UGRacing's Gear Train Solutions from Combustion to Electric

Jordan Pitt

UGRacing is the University of Glasgow's Formula Student team. Since its inception in 2005, the team has been working to compete at Formula Student UK (FSUK). Over the last decade, the team has grown to over 150 members across ten disciplines. With a strong focus on knowledge transfer and iterative design, the team has worked year after year to develop new technologies and a more refined package. In 2022, the team saw a culmination of all their hard work when they placed first overall in FSUK with their final internal combustion vehicle. The following switch to an electric powertrain brought new challenges. Through the constraint of a new powertrain architecture, the team has explored and innovated drivetrain concepts which, in future years, will improve vehicle performance.

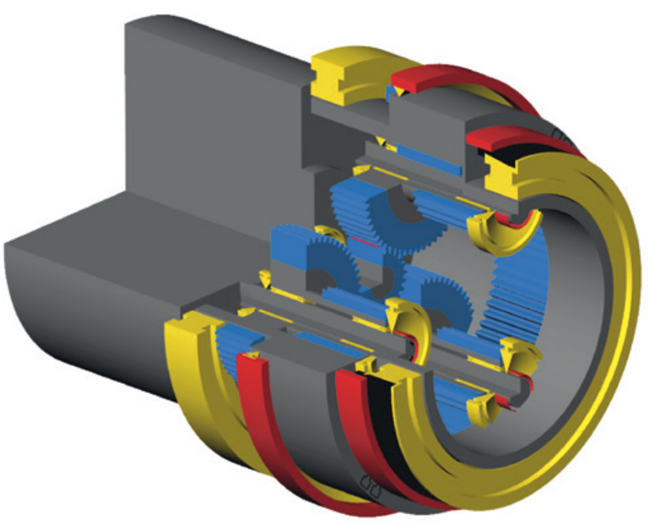


***Figure 1—Compound planetary gear train within* KISSsoft.**

Technical Problem

The drivetrain team faced an important technical challenge in designing an appropriate gear train that will be used when they transition to hub motors. Hub motors refer to electric motors being mounted within each wheel assembly, and the motors provide drive to the vehicle's hubs via a gear train, avoiding the conventional drivetrain setup, which involves driveshafts.

With the electric motor and gear train being constrained to fit within the ten-inch magnesium wheels that they currently use, a compound planetary gear train was required and modeled within *KISSsoft,* as shown in Figure 1. Due to each planet gear consisting of two stages that are constrained in terms of the center distance for each stage, the macrogeometry tool within *KISSsoft* allowed them to obtain appropriate gear sizes according to the ISO 6336 standard whilst meeting our desired gear ratio. By defining the required safety factors followed by the specific conditions, the macrogeometry tool provided ear sizes that minimized and balanced the specific sliding of the gear mesh and provided hunting tooth ratios to improve wear distribution and minimize gear vibration. For their first electric vehicle entry last year, the drivetrain sub-team designed a custom planetary gearbox using *KISSsoft.* Following this design, they had a specific oil supplied by one of their sponsors in terms of yellow metal protection and viscosity. For the design of this new gear train, they wanted to incorporate the properties of this oil into the gear calculations. Within *KISSsoft,* they were able to add their own oil data into the software through the "own input" function which allowed them to alter the gear design to ensure their contact, bending and scuffing safety factors were met. Figure 2 shows the list of gear sizes obtained for the first stage of the planetary gear train.

Fine sizing macrogeometry

Conditions I | Conditions II | Conditions III | Summary | Results | Graphic

a [mm]	z_1	z_2	x_1	x_2	ε_α	ζ_{f1}	ζ_{f2}	Hunting
34.0000	**24**	**59**	**0.5127**	**0.5715**	**1.4575**	**-0.8846**	**-0.8845**	Yes
34.0000	24	58	0.7061	0.9789	1.4609	-0.8091	-0.8090	No
34.0000	24	59	0.3127	0.7715	1.4790	-1.2793	-0.7212	Yes
34.0000	24	59	0.4127	0.6715	1.4699	-1.0675	-0.8020	Yes
34.0000	24	59	0.5127	0.5715	1.4575	-0.8846	-0.8845	Yes
34.0000	24	60	0.1512	0.3704	1.5115	-1.5356	-0.8212	No
34.0000	24	60	0.2512	0.2704	1.4991	-1.2500	-0.9155	No
34.0000	24	60	0.3512	0.1704	1.4855	-1.0120	-1.0120	No
34.0000	25	61	-0.0745	-0.4025	1.7171	-2.8474	-1.2856	Yes
34.0000	25	61	0.0255	-0.5025	1.6981	-2.1158	-1.4340	Yes

