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Analysis of the structure of wood-plastic composite coated co-extrusion head

Zhenghao Ge[1], Hongli Chang and Shanshan Ren

Mechanical and Electrical Engineering College,Shaanxi university of science and technology, Xi'an,Shaanxi 710021, China

[1] Email: gezh@sust.edu.cn

Abstract. In order to further solve the problem of the flow path of the head of the existing wood-plastic composite co-extrusion, the structural defects of the head are accurately found. This article first simulates the core and shell flow channels separately to simulate whether they are uniformly extruded and whether the exit speed is consistent. It is further analyzed that the cause of the uneven coating of the part is the problem of the shell flow channel and its structure. It does not meet the design requirements. Then, by proposing a variety of different flow channel structure optimization schemes, further simulations are performed, and the fluid flow trend is analyzed based on the simulation results. First of all it is determined that the existing flow path shape itself has problems. Considering the structure of the overall nozzle flow channel, based on the analysis of the flow channel trend, a new solution for the design of the co-extrusion ring flow channel is proposed. Further solve the structural problem of the coating head,which improved the design efficiency and reduced the waste of personnel and materials caused by continuous die testing. It has certain reference value for follow-up.

1. Introduction

Wood plastic composite is a new kind of composite material, which is generally made of wood powder and thermoplastic in proportion[1]. It combines the excellent properties of wood powder and plastic.Existing co-extrusion technology has relatively low accuracy in extruded products in actual production operations, it is difficult to achieve uniform and stable extrusion, and there are problems such as unstable coating and co-extrusion interfaces, poor adhesion between the core layer and the shell layer, and other problems. The experimental material used in this paper is HDPE based wood plastic composite for core material and polyethylene plastic for surrounding cladding (shell). In the experiment, the shell and core layer were observed obviously, and the pigment was added in the shell extrusion[2].

There are many unstable factors in the use of ordinary single screw co-extrusion. For example: the material will be dispersed in the hopper; the material in the equipment cannot be completely melted; the temperature control is uneven; the screw and the draft speed are not stable; the screw and the barrel are worn or corroded; the material cannot be well mixed[3].

The co-extrusion machine can make two or more kinds of materials finally converge and form. It combines the advantages of single extrusion and can get satisfactory plastic products. However, in the experiment, the core and shell of the product have four corner coating uneven, so in this paper, the core and shell have four corner coating uneven in co-extrusion experiment is simulated by numerical CAE and the design is optimized according to the results[4].In view of these problems, we need to conduct further research on the co-extrusion, further design and optimize its structure, and improve the stability of its extrusion.

2. Problems found in the experiment
Figure 1. shows the co-extrusion experimental product.

Through a large number of experiments, it is found that the core and shell of co-extrusion products are coated unevenly, especially at four corners.

In order to find out the reason, it is initially determined that it is the structure problem of co-extrusion head according to repeated experiments, so the core layer and shell channel of the head are simulated separately with CAE software to find out the specific problems.

3. Establishment of internal and external flow channel model of co-extrusion head

3.1. Co-extrusion head model
Figure 2. is the co-extrusion schematic diagram. The fluid from the core layer and the shell layer respectively enters the co-extrusion flow channel and converges and extrudes at the front die head together.

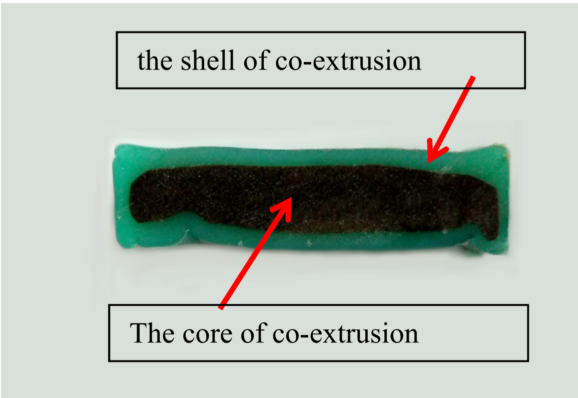

Figure 1. Co-extrusion head extrusion drawing.

