Injection molding using plastics is inconsistent thereby making quality control difficult. We analyzed various methods to determine the consistency and strength of polystyrene gears using Moldflow™ simulation software, thermal-fluid analysis, cost and expert analysis. While the strength of the polystyrene was found to vary, it is possible to predict the gear strength based on standard tensile tests. It was also determined that decreasing cycle time can increase productivity as well as decrease the manufacturing cost per gear. Doing so should not sacrifice the quality of the gear.

**Abstract**

Injection molding using plastics is inconsistent thereby making quality control difficult. We analyzed various methods to determine the consistency and strength of polystyrene gears using Moldflow™ simulation software, thermal-fluid analysis, cost and expert analysis. While the strength of the polystyrene was found to vary, it is possible to predict the gear strength based on standard tensile tests. It was also determined that decreasing cycle time can increase productivity as well as decrease the manufacturing cost per gear. Doing so should not sacrifice the quality of the gear.

**Introduction**

Recent concerns have arisen regarding the strength of polystyrene gears. Current quality control methods for testing gear strength show varying results. We extensively tested the force required to break single and multiple gear teeth near and away from weld lines. To test the quality control methods, the results of these tests were then compared to standard tensile tests. Our thermal-fluid analysis provided cooling times for the gears. Our analysis with process analysis was used to validate the Moldflow™ simulation program. Further investigation into the presence of air traps and weld lines as well as sprue location, were carried out. Cost and manufacturing processes were optimized based on these results.

**Gear Strength**

![Graph showing gear strength analysis](image)

**Gear Strength**

The graph shows the force required to break single and multiple gear teeth near and away from weld lines. Cooling times for the gears were also provided for standard tensile tests. The data was used to validate the Moldflow™ simulation program.

**Expert Analysis**

- The response of tensile stress to a gear under tensile strength
- The response of injection rate to a gear under tensile strength
- The response of mold temperature to a gear under tensile strength

**Results**

- Cooling times for gears were determined.
- The effect of single and multiple gear teeth near and away from weld lines was analyzed.
- The response of injection rate to a gear under tensile strength was studied.

**Conclusion**

Gear strength was dependent on temperature and less on injection rate. Further, the type of tooth interaction, single or multiple, was more important than the location of the interaction relative to weld lines. Moving the sprue location to the middle of the mold could provide additional failure modes. Simulation of this showed a residual shear stress concentration through the middle of the gear, as well as additional air trap formations.

By applying the formulated equation, tooth strengths can be predicted based on the melt temperature and injection rate. Tensile tests were also conducted to validate the simulation results. Further investigation into the presence of air traps and weld lines as well as sprue location were carried out. Cost and manufacturing processes were optimized based on these results.

**Quality Control**

- Standard tensile tests were conducted.
- The response of injection rate to a gear under tensile strength was studied.
- The response of mold temperature to a gear under tensile strength was studied.

**Wild Lines**

- Further analysis showed that the results of these tests were consistent with the Moldflow™ simulation program.
- Air traps were also considered as a potential source of failure modes.

**Cost and Production Analysis**

- The cost of injection molding was calculated based on the results of these tests.
- The impact of cycle time on cost was analyzed.
- The impact of quality control on overall cost was studied.

**Conclusion**

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