Finite Element Analysis of UHMWPE Film Extrusion Molding

[1]Lianpeng Mei, [2]Qingxue Zhang and [3]Yan Sun,
[1, 2, 3]College of Mechanical and Electronic Engineering, Shandong University of Science and Technology, Qingdao, China

***Abstract*—**Due to the poor mobility of ultra-high molecular weight polyethylene (UHMWPE), its melt index is almost zero. At present, UHMWPE thin films are mainly made of UHMWPE sheets and machined. UHMWPE film can be stretched into sheet after melt extrusion, which has the advantages of low cost, energy saving and environmental protection, continuous production, high efficiency and simple operation. In this paper, the Polyflow software is used to simulate the melt flow behavior in the UHMWPE film flow channel. Through the analysis of the velocity field and pressure field in the flow channel, the regularities of distribution of the pressure and velocity fields of UHMWPE melt in the flow channel are obtained, and some suggestions for the extrusion die and process design are given.

Keywords*—UHMWPE; flim; Polyflow; extrusion die; flow channel*

I. INTRODUCTION

UHMWPE is a polyethylene with a molecular weight of 1 million ~400 million or even higher. Its molecular structure is exactly the same as the structure of HDPE, and the difference is that the molecular weight of UHMWPE is very high. UHMWPE has some excellent properties, such as excellent abrasion resistance, impact resistance and low temperature resistance, which are not possessed by ordinary polyethylene (PE) and other resins [1]. In addition, the density of UHMWPE is about 0.935g/cm^3, which is the lightest plastic in engineering plastics [2]. UHMWPE has low friction coefficient and is an ideal self lubricating material [3]. UHMWPE film has become a widely used industrial raw material. It is widely used in coal mining, shipbuilding, transportation, insulation materials, anti friction gaskets and many other occasions and products.

This paper has established the finite element model of extrusion processing for UHMWPE film melt. The extrusion die of UHMWPE film is designed with fishtail die adopted while the thickness is 1mm and the amplitude is 100mm. Polyflow is used to carry out finite element simulation of melt flow in extrusion channel. The distribution of velocity and the pressure of the melt in the channel have been obtained by using the different geometric models respectively. The influence of baffle block, steady flow region and the length of forming region on the flow are discussed. It has been obtained that the height of baffle block and the length of steady flow region and forming region has influence on extrusion processing, and certain reference on the design of the UHMWPE film extrusion die is proposed.

II. FLOW CHANNEL STRUCTURE DESIGN

The commonly used sheet extrusion heads are mainly fish tail type head, branch tube head and hanger type head. The branch head and hanger type head are suitable for the melt with better fluidity. The fish tail type head is suitable for the melt with poor fluidity. In this paper, the fish tail type head is used in the UHMWPE.

The fishway structure is mainly divided into four parts: the transition region, the fishtail region, the steady flow region, and the forming region. The transition region adopts the circular variable square free transition [4]. The expansion angle of the runner is 80 degrees, the thickness of the die area is 1mm, the width is 100mm, the inlet thickness of the fishtail area is 7mm, and the outlet thickness is 5mm. Because the structure of the flow path is planar symmetry, the 1/2 flow channel is selected for analysis, as shown in Fig. 1.

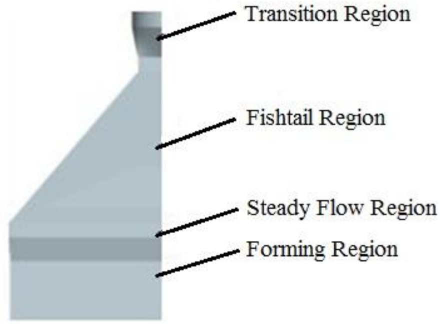


Fig. 1. Channel structure with fishtail type

III. FINITE ELEMENT MODELING

According to the theory of polymer rheology and the characteristics of UHMWPE film extrusion molding, the following assumption is made to the finite element model [5,6]: (1) no slip on the wall; (2) neglecting the inertia force; (3) isothermal laminar flow; (4) the melt is incompressible.

The flow behavior of melt in the flow path conforms to continuity equation, momentum conservation equation and energy equation. The constitutive equation is selected as the Power model, and the modified UHMWPE is selected as the research object. The zero shear viscosity is 13000Pa·s, the relaxation time is 0.3s, and the power law index is 0.275 [7]. The volume flow rate of the entrance is $Q=1.6\times10^{-5}m^3/s$. The Picard algorithm is used for iterative calculation [8].