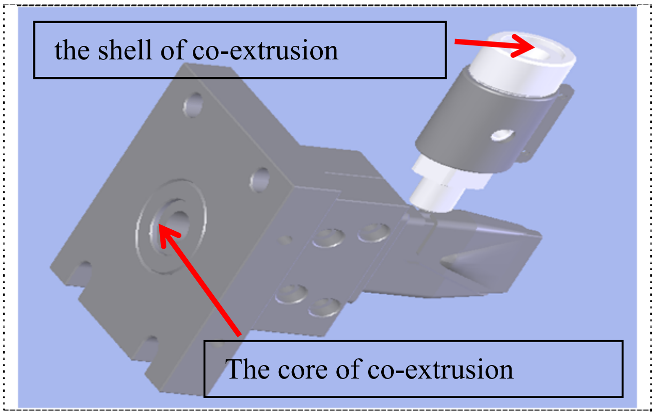

Figure 2. The 3D design schematic of co-extrusion die head.

3.2. Co-extrusion channel model

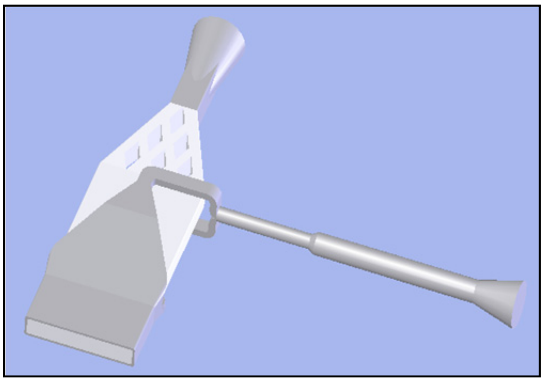

Figure 3. CREO modeling diagram of inner and outer layer flow channel.

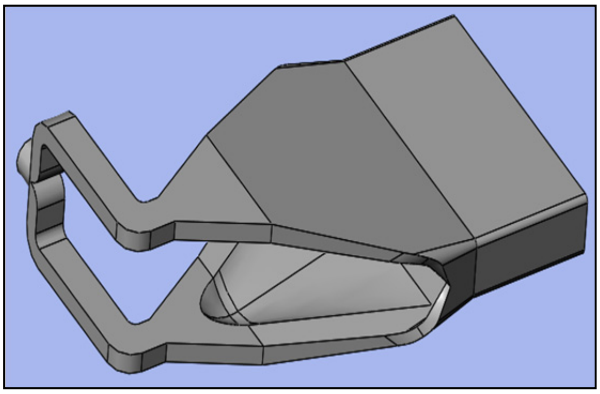

Figure 4. 3D design of shell flow channel.

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According to the position and size of the surface of the coating layer, the co-extruded runner can be divided into a full surface coating and a partial surface coating. In this paper, wood-plastic composite coating co-extrusion chooses full-surface coating. Most full cladding uses a labyrinth mesh co-extrusion channel. The labyrinth grid has the function of constant pressure shunting, and the uniformity of the flow channel is very high for the entire coating layer. Therefore, the flow channel design must be symmetrical. The 3D design of the co-extruded inner and outer flow channels is shown in Figure 3, and the 3D design of the shell flow channels is shown in Figure 4.

4. Analysis of simulation results of inner and outer flow channels

4.1. Analyze inner runner

The power law constitutive model is also suitable for the simulation of core flow channel. Figure 5. is a pressure change cloud chart of core material. It can be seen that the pressure decreases gradually from the inlet, and the pressure at the inlet is 115400000Pa. The simulation conforms to the pressure change characteristics of visco-elastic fluid in the actual process. Therefore, the core pressure distribution meets the requirements.

