Web-based Interference Verification System for Injection Mold Design

In-Ho Song[1], Jong-Myoung Park[2] and Sung-Chong Chung[3]

[1]Innovative PLM Solutions, ihsong@inops.co.kr
[2]Hanyang University, pjm0404@empal.com
[3] Hanyang University, schung@hanyang.ac.kr

ABSTRACT

This paper describes the development of a web-based interferences verification system in mold design processes. Although several commercial CAD systems offer interference verification functions, those systems are very expensive and inadequate to perform collaborative works over the Internet. In this paper, an efficient and precision hybrid interference verification algorithm for the web-based interference verification system is studied for injection mold design processes. In order to design a collaborative system over the distributed environment, the proposed system uses lightweight CAD files produced from the optimally transformed CAD data through ACIS kernel and InterOp. Collaborators related to the development of a new product are able to verify the interference verification over the Internet without commercial CAD systems. The system reduces production cost, errors and lead-time to the market. Validity of the developed system is confirmed through case studies.

Keywords: Collaboration, Injection mold, Interference verification, Internet, Lightweight CAD file.

1. INTRODUCTION

Injection-molded products are widely used and their significance is increasing. Life cycle of plastic products are shorter and shorter. Injection mold companies reduce lead-time by using 3D CAD systems. However, various problems occur in the design process of injection molds, such as a loss of cost due to the transformation process of 3D CAD data to 2D CAD data for fabrication of molds, a loss due to dispersed environment at the modification stage of design, design errors of designers, and large amount of investment cost and maintenance expenditure of CAD systems, and so on. Most injection mold companies want to use collaborative CAD viewers to overcome these problems. Several commercial web-based viewing tools, such as Spinfire of Actify corporation [1] and AutoView of Cimmetry system[2] have been developed. However, the commercial viewing tools offer only simple measurement functions and does not have accurate interference verification functions applicable to injection mold design processes. In addition, as they are general viewers, it is difficult to apply the viewers to the design process of injection molds.

Ye et al. [3] proposed the automatic assembly algorithm using definitions of hierarchical relationships and geometrical constraint of injection mold parts. Chin and Wong [4] studied a knowledge-based evaluation system in the conceptual design stage of injection molds. Shin and Lee [5] proposed interference verification algorithm, to verify interference of surfaces of injection molds. They proposed a search algorithm to eject the mold product by using side cores. If interference occurred at slide cores, they are modified automatically. However, application of this paper was limited according to the form of injection molds.

In order to design a general viewer with accurate measurement functions, a web-based design verification system was developed through ActiveX control [6]. To apply this system to the design verification process of injection molds, a draft verification system was developed through the incorporation of the draft verification algorithm into the previously developed web-viewer [7]. An optimized lightweight CAD file produced from a commercial CAD file is used to develop the dimension verification, markup and draft verification modules. However, interference verification of injection molds has not been studied yet.

Interference of injection molds generates fatal problems such as impossible assembly, damage of injection molds, and so on. As interferences of injection mold parts occur at the small region, it is difficult to find interferences at the design stage. It is also difficult to confirm the interference free mold in the design process of molds. They are usually found at the assembly stage of injection molds. It is required to check and compensate for the interference before releasing the final design drawings. Interference between an angle pin and an evasion hole of the angle pin directly affect the fitting of a slide. A lot of time and cost are required to compensate for the interference in the manufacturing process of injection molds. In this paper, AABB (axis-aligned bounding boxes) tree [8] and data structure of the lightweight CAD file [9] are used to develop an interference verification algorithm. By combining this interference verification algorithm with the previously developed web-viewer, a web-based interference verification system for injection molds is developed in this paper.

2. CLASSIFICATION OF INTERFERFERENCE PARTS FOR INJECTION MOLD

Interferences of injection mold primarily occur by slide cores, angle pins, ejector pins, bolts, etc. Interference of a slide core occurs at the curved surface between the slide and the lock. In this case, the slide core is not assembled well due to the interference. Fig. 1(a). shows an example of the interference between the slide and the lock.

An angle pin is a locking unit to fix a slide core preventing interference between the product and the injection mold. It changes the length and the inclination angle of the angle pin according to working distance of the slide core. Interference between an angle pin and an angle pin evasion hole occurs according to length and inclination angle of the angle pin. The interference between the angle pin and the angle pin evasion hole damages slide cores. Fig. 1(b). shows the example of interference between the angle pin and the angle pin evasion hole.