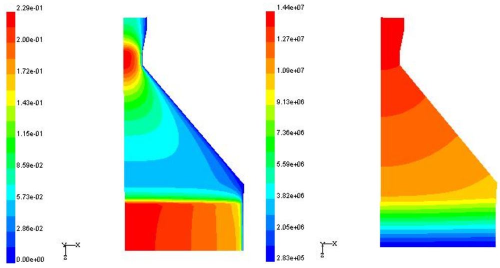
IV. SIMULATION RESULTS AND ANALYSIS

A. *Influence of baffle block on Molding*

The nonlinearity of material and the irregularity of mold structure. In order to obtain the uniform velocity distribution at the outlet, the forming law with and without the baffle block is simulated in the case of no steady flow, and the influence of the baffle block on the velocity field and pressure field is studied.

1) Distribution of velocity and pressure fields without baffle block

Fig. 2 is the distribution of velocity and pressure fields without baffle block. It is known from Fig. 2 that the velocity distribution tends to decrease from the center to both sides, and the velocity varies greatly in the tail area, and the velocity is relatively large in the forming area, which is due to the relatively small cross section area of the forming area. The pressure of the melt in the extrusion direction gradually decreases, and the pressure gradient in the tail area is larger and the transverse distribution of the extrusion direction pressure is gradually uniform, and the distribution uniformity is best in the width direction in the forming area. Considering the velocity and pressure distribution, the velocity uniformity of the outlet is very poor, so the scheme can not meet the requirements of product processing.



(a) velocity distribution (b) pressure distribution

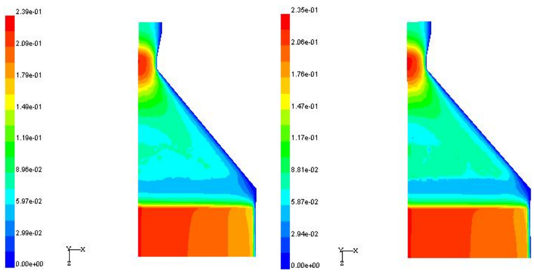
Fig. 2. The distribution of pressure and velocity without baffle block

2) Distribution of velocity and pressure fields with baffle block

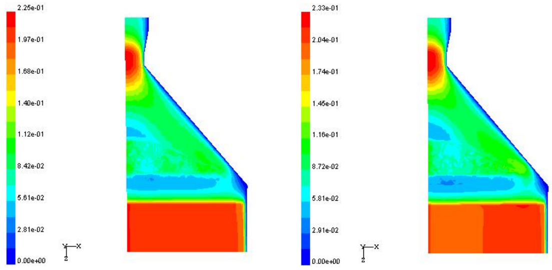
The baffle blocks with different heights were designed in the channel, and the flow law of the melt was simulated by finite element method. Fig. 3 and Fig. 4 are the velocity and pressure distributions of the melt in the flow channel of four high block blocks respectively, where h represents the length of the molding zone.

Fig. 3 is compared with Fig. 2(a). It is known that the velocity changes in the fishtail area of the blocker block are relatively small, and the velocity distribution in the forming zone is relatively uniform and the velocity gradient is relatively small. A comparison of Fig. 3(a)-(d) shows that when the height of the block is 2mm, the velocity distribution is relatively uniform, and the speed uniformity at the exit is the best, which ensures the molding quality. In Fig. 3, compared with Fig. 2(b), the transverse distribution of pressure in the tail area tends to be uniform; at the same time, the maximum pressure drop at the exit and entrance of the choke is significantly higher than that of the unhindered flow block. Compared with Fig. 4(a)-(d), the pressure distribution in the forming area is very uniform in different height blocker blocks, but when the height of the block is 2mm, the lateral pressure distribution in the tail area is more uniform, which indicates that the blocker has a greater influence on the pressure distribution in the fish tail area and has less influence on the pressure distribution in the forming area.

According to the distribution of velocity and pressure, blocker blocks can effectively change the distribution of physical field in the flow channel, and the selection of the height of the choke blocks is very critical. According to the distribution of pressure and velocity, the fishtail flow channel in the model with 2mm height is the most reasonable.

