Fluent Software for Screw Flow Analysis of Wood Plastic Composite Synthetic Type Twin-screw Extruder

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Keyword: FLUENT, WPC , Extruder , Metering section, CFD

Abstract. The paper analyzed the flow of the diameter of 72mm twin screw extruder screw-type’s field measurement from some machinery co., LTD by FLUENT software. Firstly, through established the flow channel of three-dimensional entity model by Gambit, defined the boundary and completed the meshing simultaneously. Then, the property parameters of a formula processing of wood plastic composite materials were recorded as the already-known condition, and defined a model in FLUENT 3D calculator. Ultimately, fitting and solving in the FLUENT. Therefore, the nephogram of the pressure, temperature, velocity and shear stress distribution have been put out. Analyzing the wood plastic composited melting’s flow condition in this screw unit in order to investigated the problems existed in melt shear and delivery process. Actually these solved problems can direct the project designers choose the next-step optimal designing and technological parameters successfully so that yielding the wood plastic products with high quality and improving the competitive ability of the industry.

Foreword

Screw extruder[1][2]has been widely used In the field of plastics、 rubber、 food and medicine.Especially in the plastics industry, screw extruder[1] plays an important role。In the field of the plastic processing, the screw extrusion process what mainly is plastic or special materials containing plastics melt, mixed and then extruded through a screw.This process is directly related to the follow-up product quality is good or bad.The traditional trial and error approach to the design of the extruder screw, mainly rely on the expert's experience and personal feeling,witch lack of an experimental basis, and always with great blindness, will undoubtedly increase the cost of equipment design and manufacturing [3][4][5].Especially in this current period of rapid development of new materials, witch the Specificity of extrusion equipment is increasingly high, this design approach is more unsuitable.

However,the FLUENT software[4][6] witch based on fluid dynamics and developed can be a good deal to handle the problem with free surface flows,thus, applying it to studying simulation screw extrusion process, can greatly improve design efficiency.So,this paper based on the FLUENT software,analyzed the screw of co-rotating screw extruder witch dedicated highly to WPC,get the design parameters of WPC extrusion equipment by the function of reverse extrusion。

Establishment of mathematical model

According to the basic knowledge of fluid mechanics, any fluid satisfy the continuity equation, momentum equation and energy equation[6][7].Meanwhile, when the WPC sheared in a twin screw extruder, it is a non-Newtonian fluid that with high viscosity, and difficult to compress.。 Accordingly, when the wood plastic composite filled twin screw grooves, can be approximately regarded as a melt that non-compressible and flow stability.

So there is the mathematical relationship:

Continuity equation:

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$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \qquad (1)$$

Among them, u、v、w representing the fluid velocity in x、y、z direction.

Momentum equation:

$$\begin{cases} -\frac{\partial p}{\partial x}+\frac{\partial}{\partial x}(\eta\frac{\partial u}{\partial x})+\frac{\partial}{\partial x}(\eta\frac{\partial u}{\partial y})+\frac{\partial}{\partial x}(\eta\frac{\partial u}{\partial z})=0 \\ -\frac{\partial p}{\partial y}+\frac{\partial}{\partial y}(\eta\frac{\partial v}{\partial y})+\frac{\partial}{\partial y}(\eta\frac{\partial v}{\partial y})+\frac{\partial}{\partial y}(\eta\frac{\partial v}{\partial y})=0 \\ -\frac{\partial p}{\partial z}+\frac{\partial}{\partial z}(\eta\frac{\partial w}{\partial z})+\frac{\partial}{\partial z}(\eta\frac{\partial w}{\partial z})+\frac{\partial}{\partial z}(\eta\frac{\partial w}{\partial z})=0 \end{cases} \qquad (2)$$

Among them,*P* is pressure,the unit is Pa; η is the apparent viscosity of the fluid,the unit is $Pa{\bullet}s$.

Energy equation:

$$\rho C_p(u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}+w\frac{\partial T}{\partial z})=k(\frac{\partial^2 T}{\partial x}+\frac{\partial^2 T}{\partial y}+\frac{\partial^2 T}{\partial z})+\eta\gamma\frac{1}{2} \qquad (3)$$

Among them: ρ is the material density,the unit is Kg/m^3;C_p is the Specific heat capacity of materials,the unit is J/(Kg•K);*T is the t*emperature,the unit is K; γ is the Shear rate,the unit is s^{-1};*k* is the thermal Conductivity;the unit is W/(m • K).