Interferences of ejector pins or bolts mainly occur owing to not only the position errors between the ejector pin and the ejector pin hole but also the long length of the ejector pin. Bolt interference occurs when the bolt is longer than the depth of a hole. Fig. 2(a). shows an example of the interference between the ejector pin and the bolt.

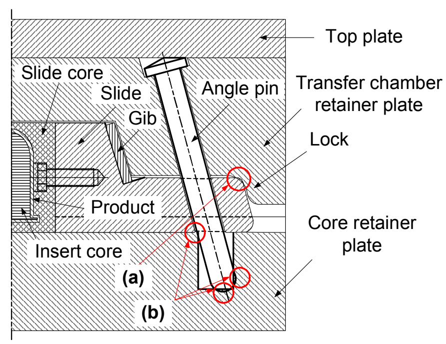


Fig. 1. Interference between two parts : (a) slide and lock, (b) angle pin and angle pin hole.

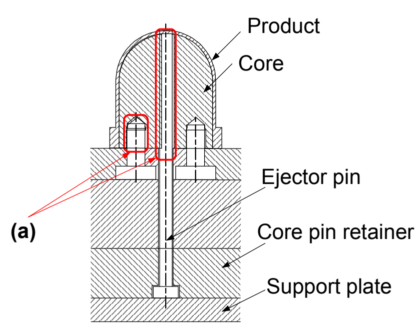


Fig. 2. Interference between ejector pin and core.

3. RELATED RESEARCHES

Interference of objects in the virtual reality should include an interaction among objects such as interference occurring in the actual reality. However, in order to express interference objects in the virtual reality, a lot of time and cost are required. It requires hierarchical object representation methods to realize the effective interference verification in the virtual reality. BV(bounding volume) and space division methods have been used for hierarchical object representation OBB (oriented bounding box) tree and Spheretree methods use BV to check interference. Gottshark proposed an interference verification algorithm using the OBBtree [10]. He introduced a fast and accurate separating axis theorem. However, efficiency of the system in the case of non-convex hull and parts of an injection mold is degraded. Hubbard proposed an interference verification method using the Spheretree and Space-Time bounds [11]. However, in order to model a cubic surface like an injection mold part needs many spheres, and the accurate interference verification is difficult due to empty space of spheres.

An interference verification using a space division is Octree and BSP(binary space partitioning)tree etc. Vemuri et al. proposed algorithm make certain interference verification which uses the Octree at the moving process of small part with a curved surface [12]. They worked at fast interference verification at objects of convex hull or non-convex hull which use Octree. Ar et al. introduced concept of self-customized data structures, and investigated it in the case of BSPtree for interference verification [13]. However, compared with an interference verification which uses the BV, an interference verification which uses a space division is inefficiency. Preceding interference verification algorithms are hard to practice an effective interference verification of injection mold which is composed form of an axis-aligned cubic or cylinder. Consequently, in this paper, we propose the interference verification algorithm for overcome a defect of interference verification algorithm of previous and an effective interference verification at the injection mold, the proposed algorithm consist of an AABBtree and hierarchical structure of the lightweight CAD file.

The AABBtree is verification methods which create align BV with a coordinate plane at each objects and use BV for interference between the each objects. This method is able to certify a simplify and fast interference between boxes using a maximum and minimum vertex of bounding box, especially, It is possible to maximize of an advantage of the AABBtree, in a verification interference of axis-aligned parts as injection mold. An interference verification method of this paper practice to the fast interference verification using the AABBtree and if a result of interference verification using the AABBtree is determined to interfere, it is method that practice verification at subordinate hierarchy.

The structure of the lightweight CAD file and the detailed interference verification method describes in the next chapter.

4. DESIGN OF HYBRID INTERFERENCE VERIFICATION METHOD

4.1 Feature of Hybrid Interference Verification

In this work, we perform an efficient interference verification which uses CAD file hierarchical structure of developed lightweight CAD file [9]. This work uses data structure like this presents a hybrid algorithm which uses the AABBtree and the structure of lightweight file for an effective interference verification of injection mold. As shown in Fig. 3. In addition, it makes certain interference through stepwise search of the solid, the face and the triangle mesh.

