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AN AUTOMATED MOLD DESIGN SYSTEM FOR TRANSFER MOLDING PROCESS

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ABSTRACT

This research presents a novel method for the development of an automated mold design system for transfer molding process in semiconductor packaging industry. In this method, highly robust parametric templates for mold shot for different types of packages are created and stored in the library. Mold design terms and all related design rules are standardized and streamlined in an excel file for each template. The mold shot is used to cut out mold parts during next design stage. Leadframe configurations, customer input as well as technical specifications and the design input are standardized to create the robust mold shot. Some critical features of mold parts like clamping area, location position, and gate dimensions are decided on mold shot. The mold shot is used as a positive cut-out for the top and bottom cavities as well as cull and sleeve strips. After completion of cut-out process based on mold shot, air venting for packages and runners, clamping areas, shutoff areas, side-rail areas, relief areas, locating pins holes and their relief, misalignment pins holes and their relief are created by automation. Finally ejection pins, support plugs and other parts are created using parametric parts library. The method is implemented in Solid Edge platform using VB.NET programming language and Solid Edge API.

Keywords: Transfer molding, Packaging mold, Moldshot.

1. INTRODUCTION

In today's global economy and changing manufacturing environment the ability to introduce quality products in the shortest possible time is a decisive factor to capture market share. The increasing competitiveness in the manufacturing sector has led to the development of different computer-aided design and manufacturing systems and automation of various planning functions in manufacturing. Mold making is no different. The mold design process is generally the critical path of a new product development. Conventionally, mold design has always been a much "mystified" art; requiring years of experience before one can be relatively proficient on it. Due to the initial difficulty in learning this art, less and less people are benefiting from experience and knowledge of the experts in this field. To change current situation, one way is to use computer-aided design system. However, at the present time, most CAD systems provide only the geometric modeling functions that facilitate the drafting operations of mold design, and do not provide mold designers with the necessary knowledge (design rules) to design the molds.

In semiconductor packaging, transfer molding is used to encapsulate package to protect fragile IC assemblies with their fine interconnection wires and to maintain high electrical insulation between conductor, interconnections, components and other electrical parts. Due to the high accuracy of transfer molding tooling and low cycle time of the process, transfer molding is used in semiconductor package encapsulation [1]. Transfer molding is a process where the amount of molding material (usually epoxy resin) is measured and inserted before the molding takes place. The molding material is preheated and loaded into a chamber known as the pot. A plunger is then used to force the material from the pot through channels known as a sprue and runner system into the mold cavities. The mold remains closed as the material is inserted and is opened to release the part from the sprue and runner. The mold walls are heated to a temperature above the melting point of the mold material; this allows a faster flow of material through the cavities. Fig. 1 shows the layout of a semiconductor packaging mold. Like plastic injection mold, it consists of different plates, components, different types of pins, springs etc. The main components are cavity strip, sleeve strip, unit block, end bar, ejector plate, mount plate, ejector holder and number pins and springs. The mold is divided into two parts: the top mold and the bottom mold.

Like plastic injection mold design, semiconductor packaging mold design involves extensive heuristic knowledge about the structure and functions of the components of the mold. Generally, thermal expansions and shrinkage need to be considered so that molding will be the correct size and shape at the processing temperature. Gates, sub-gates, runners and vents to be added and the process of clamping and ejection also need to be designed carefully. For the last decade, a significant amount of research has been carried out to automate injection mold design process (2-8). However, no significant effort has been carried out in transfer molding area. For this reason, this research has been carried out and it presents a novel method for the development of a computer-aided mold design system for transfer molding process in semiconductor packaging industry.