Establishment of Physical model

Taking a same direction intermeshing twin-screw extruder with a diameter of 72mm produced by some machinery company as a model ,analysis the material status in unit runner of screw metering section,provide a theoretical basis for the improvement of follow-up equipment.Figure1、Figure2 are physical model of the screw fully engaged.The engaging direction is counterclockwise.And specific size:Diameter *D*=72mm；*Ds*=48mm；*d*=40mm；Screw center distance *a*=60.5mm；Screw thread lead *S*=56mm；The length of original screw thread *L*=56mm；The inner diameter of the sleeve D_b=75mm。

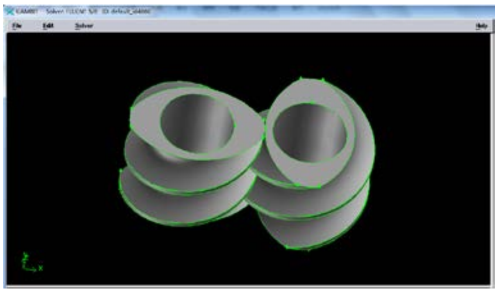

Figure 1 The three-dimensional model of co-rotating twin-screw extruder screw kneading

According to Figure 1,using the Gambit that a software developed by the FLUENT company for FLUENT software pre-treatment to establish the three-dimensional fluid model.

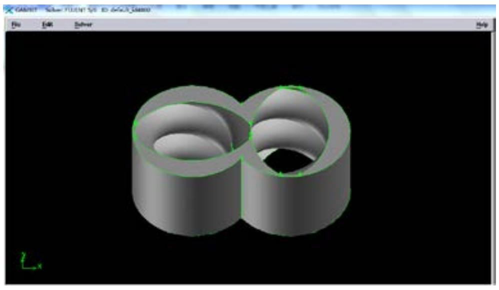

Figure 2a The flow model of twin-screw kneading

Figure 2b Gird flow field display

Define the boundary conditions in Figure 2,at both ends are set to：speed entrance,pressure outlet.Internal is set to no-slip rotation wall, while the outer surface is set to no-slip still wall .While its mesh, mesh resulting number is 151960.Trellis diagram shown in Figure 3.

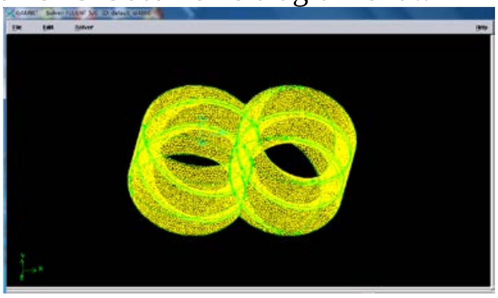

Figure 3 Fluid grid model

FLUENT Calculation and results analysis

FLUENT calculation

Use the hydrodynamic simulate the material parameters of a kind of WPC extrusion granulation process:WPC melt temperature was set at T=438K;Specific heat capacity Cp=1700J/(Kg • K);Non-Newtonian Fluid Index$n$=0.21;Carreau Model parameters λ =0.33s;Density ρ =657Kg/m3;Viscosity η =46800Pa • s;Thermal Conductivity k=0.18W/(m • K);Screw speed N=70rpm;Outlet pressure P=2.9MPa.

The fitting result of initialization model in FLUENT,as shown in Figure 4.

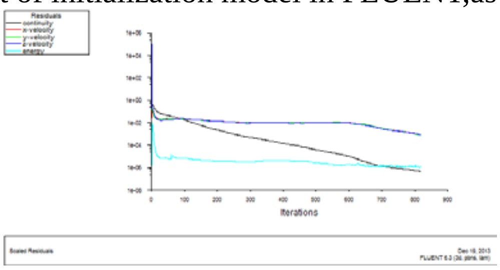

Figure 4 Model fitting results

From Figure 4, it can be seen that the velocity, energy, and the total control line of the model converges after 819 times calculation . Thus, the model can be calculated in the FLUENT software.