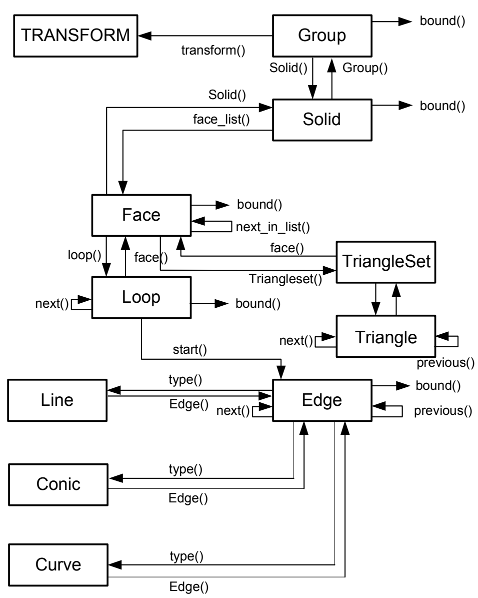


Fig. 3. Structure of the lightweight CAD file.

4.2 Method of Hybrid Interference Verification

In this work, we propose the interference verification method which is suitable in injection mold design process. It shows the algorithm of the interference verification method which is improved in Fig. 4. Process of the interference verification is as follows.

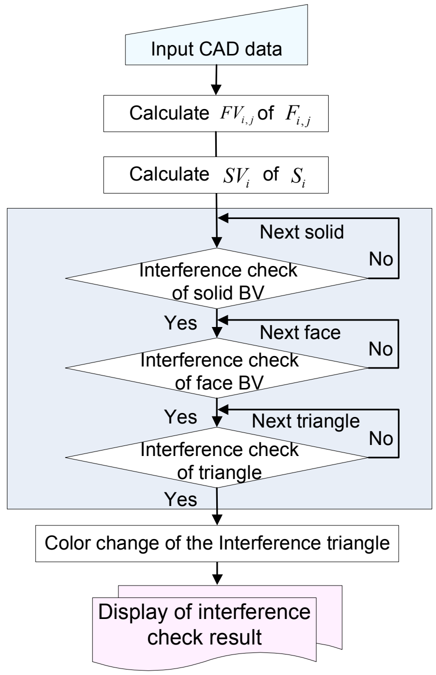


Fig. 4. Algorithm for the hybrid interference verification.

(1) The maximum and minimum value of vertexes composed a face is computed by the vertex information and BV is computed by the maximum and minimum value ($FV_{i,j}$) that is stored at the class of face ($F_{i,j}$). The BV of solid (SV_i) is computed by the BV values of generated face in class.

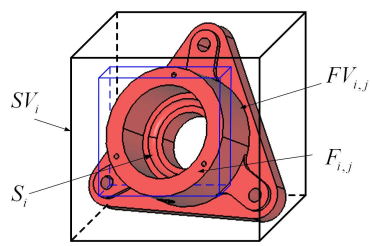


Fig. 5. BVs of a solid and faces.

(2) The interference verification for BV of the first solid and the other solids is practiced by the inputted CAD data. If the interference not occurs, practicing the interference verification for BV of next solid and another solid. The interference verification for BV of total solids are practiced by recursive method.

(3) If the interference verification for BV of two solids occur, select the first face of contained face datum in the first solid of occurred interference solids with BV of this face and BV of contained face in the second solid is performed by sequential the interference verification. At this time, if not, BV of next face of the first solid with BV of contained face in the second solid is performed the interference verification. The interference verification for BV of included total face in the two solid is practiced by recursive method like this.

(4) If the interference verification for BV of two faces occurs, select the first triangle mesh of contained triangle meshes in the first face with contained triangle meshes in the second face are performed sequential the interference verification.

At this time, if not, next triangle mesh of the first face with contained triangle meshes in the second face is performed the interference verification. The interference verification of included total triangle mesh in the two faces is practiced by recursive method like this.

(5) If the interference of two triangle mesh occurs, through change of color of interfered triangle meshes visualize a result of the interference verification. Using the interference verification like this, it is possible to verify interference occurrence region of the injection mold parts at the injection mold design.

4.3 The Interference Verification Between Solids

The maximum and minimum value of vertexes composed a solid is computed by the vertex information and BV of solid is composed by the maximum and minimum value, for interference verification between solids. Interference between BV of the solid can be comprehended by the following interference condition [14].

$$if\,(S_i^{\min} > S_{i+1}^{\max} \ or \ S_{i+1}^{\min} > S_i^{\max}) \tag{1}$$

If the conditions are satisfied with an appliance of Eqn. (1). at each axis, BV of two solid does not occur the interference. However, if not, BV of two solid occur the interference.

