Influence of Glass fiber orientation on FE results for GF material models

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Abstract. The plastic parts with glass fiber filled material behaviour is different from the parts with no glass fiber material. While considering the material data in Finite Element Analysis as multilinear isotropic but this assumption leads to inaccurate results from FEA. So to get better results, the steps needs to follow in FEA process are presented in this paper. In addition to this material properties other factors like, Geometry conditions, loads and boundary conditions, etc., are also have major influence on FEA results. However, the study in this paper is limited to 10% glass filled plastic parts only.

Keywords: Glass fiber, orientation, breaking strain, Multilinear Isotropic, Moldflow, ANSYS, Digimat.

1. Introduction
In any structural Finite Element Analysis model, material properties used in CAE tools based on standard assumptions under standard conditions. Generally, in linear structural simulations we use linear material properties especially for the metal parts. In case of plastic parts, the behavior is non-linear unlike metals. Material stress-strain curve for the metals have clear indication of yield point but not the same with plastic material property. So always recommended to use non-linear (Stress-strain) data for plastic parts in FEA. To improve the strength of plastic parts, manufactures use the glass fiber filled plastic materials. This inclusion of glass fiber in plastic material matrix will change the strength of the parts and hence the change in material properties. Therefore, the material property to be used in FEA should include the influence of these fibers in Plastic parts.

2. Glass filled plastic materials²
To improve the mechanical properties like strength, thermal properties, etc., of components glass fibers are added to the base plastic material while manufacturing of the parts under molding process. These glass fibers are added in volume fraction of 10 to 35% based on the requirement of their performance in applications.

For these standard materials, the stress-strain data are published through CAMPUS (www.campusplastics.com) by material suppliers. In this database, standard material properties are published in addition to stress-strain curve under different testing conditions.

2.1. CAMPUS data
The data available in CAMPUS is standard data obtained under standard testing conditions with standard specimen. Figure 1 and 2 shows the Campus database for the material PBT GF10 from BASF.

**Figure 1.** CAMPUS data base.

**Figure 2.** Stress-strain data from CAMPUS.
2.1.1. Fiber orientation in test specimen.

The orientation of fibers in test specimen has greater influence on stress-strain data and hence the output results of FEA. Figure 3 shows the stress-strain data for the specimen under different fiber orientation.

![Figure 3. Stress-strain data for 3 different orientation of fiber in test specimen.](image)

3. Geometry model

Figure 4 shows the pro-E geometry model of the latch part is considered for this study, which is manufactured through molding process with PBT GF10 material. This Pro-E model is under nominal dimensions and is used to create Finite element model. Simplified CAD model shown in figure 5 considered for simulation to save the solution time.
4. Finite Element Model with loads and boundary conditions

Portion of the Geometry considered for Finite element modeling to reduce the solution time without compromising on stiffness of the model. Hypermesh tool used for Finite element modeling and Ansys is used for solving and post processing the results.

Figure 6 shows the FE model with second order tetrahedron elements and fixation and loading condition. Latch displaced using rigid portion of the counterpart which moves the latch part while assembling the two parts.

5. Lab test

There were twenty samples selected for physical test, these samples selected from different cavity molds to cover the complete possible range of elasticity of the latch part. Tool speed used is 50mm/min. Figure 7 shows the test set up of the sample.
6. Results and discussion

Two parameters considered while comparing the Test and FEA results. First Parameter is Elasticity and second parameter is failure criteria. For elasticity comparison, average value of reaction force of all the twenty samples considered in this study. Figure 8 shows the force versus displacement curve for the lab test models and FEA results. We can observe that, FEA results are close to the lab test (maximum curve) result from elasticity point of view.

![Graph showing force versus displacement](image)

Figure 8. Force [N] versus applied displacement [mm].

Von-Mises strain distribution and principal-1 strain distribution at applied displacement of 3 mm is shown in figure 9. We can observe that, the strain value exceeded the two times the breaking strain of the material. Where we can expect the initiation of crack. Similarly the figure 10 shows the strain values at applied displacement of 3.3mm displacement, at this condition the breakage region is clear and same effect observed in lab test too. Failed test samples and FEA results at applied displacement of ~6.2 mm
is shown at figure 11. At failed components we can see the fibers cut off at root of the fillet. The force curve increase even after the crack initiation is due to strength of fibers, this force curve suddenly drops once these fibers cut off at the root of the fillet. This fiber orientation influence effect is considered in FEA using digimat\textsuperscript{1} simulation by overlapping the mold flow model. This will capture the fiber orientation effect in FE model.

Figure 9. von-Mises strain and principal-1 strain distribution at applied displacement of \(\sim 3\) mm.

Figure 10. von-Mises strain and principal-1 strain distribution at applied displacement of \(\sim 3.3\) mm.

Figure 11. von-Mises strain distribution at >6mm displacement and test samples after the breakage.
7. Conclusions

- For the Glass fiber plastics it is always recommended to use the material properties extracted by considering the fiber orientation effect.
- Matching of elasticity is not so critical by using proper FE model, reliable material data and realistic boundary conditions.
- To identifying the failure region and failure time/displacement is more critical. For this, careful study of strain distribution in FE model and use of proper material data in FE model is very much required.
- It is always recommended receive the proper material data from the material supplier under required strain rate condition to get better results from CAE tools.
- Special care should be taken while creating the FE model and applying loads and boundary conditions.

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