The Analysis of Result

Analysis of pressure field

In FLUENT, the pressure distribution is calculated as follows:

Figure 5 XY plane static pressure contours

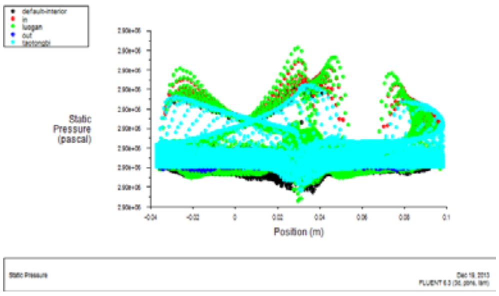

Figure 6 The static pressure contours in various boundary conditions

Figure 5 shows the static pressure contours in XY plane and can be seen from the figure,the static pressure distribution changes along the direction of rotation of the screw.The static pressure reaches the maximum before the material going into the kneading zone.And at screw spiral groove the static pressure reaches minimum.Figure 6 is a scatterplot of static pressure distribution on various boundary conditions,as can be seen from the figure,nearby the two wall boundary conditions,the static pressure distribute wide, and the minimum static pressureappeared at 0.03m.At the same time it can be seen that the static-pressure much more higher at inlet boundary condition than other.

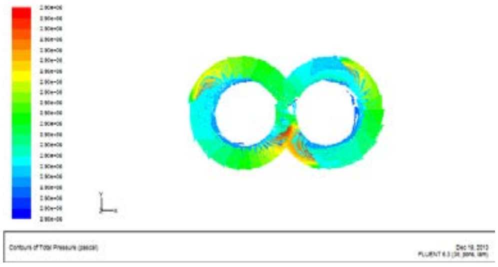
Figure 7 Total pressure contours of imports surface

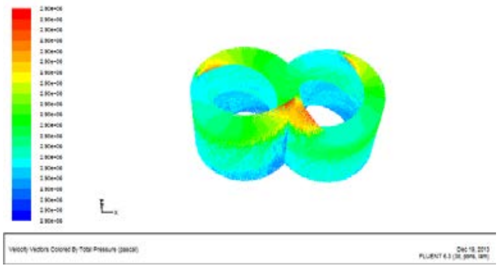
Figure 8 Total pressure contours

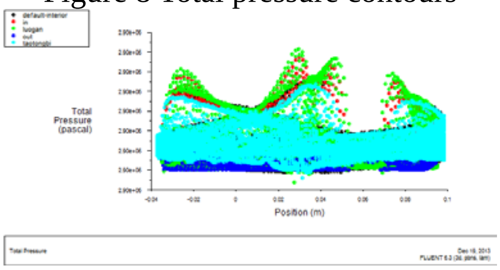

Figure 9 Distribution scatter plot of total pressure

From Figures 7 to 9, shows the total pressure distribution diagram of the model, it can be seen from the figure that the total pressure distribution is related to the boundary conditions.From Figure 7 and Figure 8, it can be seen in that when the material is about to enter the left screw kneading zone and left the right screw kneading zone, a total pressure peak appears, therefore,cut the best material here.At the same time it can be seen that near the sleeve wall along with the direction of rotation of the screw, the total pressure decreased.It will lead to that the material in the wall near the sleeve stays at the surface, and leakage appears even stuck in the barrel wall, forming a layer of mucous membrane, witch is not conducive to improving thermal efficiency.

As can be seen from Figure 9, the total pressure unevenly distributed in the respective boundary conditions. At the inlet total pressure are larger.At the outlet of the pressure, the total pressure is generally low. This is conducive to the formation of a smooth flow path for materials within the spiral groove, which is help to increasing the production.

Temperature distribution

In FLUENT, the temperature distribution is calculated as follows:

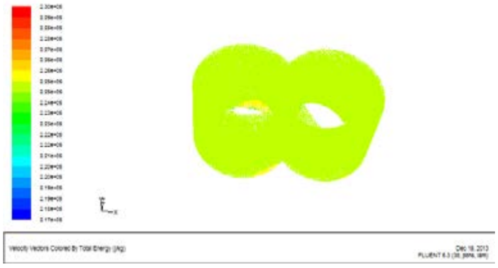

Figure 10 Total endothermic of the system

Figure 10 shows the total endothermic of the system,as can be seen from the figure,only higher at the inlet boundary, and therefore, the material has been substantially melting completely before entering the zone.At the same time, incompletely melted portion is fully melted in the region .