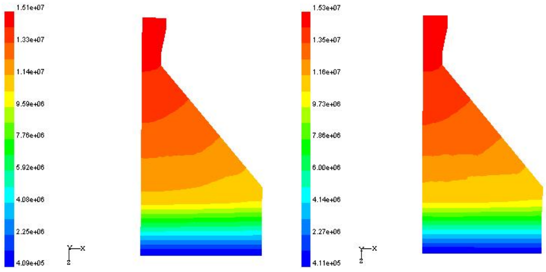


(a)h=1.6mm (b)h=1.8mm

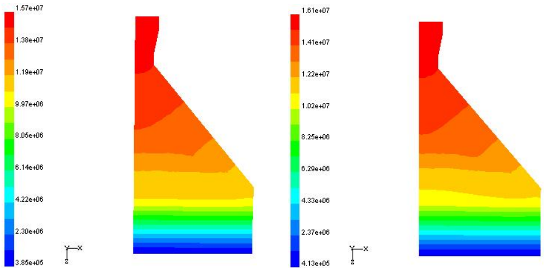


(c)h=2.0mm (d)h=2.2mm

Fig. 3. The velocity distribution of different height of baffle blocks



(a)h=1.6mm (b)h=1.8mm



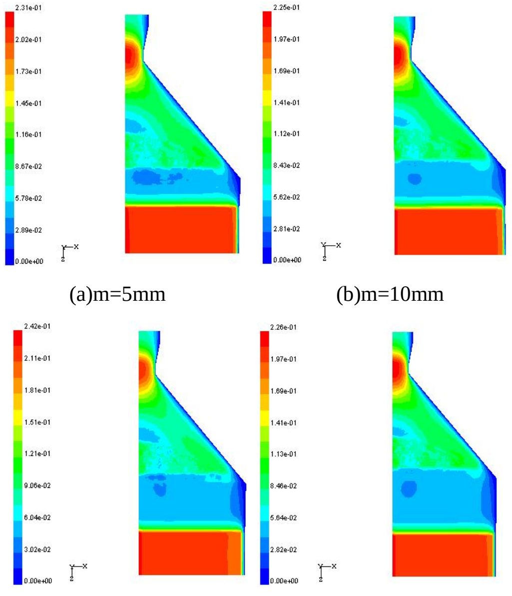
(c)h=2.0mm (d)h=2.2mm

Fig. 4. The pressure distribution of different height of baffle blocks

B. Influence of steady flow zone on velocity field and pressure field

Practice shows that the steady flow area can improve the inhomogeneity of velocity and pressure in fishtail area. The velocity distribution and pressure distribution in the flow channel are simulated by adding the length of 5mm, 10mm, 15mm, 20mm steady flow zone in the flow channel of the choke height of 2mm, respectively, as shown in Fig. 5 and Fig. 6, in which the length of the forming zone is expressed by m.

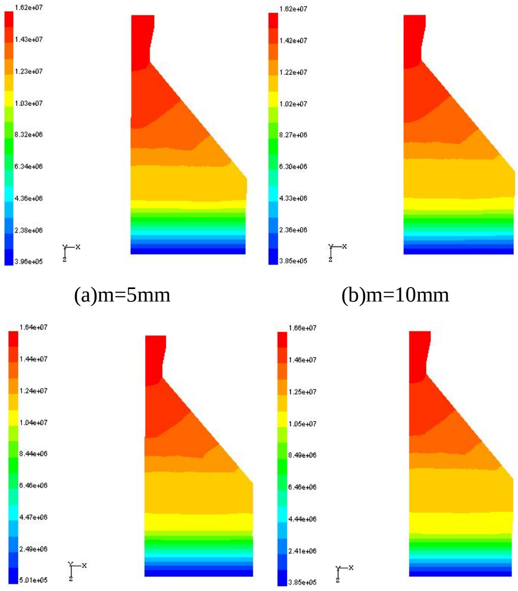
It is known from Fig. 5 that the velocity distribution of UHMWPE melt changes in the forming area after increasing the steady flow zone. Compared with the other three lengths, the velocity of the forming zone is the most uniform when the length of the steady flow zone is 5mm. Compared with Fig. 6 and Fig. 4(c), after increasing the steady flow zone, the pressure distribution trend in the flow channel is basically the same, the maximum inlet pressure is 16.2Mpa, 16.2Mpa, 16.6Mpa and 16.6Mpa, which can be seen that the total pressure drop in the channel is not much difference. It can be seen that increasing the length of the steady flow section in a certain range has no obvious effect on the pressure. This is because the thickness of the steady flow area is large and the resistance of the flow path is small. From Fig. 6(a) and Fig. 3(c), it is known that after increasing the steady flow area, the velocity in the forming zone is more uniform in the width direction than in the non steady flow area. Considering the speed and pressure distribution, the length of the steady flow area is 5mm, which is most beneficial to the extrusion of UHMWPE thin film, and the product with relatively stable size can be easily obtained.