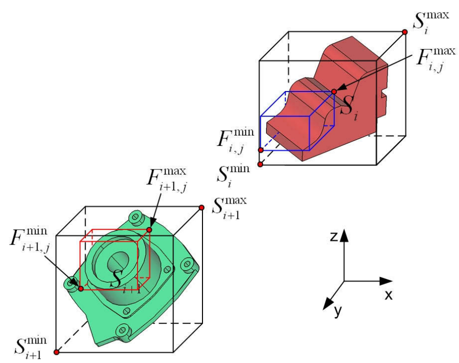


Fig. 6. Maximum and minimum points between BVs.

4.4 The Interference Verification Between Faces

The interference verification between faces uses BV of face which is searched by the interfered solid. If a condition is satisfied with an application of Eqn. (2). to each axis, BV of two face is not occur the interference at the calculated each BV. However, if not, BV of two faces occur the interference.

$$if\,(F_{i,j}^{\min} > F_{i+1,j}^{\max} \ or \ \mathrm{F}_{i+1,j}^{\min} > F_{i,j}^{\max}) \tag{2}$$

4.5 The Interference Verification Between Triangle Meshes

The interference verification between triangle meshes is composed of three levels of calculation of plain equation for triangle, calculation between line and intersection point and calculation of interference verification for between triangles [15].

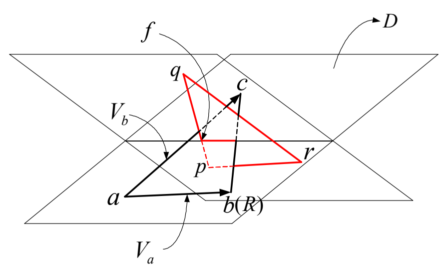


Fig. 7. Triangles consisted planes.

4.5.1 Calculation of the Plane Equation of a Triangle

In order to verify of interference of a triangle, it denote each three points of two triangles. Vector V_a and V_b is computed by three points a, b and c of the first triangle. Cross product of each axes is computed by vector V_a and V_b, this results is each as C_x, C_y and C_z. Equation D of plane is computed by on the plane point R.

$$D = -(C_x x_b + C_y y_b + C_z z_b) \tag{3}$$

4.5.2 Calculation of the Intersection Point between a line and a Plane

An intersecting point f between line segment and plane is computed by the two angular points P and Q (Fig. 7.) of the second triangle and the computed plane of the first triangle from plane equation. The order of calculations are as follows Eqn. (4), (5), (6).

$$p(x_p, y_p, z_p)t = q(x_q, y_q, z_q)(1-t) \tag{4}$$

$$t = -\frac{((C_x x_q) + (C_y y_q) + (C_z z_q) + D)}{(C_x(x_p - x_q) + C_y(y_p - y_q) + C_z(z_p - z_q))} \tag{5}$$

$$f(x, y, z) = p(x_p, y_p, z_p)t + q(x_q, y_q, z_q)(1-t) \tag{6}$$

where, $p \in x_p, y_p, z_p$, $q \in x_q, y_q, z_q$

4.5.3 Calculation of Interference Verification for Between Triangles

If the sum of angle between each angular points of the first triangle and computed intersecting point t from Eqn. (7) is 2π, two triangles is interfered. Computation of angle between each angular points and intersecting point is as follows. In Fig. 8. the vector V_1 and V_2 are computed by difference between two angular points of the first triangle and the intersecting point t. Vector V_1 and V_2 are computed by dot product of Eqn. (7).

$$\theta = \cos^{-1}\frac{(V_1 \bullet V_2)}{(|V_1||V_2|)} \tag{7}$$

Sum of angle between three angular points of the first triangle and intersecting point t is as

$$\theta_{Total} = \theta_1 + \theta_2 + \theta_3 \tag{8}$$

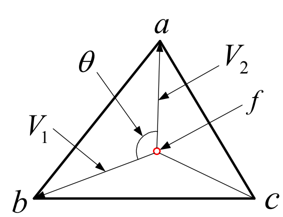
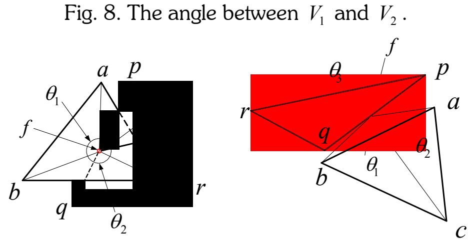


Fig. 8. The angle between V_1 and V_2.