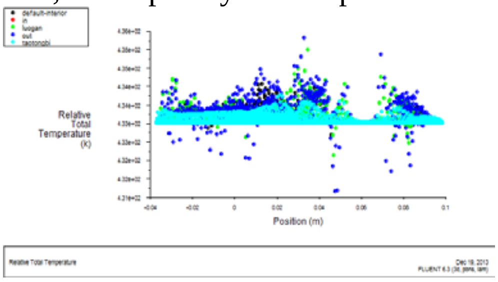

Figure 11 Scatterplot of total temperature distribution

Figure 12 Total temperature contours

Figure 11 and 12 shows the total temperature distribution contours of the model, it can be seen from the figure that the temperature of the model distributed evenly.The main reason is that the material is substantially in the molten state in the region , and the the temperature has stabilized.It can be seen that, under this model, the material is melt better.

Velocity distribution

In FLUENT, the velocity distribution is calculated as follows:

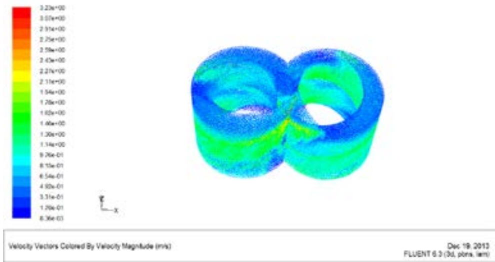

Figure 13 Overall velocity contours

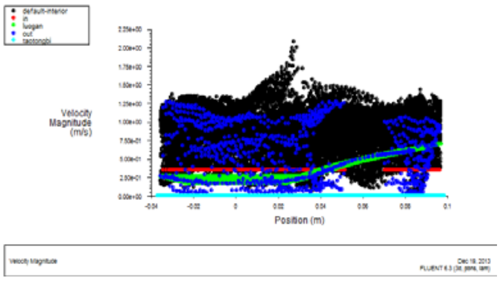

Figure 14 The scatter plot of overall velocity distribution

Figure 13 and 14 shows the scatter plot of overall velocity distribution,as can be seen from the figure,the velocity distribution at the respective boundary conditions are quite different.Especially in figure14 performed significantly. The material flow rate close to zero near the sleeve wall.therefore, it can be seen that leakage impact the material near boundaries flow forward .

The distribution of screw shear force field

In FLUENT, the screw shear distribution was as follows:

Figure 15 Shear contours

Figure 15 shows the shear contours.As can be seen from the figure, the screw shear ineffective on the screw border, particularly the screw shear smaller the closer to the wall . Therefore, it can be seen that the screw of this size does not fit high-speed mixing of the material.

Discussions

As can be seen from the above analysis,configuration of the Metering section screw of The granulator extruder kneading with a twin-screw dedicated to this WPC, processing and wood production process requires attention to the following points:

(1)Narrowing the gap between the screw outer diameter wall and the sleeve.

(2)In order to improve the quality of wood-plastic composite materials, the need for additional kneading block section of the metering unit to improve the mixing effect of wood-plastic composites.

(3)Production process, to improve the fluid pressure within the screw.Increased pressure in favor of material leading out on the one hand, while reducing the leakage flow, thereby improving yield.On the other hand,also can improve the material shear effect and improve product quality.

Conclusion

This paper obtained the pressure,temperature, velocity and shear stress contours of the metering section screw, by conducted FLUENT numerical simulation to the unit of the twin-screw extruder screw which with a diameter of 75mm that produced by a machinery company.Doing a good theoretical groundwork for optimization design of the equipment subsequent and also has important practical significance.And metering section directly affects the quality of products, it is essential to study aid of FLUENT software.

With CFD software to simulate the flow state of WPC produce and processing ,through analysis of the results data that obtained from simulated ,help to optimizing the design of the WPC dedicated extruder, thus promoting the development of wood-plastic industry.In this polymer fast-growing days proactively use CFD software to optimize the design molding equipment is particularly important.

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