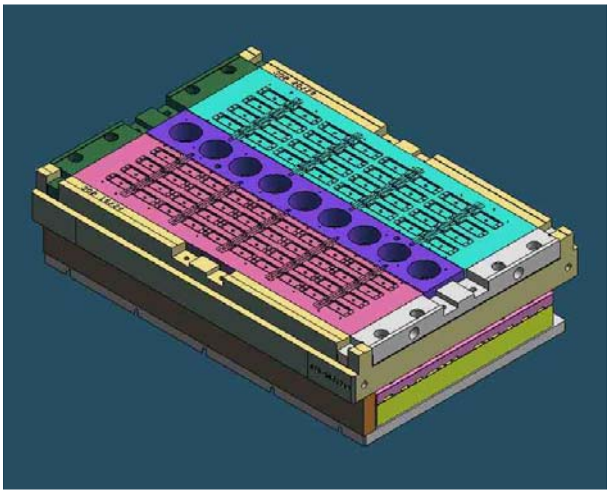


Fig 1: Layout of a semiconductor packaging mold (bottom mold)

2. PROPOSED DESIGN METHODOLOGY

In this method, highly robust parametric templates for mold shot for different types of packages such as SOIC, reel to reel, PGS, osprey etc. are created and stored in the library. Mold design terms and all related design rules are standardized and streamlined in an excel file for each template. The mold shot is used to cut out mold parts during next design stage. The proposed methodology is described in Fig 2. This mold shot also can help to calculate compound usage such as to show customer the design layout, to provide necessary information for CAE analysis.

The inputs for the proposed approach are generally derived from two sources. These are leadframe drawing and package definition. Usually leadframe drawing is provided by the customer and it describes leadframe length, leadframe width, first package position, pitches for package and runners, gate windows, number of colum, number of row, coefficient of thermal expansion etc. On the other hand, packages definitions such as packages' sizes (top/bottom package length, top/bottom package width, top/bottom package thickness), drafts, radius, etc. are used. However, secondary derivations of data are also needed to create the moldshot. They are: culls quantity per moldshot and their pitches; cull and runners integration (i.e. one cull to two, three or four runners), gates types, progressive grouping, The complexities of them are further made difficult by: (a) whether the packages are layout in symmetry w.r.t. the center of leadframe (b) whether the gates are perpendicular to the runner (and offset w.r.t package center), or entering at an angle in the package, top or bottom entries (or both) and entering parallel to the runner (with cascaded gates) (c) whether the pellet size is fixed (a constraint). Some other factors such as die up or down molding, leadframe with dambar or non-dambar, tolerance, shrinkage factor, surface finish, type of package (single side package or double side package), package with flange etc. are also considered and standardized to create the robust mold shot. Fig. 3 shows moldshots for different types of packages.

Mold shot is used as a positive cut-out for the top and bottom cavities as well as cull and sleeve strips. After completion of cut-out process based on mold shot, air venting for packages and runners, clamping areas, shutoff areas, side-rail areas, relief areas, locating pins holes and their relief, misalignment pins holes and their relief are created by automation based on rules and heuristics. The process of creating ejection pins, support plugs, mold springs and return pins layouts are done automatically or minor user intervention. The precedence order of the locations, sizes, types and quantities of these should be as follow: (a) ejection pins (b) support plugs (c) mold springs (d) return pins. Automated generation of initial layout is done by the template then changes can then be override manually. Very strong geometric parametric reasoning and mathematical formulation is used to develop such template. Basically, the geometric controls over the ejection pins obey some rules such as:

(1) Circumferences of the ejection pins holes and support plugs holes should at least have 2 mm material space.

(2) The top and bottom pins holes if they are in alignment to each other should have difference in diameter sizes.

(3) The quantity and sizes of these are derived from excel file for checking and are used in features' parametric control.

(4) The ejection force is computed automatically using the information.

Finally, creation of the remainder of the top and bottom mold parts such as unit blocks, ejection holders, ejection plates and mount plates is automated using parametric templates. Parametric models for these plates are stored in the library and user can call parametric models and update the dimensions according to their need. The inter-relationship of holes and screw positions should be robust with changes made and needs to get automatically updated should they are inter-related such as the changes in M5 through support holes changes affecting the M5 through holes at the unit block.

