Abstract: A Continuum (filled polymer) is inhomogeneous and anisotropic. The Continuum is used in an injection moulding simulation at first (generally unnewton type of fluid). Then the continuum is solid (after cooling) and it is possible to carry out ordinary dynamics structural analysis with it. The solid continuum has different mechanical properties for each of discrete element. A consequent dynamics properties (natural frequencies) will generally have different values when influence of injection moulding is taken into account for analyses.

KEYWORDS: FIBER ORIENTATION, INJECTION MOULDING, RHEOLOGY, NATURAL FREQUENCY, STRUCTURAL ANALYSIS, FEM, MESH

1. Introduction
The essence of the analysis was multiphysics task that combines structural dynamics analysis (FEM) and analysis of injection moulding for filled polymer (glass fiber). For the analysis of injection moulding technology parameters are changed according to the statistical distribution. The results of this multiphysics analysis were investigated.

2. Preconditions and means for resolving the problem
See the figure 1.

2.1. Generating of oriented mesh of elements (Mentat)

2.2. Determination of input parameters using the Monte Carlo method
They were set variables that are subjected to variation. In our case it was the injection time, melt temperature and mould temperature, in which the melt (filled polymer) is injected. It is appropriate to analyze the influence of individual variables using tools DoE (Design of Experiments). It was found that any of the factors is negligible. These factors are subsequently changed (due to the Monte Carlo method) according to a given distribution.

2.3. A random number generator
The change of the input parameters was performed through random number generator.

2.4. An injection moulding simulation
The oriented mesh was generated first in Mentat (see the figure 3). This mesh was (orientation included) imported into Moldex3D (see the figure 4) where the mesh for injection inlet was also modeled. After performing the initialization simulation, the mesh and material characteristics with a reduction were re-imported into Mentat again.

2.5. Export of the mesh with material properties of each element
Mentat loaded 225799 elements and 30418 material groups (material properties). The number of materials was therefore reduced to about one seventh. That means that roughly every 7th element has its unique material properties. Let us point out the reasons why we reduced the number of materials and why we did not create a full export of material properties for each element. Full conversion was performed but it turned out that the mesh export...
from Moldex lasted for about 1 hours and the import into Mentat took incredible 7 hours! If we add a time for the analysis of injection moulding process and for the structural analysis we get to number about 8 hours per test. These are significant time costs. This time has to be multiplied by the number of performed iterations (the number of analyses with different technological parameters). This leads to a number from 1000 to 2000 hours of computing time! To be able to make our desired summary analysis (hundreds) a reduction of material groups is required. Time per analysis is thus shortened from about 7 hours to 40 minutes. So we have reduced the required processing time about 10 times.

3. Solution of the examined problem

As we know, the results should have a statistic character. In order to make the results of a statistical sample relevant, 256 experimental analyses were performed. Note that the input parameters were changed in the range of ± 7% of the nominal value (the nominal value of injection time = 0.8s, the nominal value of melt temperature = 230°C, the nominal value of mould temperature = 30°C). Histograms of generated input parameters are showed on the figure 5.

4. Results and discussion

The resulting data are processed into graphs in figures 6 to 9, which are actually the output of our previous efforts.

From the frequency distribution it can be estimated that for an increasing number of analyses the trend of frequencies would probably converge to a curve of normal distribution. This trend is evident in all ten monitored graphs and it is even shown by the red curve of approximation, which is connected to the charts (see the figures 7 to 9) The polynomial regression of the 4th order was used for this trend curve. This frequency distribution could be expected because input technological parameters were also selected along the pattern of the normal distribution, and this assumption was indeed confirmed. Each “overlaps” and “teeth” from “ideal” approximation functions are evidently caused by a relatively small...
number of experiments - even if it seems that number of 256 experiments is relatively high, it is estimated that the extermination of these deviations would be required experimentation by one order more. Another factor that may distort the frequency distribution is the choice of the width of the intervals (classes). Inappropriate choice can lead to underexposure or overexposure of frequencies. While the frequency distributions along the lines of the normal distribution were expected,
considerable low variability in range of natural frequencies of continuum definitely surprises. Note that the input parameters are changed in the range of ±7% of the nominal value (the injection time, melt temperature and mould temperature). But an output response varies in much thinner bands. When the middle value of each histogram is taken as a nominal value then we get a range of bandwidths responses:
- The response range for the 1st natural frequency is 716,575 Hz ± 0.775 Hz ≈ 716,575 Hz ± 0.1%.
- The response range for the 2nd natural frequency is 843.3 Hz ± 1.2 Hz ≈ 843.3 Hz ± 0.14%.
- The response range for the 3rd natural frequency is 892.2 Hz ± 1.2 Hz ≈ 892.2 Hz ± 0.13%.
- The response range for the 4th natural frequency is 1039.75 Hz ± 0.75 Hz ≈ 1039.75 Hz ± 0.07%.
- The response range for the 5th natural frequency is 1113.1 Hz ± 1.1 Hz ≈ 1113.1 Hz ± 0.1%.
- The response range for the 6th natural frequency is 1362.25 Hz ± 1.15 Hz ≈ 1362.25 Hz ± 0.08%.
- The response range for the 7th natural frequency is 1401.8 Hz ± 1.6 Hz ≈ 1401.8 Hz ± 0.1%.
- The response range for the 8th natural frequency is 1652.4 Hz ± 1.4 Hz ≈ 1652.4 Hz ± 0.08%.
- The response range for the 9th natural frequency is 2154.1 Hz ± 2.3 Hz ≈ 2154.1 Hz ± 0.11%.
- The response range for the 10th natural frequency is 2423.6 Hz ± 3.8 Hz ≈ 2423.6 Hz ± 0.16%.

5. Conclusion
It follows that the variation of the input process parameters of injection moulding (the injection time, melt temperature and mould temperature) of 7% brings a variation of the output response (natural frequencies) in average range about 0.1%! It certainly was not an expected result. These results suggest that the effect of fiber orientation (caused by input parameters of injection moulding) has practically no influence on the dynamic behaviour of the continuum.

6. References