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A Design Software Tool For Conceptual Design Of Wind Turbine Gearboxes

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Abstract

The project reports the development of a design software tool for wind turbine (WT) gearboxes. It facilitates the conceptual design of WT gearboxes supporting designs with different combinations of planetary and parallel gear stages. Analyses of gear bending strength and pitting resistance are in accordance with the AGMA2001 standard. The calculations of the AGMA geometry factors are verified in accordance with the AGMA 908 information sheets. A case study of a 2 MW and three phase asynchronous generator with a nominal rotational speed around 1600 rpm has been tested to demonstrate the capabilities of the design software tool.

Project Objectives

Why:

- In an indirect drive WT, the gearbox alone counts for about 13% of the overall cost;
- Design evaluations in the conceptual design phase is essential to eliminate gearbox design faults and to improve the operational performance;
- An easy to use design software tool would allow the design team to explore various possible design concepts in the early phase of the design;
- Commercial software is available, it can be expensive, unsuitable for wind turbine applications or too complicated to be used by engineers without specialist gear design knowledge.

The developed design tool supports the conceptual design of a WT gearbox:

- Different combinations of planetary and parallel gear stages;
- Arbitrary transmission ratios at individual stages to accommodate required input/output speeds of the gearbox;
- User friendly graphical interface, providing defaults and options based on wind turbine gear technology;
- Quick, accurate analysis and refinement of the design by providing instant results for proposed design changes;
- Analyses of bending strength and pitting resistance of gear teeth in accordance with the AGMA2001 standard;
- Exporting gear geometry to Finite Element Analysis software for further analysis.