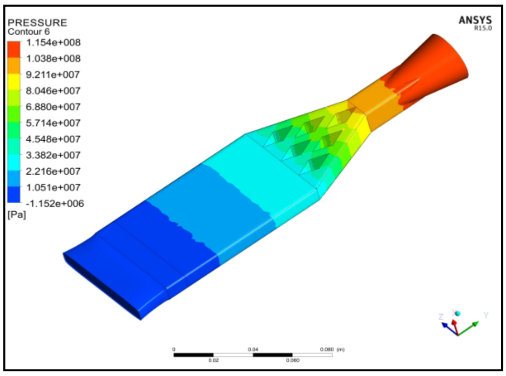

Figure 5. Pressure change cloud chart of core material.

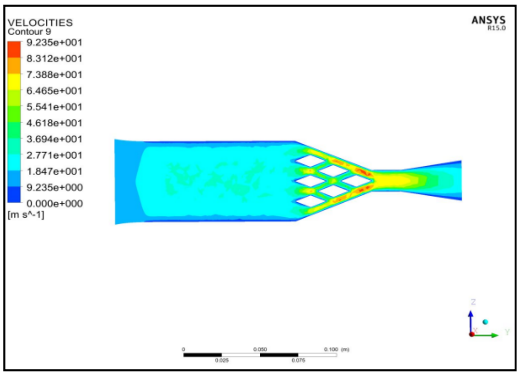

Figure 6. Velocity distribution in cross section of core layer flow channel.

The velocity field is also very important for the uniform extrusion of inner materials. See Figure 6. for the velocity field of cross-section flow in the core flow passage. The velocity of materials in the inner flow passage decreases evenly from the middle to both sides without mutation, so the cross-section velocity field of the core flow passage meets the requirements.

As shown in Figure 7. ,the velocity field at the outlet section of the core flow passage can be seen from the figure, and the velocity at the outlet of the fluid is evenly distributed as an annular contour, so the velocity field at the outlet section of the core flow passage also meets the requirements.

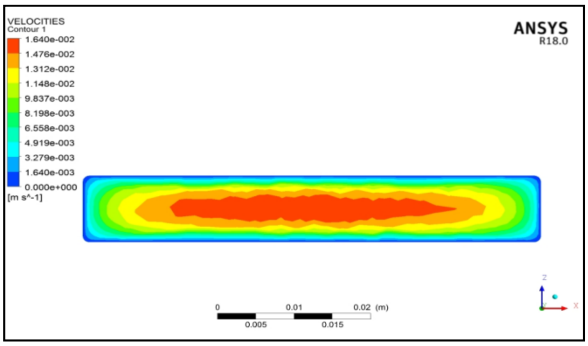

Figure 7. Velocity distribution map of core outlet section.

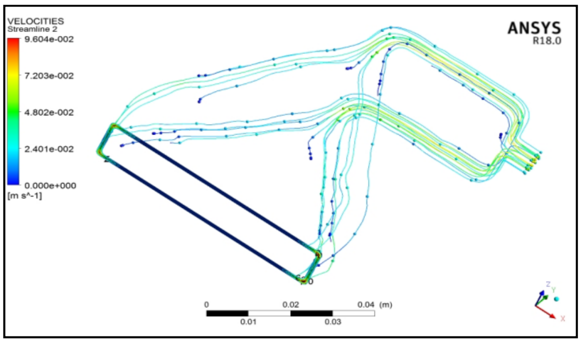

Figure 8. Cloud map of velocity distribution in shell flow channel.

According to the velocity field of cross-section flow of core runner and the cloud chart of velocity field of exit section of core runner, the core runner meets the requirements.

To sum up, the simulation of the above core layer meets the requirements, so the head position causing the uneven extrusion coating is not the core layer.

4.2. Analysis of simulation results of shell channel

Cross law model is also suitable for co-extrusion head shell material. After the boundary conditions are set in ANSYS, the ANSYS is carried out and the relevant post-processing is done.

As can be seen from Figure 8. the flow velocity of the shell flow passage is smooth and free of sudden bending. The structure of the middle damping block makes the streamline on both sides. Therefore, the flow state of the shell flow field is normal.