***Figure 2. Fine sizing results from* KISSsoft.**

Being able to model most assembly components within *KISSsoft* allowed them to define and adjust shaft and bearing sizes during the gear sizing process before creating the full model within *SolidWorks*. This can be seen in Figure 3, with it closely representing the *KISSsoft* model shown in Figure 1. Being able to do this within *KISSsoft* allowed them to save valuable design time with them limiting the iterative process of moving between *KISSsoft* and *SolidWorks*.

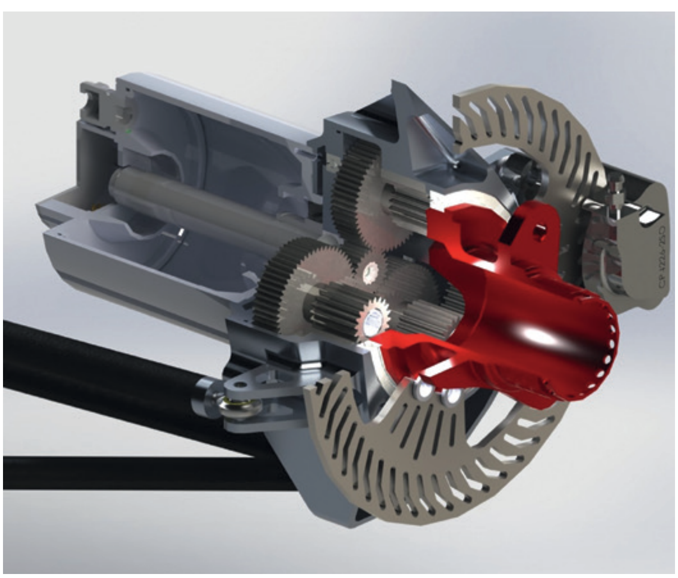


***Figure 3—Full wheel assembly model within* SolidWorks.**

Another major advantage of modeling the whole system accurately within *KISSsoft* was the ability to apply tip and root relief to the gear profile design based on shaft deflection under loading. Using the microgeometry tool, tip and root relief were applied to the gear profile, which removed contact shocks as shown in Figure 4.

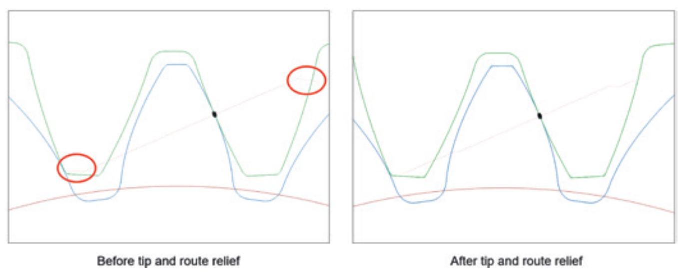
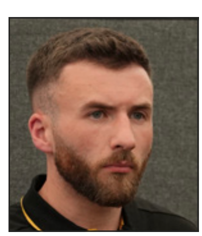


Figure 4—Tip and root relief added to remove contact shocks (circled in red).

Being able to implement tip and root relief into the gear design within *KISSsoft* is advantageous for them based on their manufacturing capabilities which are restricted to wire-EDM. Given their limitation to wire-EDM for manufacturing, they heavily depend on the accuracy of the gear involute model. *KISSsoft*'s capability to provide precise DXF files of the involute profile, including flank modifications, allows them to confidently send their designs for manufacture. This has been proven by the successful implementation of their first planetary gearbox in their electric vehicle. The support provided by KISSsoft had been crucial for the team to design highly refined gear train solutions.

PTE



Jordan Pitt graduated with a Master's in Mechanical Engineering from the University of Glasgow. He led the Unsprung Mass & Drivetrain sub-team within UGRacing, the University of Glasgow's Formula Student race team, and worked extensively on the design and development of drivetrain solutions for their electric vehicle.