(a) Internal point (b) External point

Fig. 9. The interference verification of two triangles.

Here, θ_1, θ_2 and θ_3 is each angle between two angular points couples of the first triangle and the intersection point t. If θ_{Total} of Eqn. (8) is 2π, two triangle occur interference as Fig. 5(a)., else if θ_{Total} is small more then 2π, two triangle does not occur interference as shown Fig. 9(b).

4.6 Comparison of the Number of Calculation for Interference Verification

In order to verify the efficient of the proposed algorithm, we try to compare the interference verification quantity of two solids. Two solids A and B are composed of each 10 faces (f_l, f_m) and each face is composed of 100 triangle meshes (t_l, t_m). Two solids occurred interference at the only each 1 face. In this case, let us analysis interference region. We are able to comprehend accurate interference region with computation of about 2% from result of compare fourth column of the Tab. 1 in case which uses the interference verification method of worst-case(N_{worst}) and fifth column of the Tab. 1. in the case proposed algorithm($N_{proposed}$). Therefore, this algorithm is very effective because conspicuously small computation quantity in the case of the small regional interference as injection mold.

$$N_{worst} = f_l f_m t_l t_m = 10\times10\times100\times100 = 1,000,000 \tag{9}$$

$$N_{proposed} = f_l f_m + f_n t_l t_m = 10\times10 + 1\times100\times100 = 10,100 \tag{10}$$

	A	*B*	*Worst-case*	*Proposed*
Solid	1	1	-	1
Face	10(f_l)	10(f_m)	-	100
Triangle	100(t_l)	100(t_m)	1000000	10000

Tab. 1. Comparison of the worst-case and the proposed algorithm.

5. SYSTEM ARCHITECTURE

In this work, the total framework of the system which is developed is in Fig. 10. In order to register, search, upload and download of CAD data, the integrated server exchanges messages with designer clients or web clients for transmission of file information. Message exchange is realized by using socket communication. The system consists of designer client, integrated server and web clients. The principal functions of the developed system are shown as follows. The web-server notifies web page and grants user to certifications. In addition, a designer is able to register CAD data by webpage which make use commercial CAD system. Translation server translates the registered commercial CAD file into the lightweight CAD file for web-based verification. Translation server uses the InterOp module and the kernel of the Spatial Inc. for translation various commercial CAD file into the lightweight CAD file [9]. Design registers should set to work search, design and interference verification through internet. Searched the lightweight CAD file which corresponds to the commercial CAD data is transmitted by the server to the client, so it is possible to work of verification. Searched design information performs interference verification and design verification on the web, and after verification, the result is saved by the lightweight CAD file, and it is transferred to integrated server, it is possible to accommodate multi-user at the same time.

The interference verification and design verification module consist of the lightweight CAD file transfer, the 3D viewing module, interference verification module, markup module and markup read/write module as Fig. 11. Each module is realized by using ActiveX technology of the Microsoft and programming by MFC and the OpenGL of the Silicon Graphics Company at internal of the ActiveX is used for handling 3D data. HTML is used to notify ActiveX controls on the Web. And, VBScript is utilized interface for plug-in. In this architecture is automatically installed by ActiveX when a client is connected to the server, since then a user is connected to the server, versions of the distributed ActiveX controls are checked. And then the updated ActiveX controls are automatically distributed. In addition, the interference verification system is performed at the client's PC, which can reduce network performance and server overload, in the case of a complex work as 3D visualization or draft verification [6].

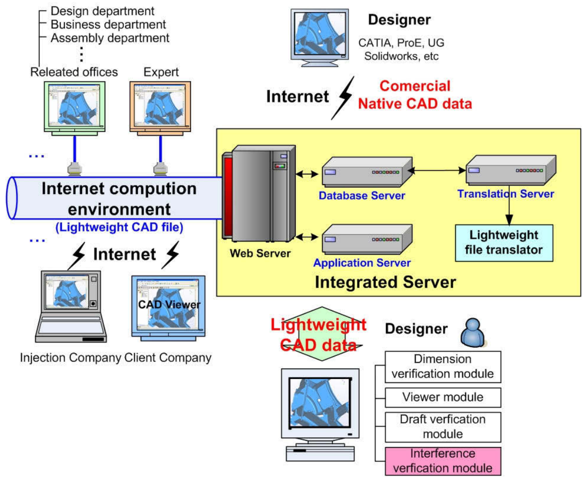


Fig. 10. Framework for the proposed system.