See Figure 9. cloud chart of shell material pressure distribution. It can be seen that the pressure decreases gradually from the inlet, and the pressure at the inlet is 185200000 Pa. The simulation conforms to the pressure change characteristics of visco-elastic fluid in the actual process. Therefore, the shell pressure field meets the requirements.

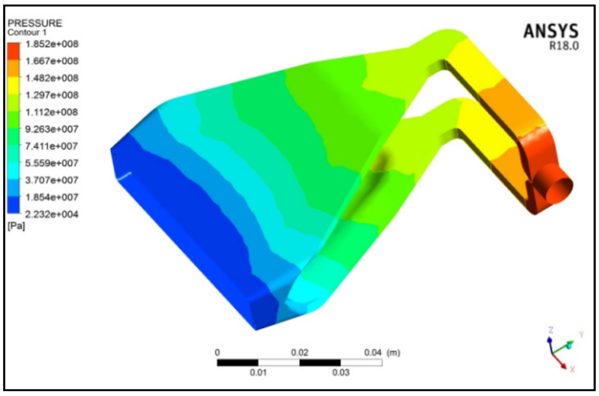

Figure 9. Pressure field of shell material.

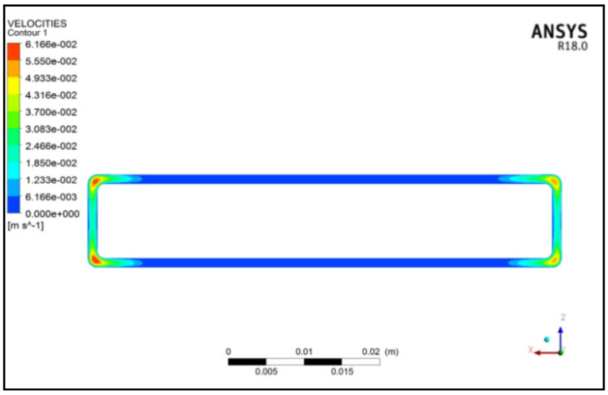

Figure 10. Velocity change cloud chart at the outlet of shell flow channel.

Neglecting the influence of the simulation at the entrance of the shell structure, because the rest of the shell structure is symmetrical, 1/4 of the simplified model is adopted for simulation.

As shown in Figure 10, the flow velocity at the outlet of the shell flow passage has a sudden change at the corner bend, so it is inferred that the shell flow passage may be unreasonable. When the constitutive model is set to viscosity constant, the flow rate is set to a very small value. Therefore, it is found that the reason for the shell flow passage is found. Next, different optimization schemes are proposed.

From the experimental results, it can be seen that the four corners of the co-extruded parts are covered unevenly, and the finite element analysis is the reason of the shell structure. Therefore, this paper proposes the following two optimization schemes for the optimal design of the shell flow channel.add blocking in bending area and the effect of increasing the inclination of the bending side on the melt flow.

5. Improvement of shell runner structure and finite element analysis

5.1. Add damping block in bending area

5.1.1. Add damping block in a small range in the upper position of bending area. Because the simulation results show that the sudden change of four corner velocity value of co-extrusion parts is large, in order to improve the sudden change of velocity, a damping block is added near the corner for simulation verification.

As can be seen in Figure 11, the maximum pressure of the outlet of the flow passage where the damping block is added is, and there is no obvious change compared with the maximum pressure of the original damping block. Therefore, adding damping blocks in a small area above the bending zone can not improve the unevenness of abrupt extrusion coating.

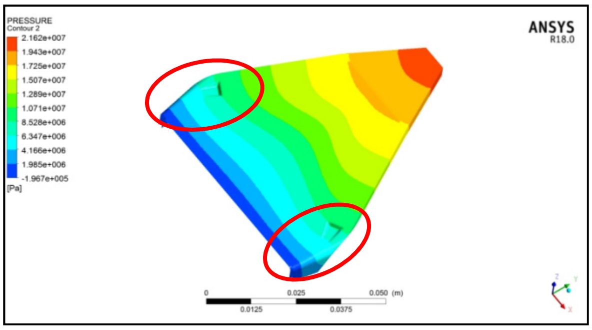

Figure 11 The pressure field at the exit of damper in a small range at the upper part of bending zone.

