenses of maintenance of all injection molds (294 pcs) amounted to CZK 32,273,357, which is an increase by 11.2 % on the year-to-year basis. These increased expenses were due to the faulty condition of injection molds. The highest costs of the maintenance of injection moulds seem to account for the unscheduled maintenance. These costs cannot be accurately determined, depending on the size and severity of a disorder. However, the good preventive maintenance can prevent these disorders. The period of the preventive maintenance of injection molds is determined by the number of strokes when it comes to opening and closing of the mild. The injection mild 1 has the prevention after 15,000 strokes, whereas injection molds 2 and 3 after 30,000 strokes. The information on the number of strokes is recorded by the machine operator and entered in the book for each injection mild. Some information may be inaccurate and the result is either too early or too late execution of the preventive maintenance. The correct determination of the number of strokes affects the setting of the period of preventive maintenance and thus also the costs of preventive maintenance. It follows that it would be appropriate to introduce the RFID system (Radio Frequency Identification) in the production company, which records, stores and first of all provides real-time data.

4. SCRAP MOLDINGS FROM INJECTION MOLDS

Own production of moldings is done by the injection technology on modern injection molding machines. The production of technical moldings is covered by the entire injection cycle (see Sec. 2.1). Scrap moldings may be caused by the injection mild, injection molding machine, machine operator, injected material or adjustment of the process parameters, see chap. 2.4.

The following sections will analyze the causes of defects in moldings with selected injection molds. In the period from January to March 2014 defects of moldings on the injection molding machine were monitored and analyzed. The injection mild is not in the analyzed period installed permanently on the injection molding machine but is replaced with other molds according to customer needs. The production company has introduced three shift-working hours, thus ensuring the maximum utilization of the capacity of injection molding machines. Following injection molds were installed on the injection machine in the abovementioned period. On the injection mild 1 51,213 pieces of moldings were produced in 713 hours, including 4,600 defective pieces. On the injection mild 2 25,696 pieces of moldings were produced in 255 hours, including 2,430 defective pieces. On the injection mild 3 2,537 pieces of moldings were produced in 53 hours, including 236 defective pieces. For types of defects and the number of defective units, including the rationale, see the **Table 3**.

Table 3 Number of defective moldings of the injection molds 1, 2 and 3

Type of defect	Number of pieces VF 1	Number of pieces VF 2	Number of pieces VF 3	Cause of the defect
Silvering	695	48	44	mild maintenance
Fatty	133	-	-	mild maintenance
Machine start-up	2 037	446	106	machine start-up
Weak injection	13	165	12	setting production parameters
Shrinkage spots	72	-	-	setting production parameters
Inclusions	904	-	4	mild maintenance
Impurities	310	235	7	mild maintenance
Scratched	98	7	6	machine operator
Visual sample	50	2	-	mild maintenance
Additional matching	233	-	33	machine operator
Faulty cutting	13	-	24	machine operator
Fallen pieces	42	-	-	machine operator
Burned	-	29	-	setting production parameters
Scrambled mass	-	1 498	-	machine operator
TOTAL	**4 600**	**2 430**	**236**	

Total scrap with the injection mild 1 approximately accounts for 9 % of the total production throughout the monitored period. Out of this, 4 % scrap accounts for the machines start-up, 4 % has been caused by the maintenance of injection molds, 0.17 % by wrong setting production parameters and 0.75 % by the machine operator. Total scrap with the injection mild 2 approximately accounts for 9.45 % of the total production throughout the monitored period. Out of this, 1.73 % scrap accounts for the machines start-up, 1.1 % has been caused by the maintenance of injection molds, 0.75 % by wrong setting production parameters and 5.86 % by the machine operator. Total scrap with the injection mild 3 approximately accounts for 9.3 % of the total production throughout the monitored period. Out of this, 4 % scrap accounts for the machines start-up, 2.17 % has been caused by the maintenance of injection molds, 0.47 % by wrong setting production parameters and

2.48 % by the machine operator. The highest number of defects is caused by the machine start-up, mainly due to the replacement of the injection mild, since the process conditions change (mild temperature, injection speed, injection pressure, etc.). The number of defective units is also dependent on the skills of the adjuster. Other defects are caused by the maintenance of injection moulds (formation of inclusions, impurities, silvering, fatty pieces, etc.), setting the parameters of production and poor machine operation (poor handling, product scratching, fallen parts). The important fact is that the production company has approximately 68 % permanent employees while the remaining 32 % are agency employees, who generate higher share of scrap parts. Defects that are caused by the machine operator can be eliminated through better and more professional training of employees.

5. CONCLUSION

The success in the area of production of plastic parts is increasingly more dependent on a manufacturing company that can quickly and economically adapt itself to customer requirements for the production of plastic parts with precisely defined properties. The increasing pressure from customers on the quality of the plastic parts, requires from the manufacturing companies that their employees still further enhance complex knowledge of their own and interrelated processes of production of plastic parts in order to minimize from their position the occurrence of manufacturing defects. The price of a plastic part is of more than 50% accounted for by the acquisition costs of the mild and the costs of mild storage, maintenance, repair and overhaul. From this point of view it is true, that not always the lower acquisition price of the mild is directly proportional to the lower cost of plastic part. Although many manufacturers are already getting completed moulds, their employees with knowledge of the principles of mild design, properties of mild materials, proper maintenance and care, with the knowledge of current trends of mild maintenance may significantly reduce maintenance costs, extend the life cycle and reduce the incidence of molding manufacturing defects associated with the design of injection molds.

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