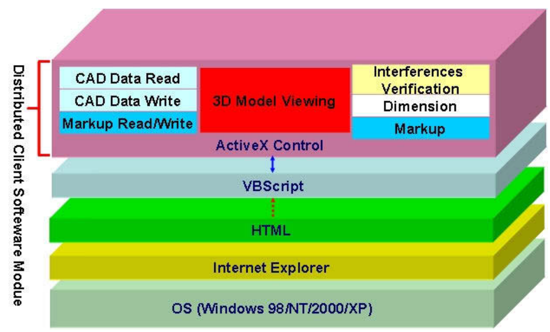


Fig. 11. Structure of the interferences verification module.

6. CASE STUDIES

In this paper, efficiency of proposed interference verification system is established by using real CAD file of injection mold. Designer design injection mold by using commercial CAD systems, and a CAD data is registered by this system through web page. Registered CAD file is transformed into the lightweight CAD file using the transformation server. After search a CAD data of injection mold on the internet, and if the designer demands verification, viewer become automatically plug-in at a web-browser and download automatically the lightweight CAD file, and it is visualized. Fig. 12 is a user interface for CAD file verification and interference verification. The performance of interference verification is practiced by selection of the interference verification menu (① of Fig. 12) of the bottom of popup menu. Fig. 13 is visualized by a result of the interference verification of injection mold between angle pin and evasion hole. This example is a result of an interference occurrence between evasion hole and length of pin at the design process of angle pin. A result of the interference verification is expressed by black color on the screen (① of Fig. 13). The designer reflects on the injection mold design through the change length of an angler pin or size of an evasion hole by this result. Fig. 14 is a result of interference occurrence between injection mold and lock. In this example, interference occurs a case that the radius of curvature of slide is small more then the radius of curvature of lock at the corner between slide and lock. Interference region is visualized by change the color at ① of Fig. 14.

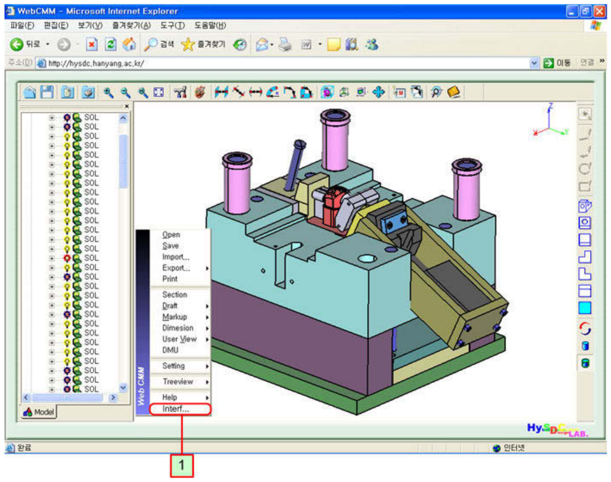


Fig. 12. User interface of the interference verification system.

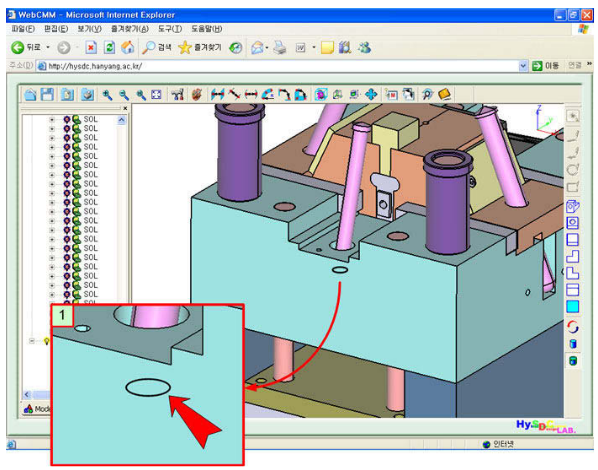


Fig. 13. Interference verification between angle pin and hall.