3. IMPLEMENTATION

The implementation of the proposed method depends on several major factors. These are: i) standardization and streamlining mold design rules and heuristics ii) proper calculation of clamping and ejection force iii) standardization of checking parameters and iv) robustness of parametric models.

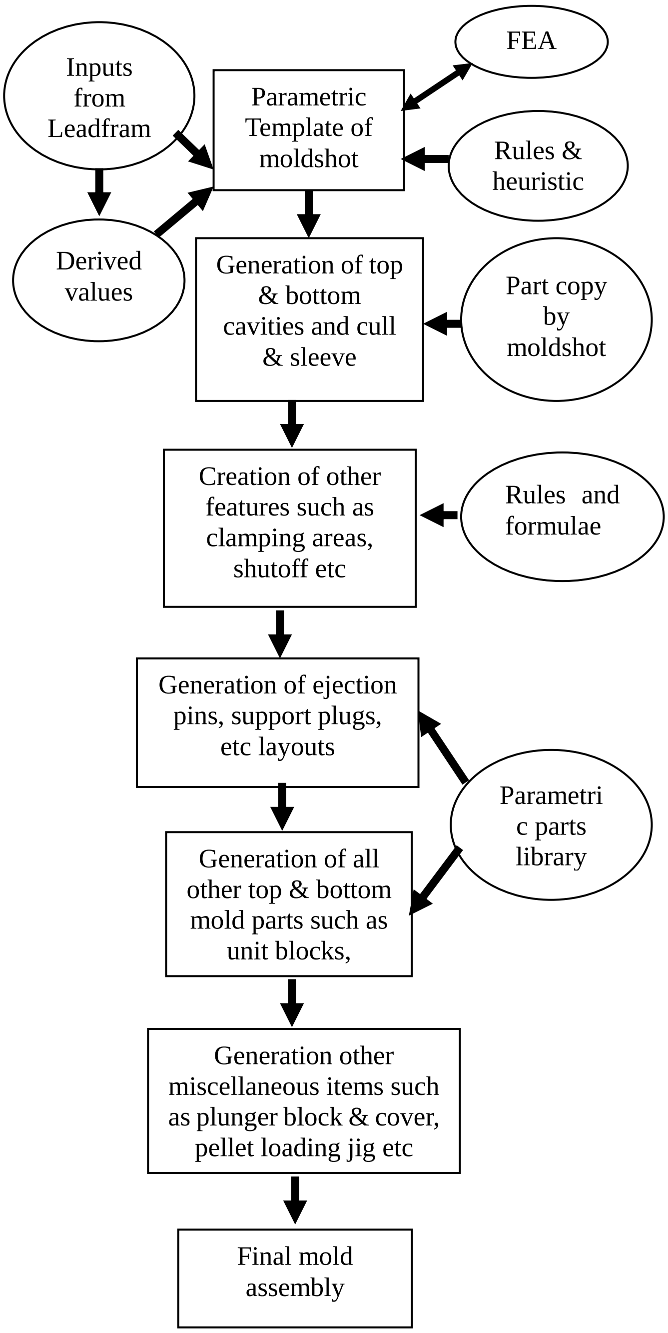


Fig 2: Flow chart of proposed method

3.1 Design Rules and Heuristics

Design rules and heuristics are collected from the experiences of the mold designers and standardized them. For example, design rules in thermal expansion and tolerance for calculation of design leadframe length are as follows:

LF_Design_Length=LF_Length* coefficient_of_thermal_expansion
Length_Upper_Limit = LF_Design_Length + Tolerance
Length_Lower_Limit = LF_Design_Length – Tolerance