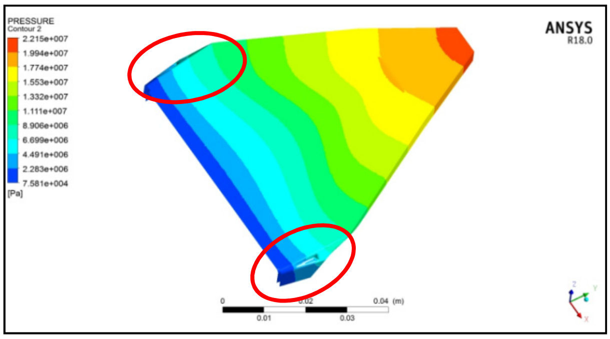

Figure 12. The pressure field at the exit of damper with sudden change of four corners.

5.1.2. Add damping block at abrupt change of four corners. As shown in Figure 12, the outlet pressure field with damping added at the bending corner is the highest pressure at the outlet corner of the flow channel after removing the damping block. Compared with the highest pressure at the outlet corner of the original flow channel before, the corner pressure value drops significantly, which improves the uniformity of the flow field to some extent, but the improvement effect is far from enough.

It can be seen from the above analysis that no matter where the damping block is added in the shell flow passage, the shell outlet pressure can not be uniform, and the outlet corner pressure is still too large.

5.2. The effect of increasing the inclination of bending side on melt flow

As shown in Figure 13, the exit pressure field when the bending inclination is increased, the maximum pressure at the exit corner of the flow passage after the bending side area inclination is increased is that compared with the maximum pressure at the previous corner pressure, the shell exit pressure value drops significantly. This scheme greatly improves the uniformity of the exit pressure of the bending area.

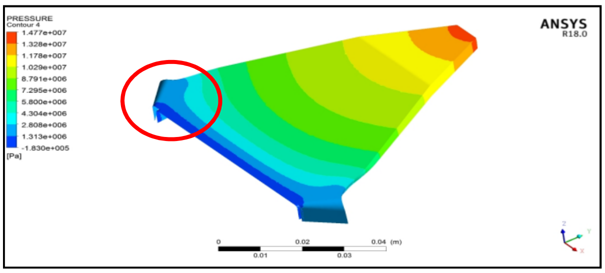

Figure 13. Exit pressure field with increasing inclination of bending position.

To sum up, scheme 1 and scheme 2 have a good optimization effect on co-extrusion results, respectively, adding damping block at bending position and increasing the slope of bending area side. Although the two schemes can improve the co-extrusion results, the effect is not obvious. Therefore, it is concluded that this is not the reason for the shell channel structure. At the same time, the preliminary conclusion is that the shape and structure of the co-extrusion head itself is unreasonable. In view of dead angle, uneven transition and other issues, the design of the extrusion head is redesigned, so the design scheme of the circular flow channel is proposed.

6. Design and co-extrusion simulation of circular flow channel of wood plastic cladding head

The overall structure of the coated co-extrusion head is initially designed, and its design section diagram is shown in Figure 14.The three-dimensional flow path of the coated co-extrusion head is shown in Figure 15.

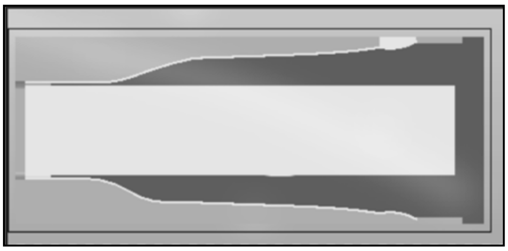

Figure 14. Design section diagram of channel of coated co-extrusion die.