(a)m=5mm (b)m=10mm

(c)m=15mm (d)m=20mm

Fig. 5. The velocity distribution of different height of steady flow regions



(a)m=5mm (b)m=10mm

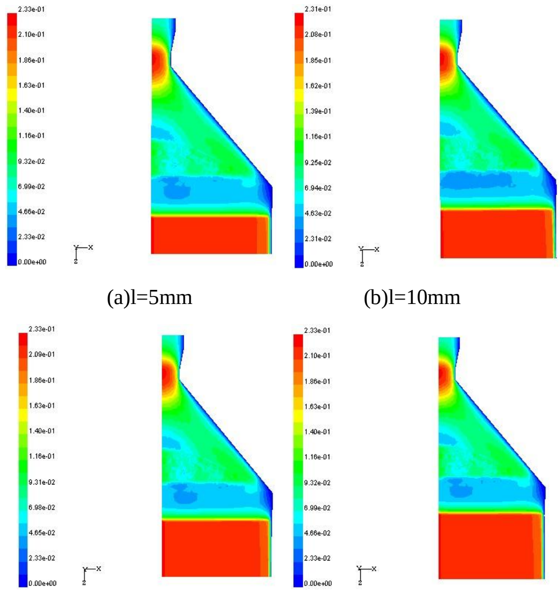
(c)m=15mm (d)m=20mm

Fig. 6. The pressure distribution of different height of steady flow regions

C. The influence of the length of the forming zone on the pressure field and the velocity field

In order to obtain the influence of the length of the forming zone on the melt flow, the length of the forming area is 15mm, 20mm, 25mm and 30mm respectively. Fig. 7 and Fig. 8 are the velocity profiles and pressure distributions of UHMWPE melt in the runner respectively. L represents the length of the forming area.

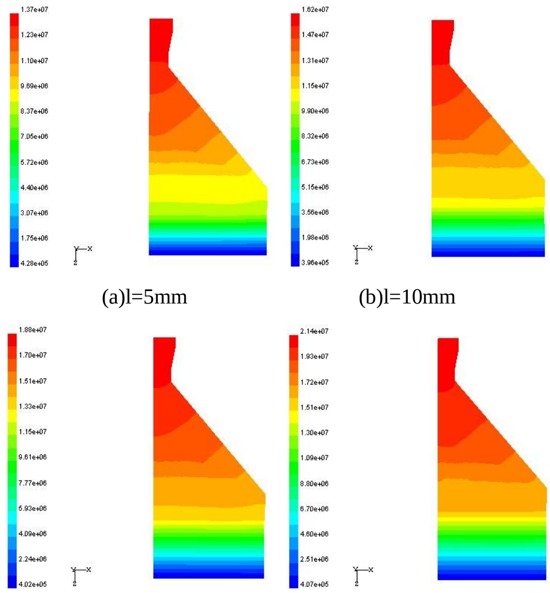
It is known from Fig. 7 that when the length of the forming area is 15mm, the velocity transverse gradient in the forming area is relatively large; the velocity distribution in the forming area is basically the same under the length of the other three forming regions. It is known from Fig. 8 that when the length of the forming area is increased, the forming pressure rises significantly, which is due to the thinner thickness of the forming area and the larger flow resistance. The pressure distribution trend in the fish tail area is slightly changed, but the pressure distribution trend in the forming area is basically unchanged. Considering the pressure distribution and velocity distribution, the increase of the length of the forming area is limited to the speed, but the pressure loss will be increased significantly. In addition, the length too long is not conducive to the processing and maintenance of the mold.



(a)l=5mm (b)l=10mm

(c)l=15mm (d)l=20mm

Fig. 7. The velocity distribution of different height of forming regions



(a)l=5mm (b)l=10mm

(c)l=15mm (d)l=20mm

Fig. 8. The pressure distribution of different height of forming regions

CONCLUSIONS

In this paper, the finite element simulation of the flow process of UHMWPE melt in the fish tail flow passage is carried out. The influence of the tail type channel structure on the extrusion molding of UHMWPE film is analyzed. The conclusions are as follows:

(1) When the flow block is blocked, the transverse pressure in the fishtail area and the velocity distribution in the molding area are more uniform. At the same time, the pressure in the runner can be increased to ensure the density of the product. The height of the block is too low or too high, which will cause the uneven distribution of pressure in the tail area, and lead to the increase of the velocity gradient in the forming area and cause the instability of the flow, which makes the product easy to have the quality problem.

(2) Within a certain length, the steady flow area has no significant effect on the pressure distribution in the flow channel, but it has a certain effect on the velocity

distribution in the molding area. The increase of the velocity gradient in the forming zone may result in defects due to the constant flow area.

(3) Properly increasing the length of the molding zone will improve the velocity distribution at the outlet, but will significantly increase the pressure drop.

Taking into account the impact of various aspects, it is recommended that block blocks should be designed when developing moulds. In order to obtain the uniform velocity of the exit, the height of the reasonable block is selected first, then the length of the forming zone is appropriately increased. Finally, the length of the steady flow zone is adjusted.

Acknowledgment

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