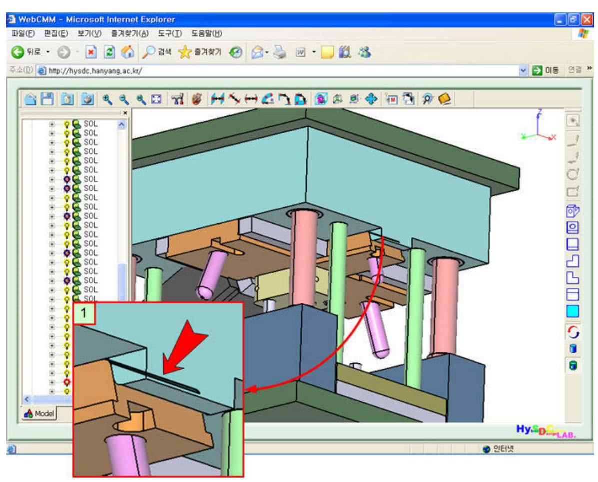


Fig. 14. Interference verification between slide and lock.

6. CONCLUSIONS

Design methodology of the interference verification system for Injection mold design is designed to obtain the following conclusions :

(1) We are confirmed interferences parts of injection mold parts through the investigation and identification of injection mold parts.

(2) Significant efforts were devoted to efficient algorithms for injection mold parts, in particular those for 3 kind of injection mold parts.

(3) This hybrid representation facilitates the combination of the advantages of the faster, less accurate BV with accurate triangle mesh of interference test.

(4) The developed interference algorithm has been implemented and is able to detect all contacts between complex geometries (composed of free-from surfaces).

(5) Using the developed interference verification system, collaborators are able to verify design results and dimensions without using the expensive commercial CAD/CAM hardware or software.

(6) Effectiveness of the proposed system is verified through the case study.

7. REFERENCES

[1] Actify Homepage, http://www.actify.com

[2] Cimmetry Homepage, http://www.cimmetry.com

[3] Ye, X. G., Fuh, J. Y. H. and Lee, K. S., Automated Assembly Modelling for Plastic Injection Molds, Internal *Journal of Advanced Manufacturing Technology*, Vol. 16, No. 10, 2000, pp. 739-747.

[4] Chin, K. S. and Wong, T. N., Knowledge Based Evaluation for the Conceptual Design Development of Injection Molding Part, *Engineering Applications of Artificial Intelligence*, Vol. 9, No. 4, 1996, pp. 359-376.

[5] Shin, K. H. and Lee, K. W., Design of Side Cores of Injection Mold from Automatic Detection of Interference Faces, ASME, Vol. 59, 1993, pp. 27-34.

[6] Chung, S. C. and Song, I. H., A Collaborative Design and Dimension Verification System on the Internet, *Transactions of NAMRI/SME*, Vol. 33, No. 1, 2005. pp. 493-500

[7] Chung, S. C., Yeon, K. H. and Song, I. H., Web-based Draft Verification System for Injection Mold Design, *Transactions of the KSME(A)*, Vol. 29, No. 10, 2005, pp. 1353-1360.

[8] Bergen, G., Efficient Collision Detection of Complex Deformable Models Using AABB Trees, *Journal of Graphics Tools*, Vol. 2, No. 4, 1997, pp. 1-13.

[9] Chung, S. C. and Song, I. H., Design of Lightweight CAD Files for Web-based Collaboration, Proceeding of the Society of CAD/CAM Engineers, 2005, pp. 752-758.

[10] Gottschalk, S., Lin, M. C. and Manocha, D., OBBTree : A Hierarchical Structure for Rapid Interference Detection, Computer Graphics Proceeding (SIGGRAPH), Vol. 30, 1996, pp. 171-180.

[11] Hubbard, P. M., Interactive Collision Detection, In IEEE Symposium on Research Frontiers in VR, 1993, pp. 24-31.

[12] Vemuri, B. C., Cao, Y. and Chen, L., Fast Collision Detection Algorithms with Applications to Particle Flow, *Computer Graphics Forum*, Vol. 17, No. 2, 1998, pp. 121-134.

[13] Ar, S., Chazelle, B. and Tal, A., Self-customized BSP Trees for Collision Detection, *Computational Geometry: Theory and Applications*, Vol. 15, No. 1, 2000, pp. 91-102.

[14] Moller, T. and Haines, E., Real-Time Rendering, A K Peters, Ltd., Massachusetts, 1999.

[15] Moller, T., A Fast Triangle - Triangle Intersection Test, *Journal of Graphics Tools*, Vol. 2, No. 2, 1997, pp. 25-30.

[16] Held, M., ERIT - A Collection of Efficient and Reliable Intersection Tests, *Journal of Graphics Tools*, Vol. 2, No. 4, 1998, pp. 25-44.