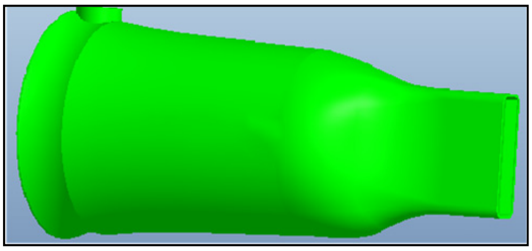

Figure 15. The 3D diagram of channel of coated co-extrusion die.

As shown in Figure 16. The value range of cone angle α in compression region is usually 10°～60°. The lower the viscosity, the greater the value.Considering that the wood plastic material belongs to the material with high viscosity, its cone angle α is taken as 23°.

When designing the flow passage, it should ensure smooth transition between sections and no dead angle, and the materials will not be piled up, so as to ensure uniform and stable extrusion. The size of the flow channel setting part should be equal to the size of the head, and each size value should be in a reasonable range. The structure diagram of the head flow passage is shown in Figure 16.

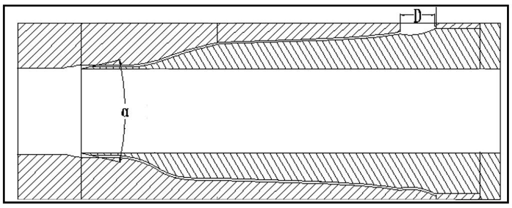

Figure 16. Schematic diagram of the overall structure of the die head.

6.1. *Pressure field distribution in co-extrusion process*

In the CAE simulation software, the boundary conditions are set first, then the calculation results are run, and finally the CFD-POST is used. See Figure 17 for the distribution of pressure field of co-extrusion shell material and Figure 18 for the distribution of pressure field of core material. It can be seen from the analysis that the overall flow channel pressure value of both shell and core decreases from the inlet to the outlet, and the pressure value when the fluid just flows into the flow channel is the largest. Take the core as an example, as shown in Figure 18, the pressure value of the core flow passage is 0.418 MPa when the fluid just enters and 0.035MPa when it exits. It can be seen that the pressure distribution in the channel is reasonable.

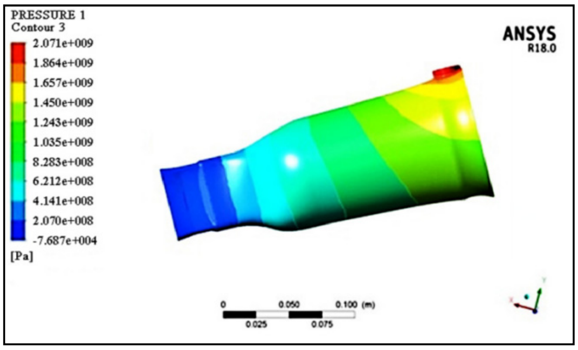

Figure 17. Pressure change cloud chart of shell material.

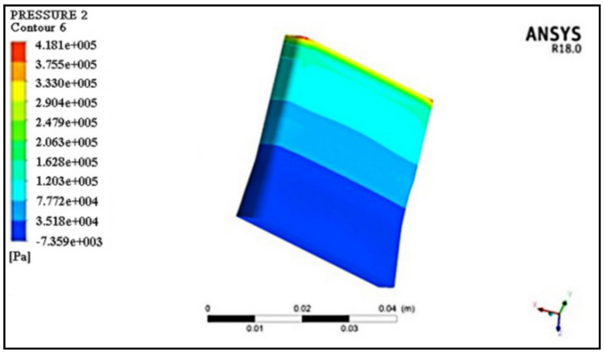

Figure 18. Pressure change cloud chart of core material.

6.2. Velocity field distribution in co-extrusion process

Figure 19, Figure 20 and Figure 21 respectively show the velocity change initial of the material at the entrance, core and shell composite parts and exit of the machine head. Based on the analysis of these three figures, it can be seen that the velocity of the material flow has the corresponding flow trend, and the velocity range is to; the velocity contour conforms to the middle value and the two values are small and symmetrical circular distribution.