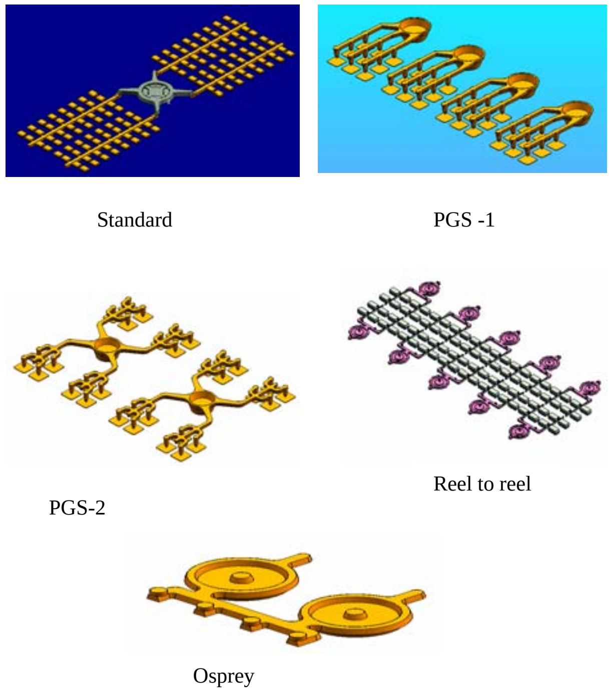
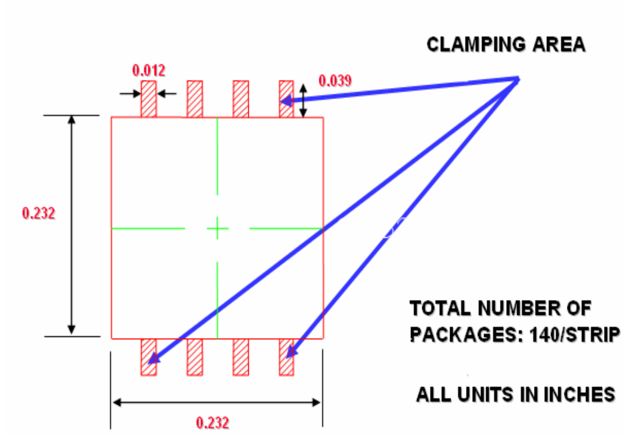
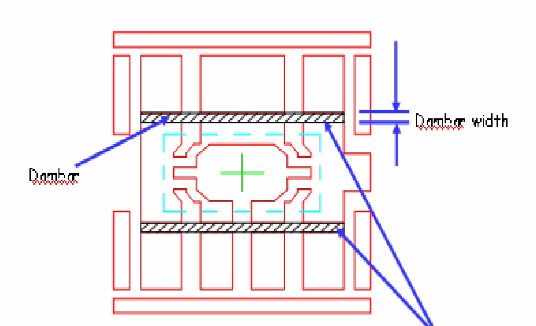


Fig 3: Moldshots for different types of packages



(a) Non-dambar clamping



b) Dambar clamping

Fig 4: Clamping area of leadframes

3.2 Calculation of Clamping Force and Ejection Force

Clamping area refers to the thin belt surrounding the cavity. The leadframe dambar that prevents plastic from rushing out between leads is usually used for clamping if there is one. Covers at least half of the dambar width if dambar width is more than 0.2mm. Total clamping force is proportional to leadframe yield strength and package unit per leadframe. It is also related to the leadframe thickness. Clamping force per package is the summation of clamping area per package multiplied by 75%~100% of leadframe yield strength and packaging force per package. For anti-flash profile (leadframe without dambar), the leads of the packages are used for the purpose of clamping.

Clamping area per package is the 50%~100% of lead area per package. For the mold chase, the maximum total clamping force to use is 80 tons, and the recommended total clamping force is around 50~70 tons. Fig. 4 shows the clamping areas of leadframes. A sample calculation for clamping force in non-dambar clamping is shown below.

Sample calculation:

Clamping area (per lead) = 0.012 x 0.039 x $(25.4)^2$
= 0.3 mm2

Clamping area (per unit) = 0.3x8= 2.4 mm2

Total clamping area = 2.4x140x2 = 672 mm2

Yield strength of leadframe = 58 kg/mm2

Clamping force to overcome yield strength of leadframe: 58x672 ≈ 40 ton

Consider sealing force (Cull/ Runner /Gate): 40x1.5 ≈ 58 ton

Recommended clamping force: 60~65 ton.