Before the core-shell material is compounded, it is necessary to ensure that the velocity of its cross-section in horizontal and vertical directions is evenly distributed. For core and shell materials, the velocity should meet the trend of larger center value and smaller on both sides. It can be seen from the figure that the maximum velocity of core material is at the center of its section, while the maximum velocity of shell material is at the center of both corners. The change of velocity in the compound position of die head usually coincides with this trend. In addition, before the core-shell composite, the velocity difference between them is larger; in the core-shell composite region, the velocity difference between the two interfaces is smaller and smaller, and the horizontal and vertical velocity distribution is also uniform. At the exit of the die, the velocity at the composite interface of shell core and shell tends to be equal, that is to say, it can basically achieve the effect of uniform and constant extrusion in the die head. The reason why the speed of the shell material increases at the exit is that the composite material has high viscosity, so the shear stress inside the core layer is strong, which makes it not easy to rebound and relax in the head, while the extrusion head will produce rebound shrinkage, which makes the wall speed increase. From the whole flow process, the distribution of melt velocity is basically uniform and reasonable.

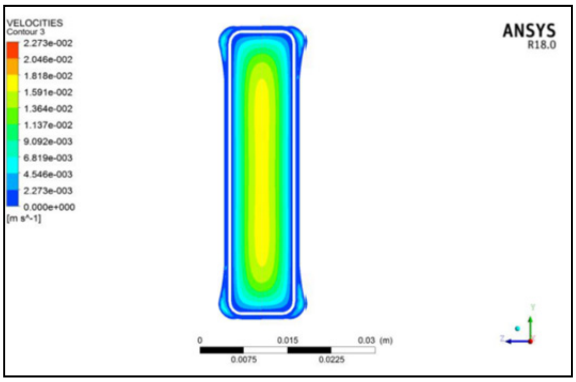

Figure 19. Velocity field at the entrance of the die head.

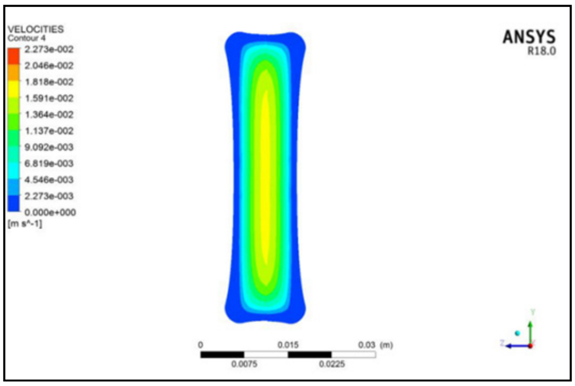

Figure 20. The velocity field of the compound part of the head.

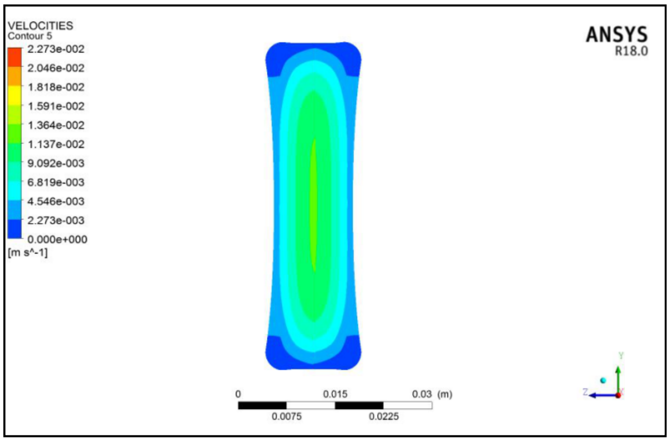

Figure 21. Velocity field of die outlet.

7. Summary

In order to solve the problem of uneven coating of wood plastic profile products in co-extrusion experiment, the flow channel analysis and Simulation of existing die head were carried out. In this paper, first of all, the core and shell flow channel of the head are simulated separately, and it is found that the problem is the shell flow channel. Secondly, through a series of improvement schemes, it is found that the existing head shape itself has problems. Finally, the design scheme of circular flow channel for co-extrusion head is proposed.

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