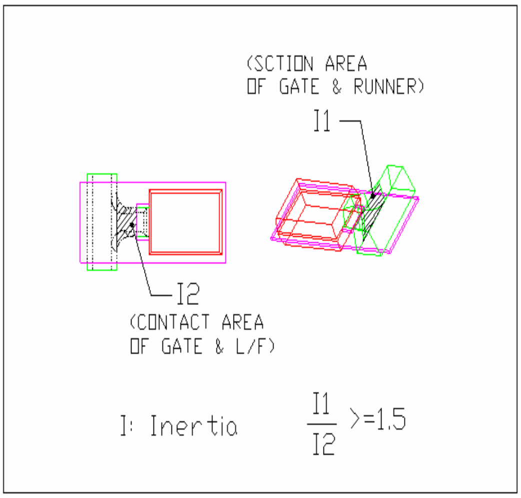


Fig 5: Calculation of de-gate inertial

After molding completion, ejector pins are required to push the molded part out of the cavity. Ejector pins are controlled by the movement of the plates such as ejector holder and ejector plate. About 40~50 ejector pins are used to eject a molded strip. The number of ejector pins used is often constrained by the space available on the leadframe. The position of the ejector pins should ensure a well balanced ejection of the molded product. The calculation of ejection force depends on the total number ejector pin quantity, total pre-load and final-load spring force.

3.3 Standardization of Checking Parameters

Following checking parameters should be considered for the successful implementation of the proposed method. These are de-gate inertial, de-runner inertial, clamping height and so on. In de-gate inertial, the distance from runner slot to starts of gate window cannot be too long, otherwise molded gate may stick onto bottom leadframe after derunner. The calculation of de-gate inertial is shown in Fig. 5.

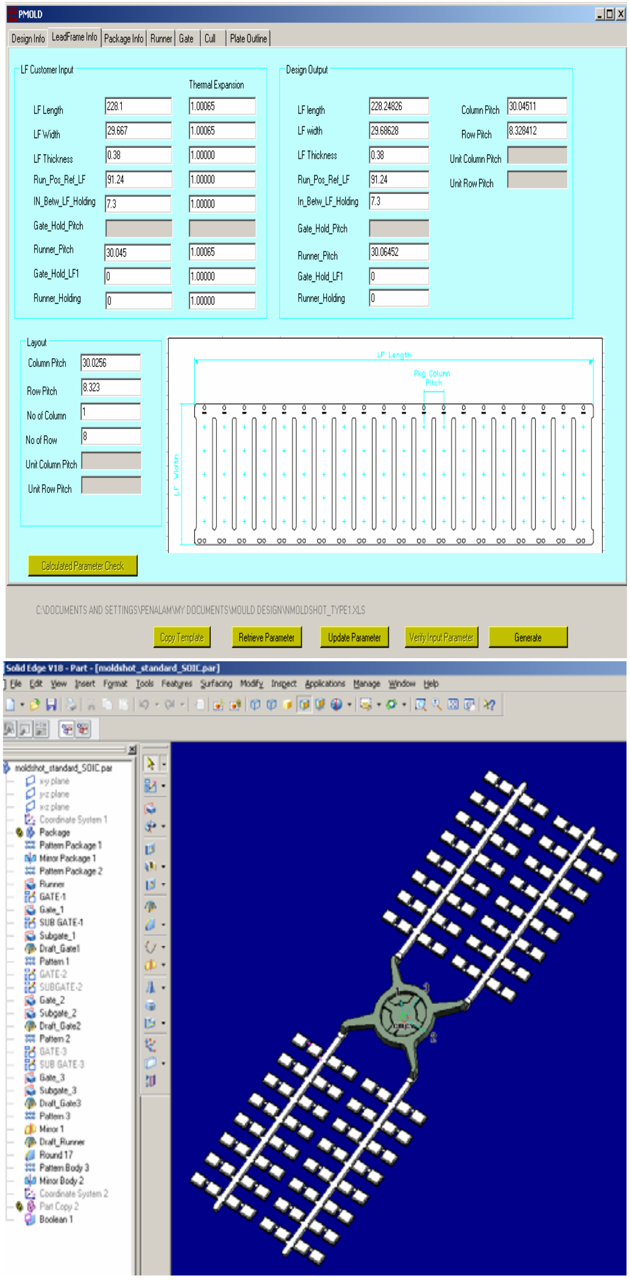


Fig 6: A part of user interface of PMOLD

4. USER INTERFACE

Using the discussed methodology, a windows-based 3D packaging mold design prototype named “PMOLD” is developed on the commercial 3D CAD software, Solid Edge V18 platform. The program is coded in VB.NET

2005 programming language with Solid Edge API. The facts that Solid Edge API interface uses an object-oriented approach and the API functions allows one to choose an objected oriented language, e.g. VB.NET, as programming language. Fig. 6 shows a part of user interface of PMOLD. Developed from the beginning as a native windows application, Solid Edge is one of the 3D mechanical design softwares for Windows. Its unique combination of production-level power, ease-of-use, and affordability and price is unmatched. Solid Edge provides strong dimension driven functionality to support parametric design. It is the logical relationship between the dimension sets which is stored in Excel file and the geometry. When a set of dimension is integrated with the corresponding parameter set of the geometry of an object, the exact model can then be obtained.

5. CONCLUSION

This paper presents a novel method for the development of a computer-aided mold design system "PMOLD" for semiconductor packaging mold design in transfer molding process. This method provides the designer with a computer-aided design environment which can both speed up design process and facilitate standardization. The interface is user-friendly and packaging mold design rules and processes are implemented systematically. The benefits gained from this method are to streamline practices for better visibilities for checking; to remove hidden human error (unwittingly design rules left out); to enable new engineers to learn mold design quickly; reduce lead-time and costs significantly. It is hoped that this research would make a significant contribution in transfer molding companies.

6. REFERENCES

1. Beckwith, S. and Benjamin, W., 1999, "Resin Transfer Molding: SAMPE Monograph No. 3", published by SAMPE, ISBN 0-938994-83-2.
2. Kong, L., Fuh, J. Y. H., Lee, K. S., Liu, X. L., Ling, L. S., Zhang, Y. F. and Nee, A. Y. C., 2003, "A Windows-native 3D Plastic Injection Mold Design System", Journal of Materials Processing Technology 139: 81-89.
3. Low, M. A. H. and Lee, K. S., 2003, "Application of Standardization for Initial Design of Plastic Injection Molds", International Journal of Production Research, 41: 2301-2324.
4. Li, C. L., 2001, "A Feature-based Approach to Injection Mold Cooling System Design", Computer-aided Design, 33(14): 1073-90.
5. Mok, C. K., Chin, K. S., and Ho, J. K. L., 2001, "An Interactive Knowledge-based CAD system for Mold Design in Injection Molding Process", International Journal of Advanced Manufacturing Technology, 17(1): 27-38.
6. Nee, A.Y.C., Fu, M. W., Fuh, J. Y. H, Lee, K. S., Zhang, Y. F., 1997, Determination of Optimal Parting Directions in Plastic Injection Mold Design", CIRP Ann. Manuf. Technol. 46 (1): 429-432.
7. Ong, S. K., Prombanpong, S., and Lee, K. S., 1995, "An Object Oriented Approach to Computer-aided Design of a Plastic Injection Mold", Journal of Intelligent Manufacturing, 6: 1-10.
8. Lye, S. W. and Yeong, H. Y., 1992, "Computer-assisted Mold Design for Styrofoam Products", Computers in Industry, 18: 117-126.