Design of the Software Tool

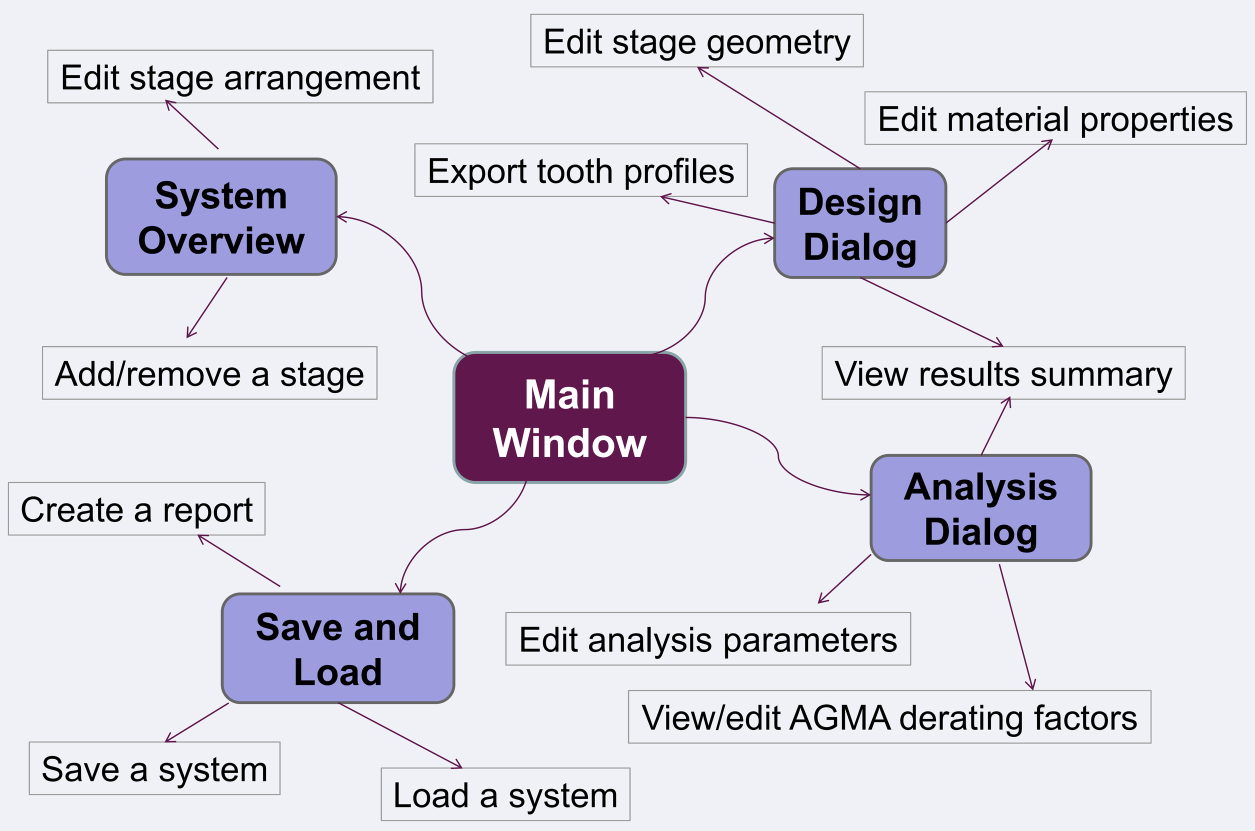

Figure 1: User navigation

Implementing the AGMA 2001 Standard

The analysis included the bending strength and pitting resistance safety factor calculations for each stage, based on the AGMA 2001 standard [1]. A particular challenge faced was in evaluating the Bending Strength Geometry Factor (J-factor) and Pitting Resistance Geometry Factor (I-factor). The calculations of these factors for any given set of input parameters require data from a series of charts and each chart only valid under certain conditions. Interpolation between these charts is not recommended. To maintain the calculation accuracy, this project implemented the full AGMA 908 calculations for both I and J factors [2].

Structure of the Program

The program is written using the Object Oriented Programming (OOP) paradigm. Figure 1 illustrates how the user can navigate through the program to perform the tasks required to edit, analyse and produce a report on the design. It includes System Overview, Design Dialog, Analysis Dialog, and Save and Load dialogs.

Case Study – Designing a Reliawind R80 Gearbox

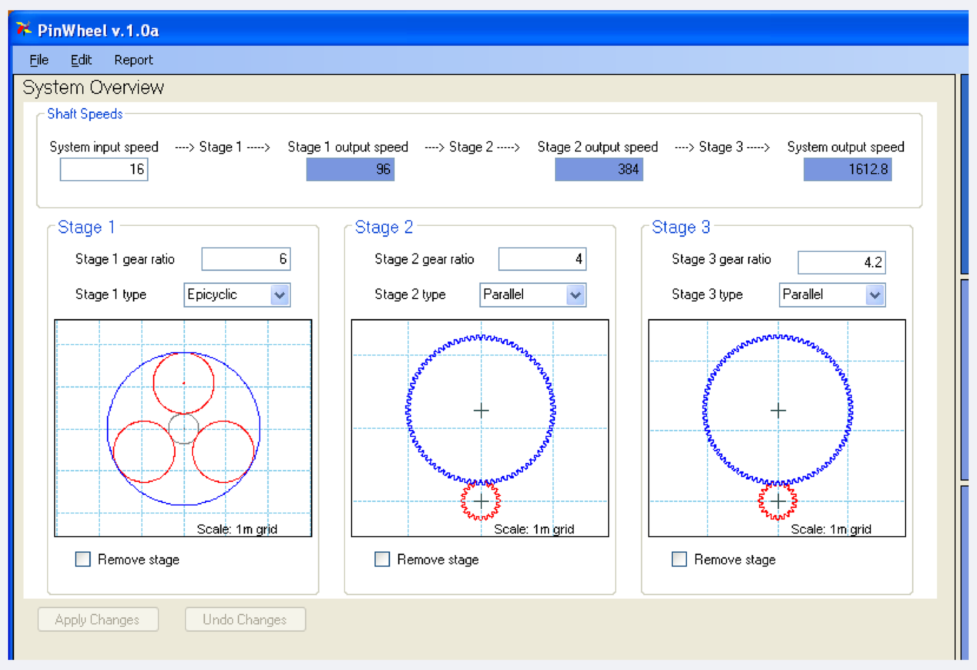

Figure 2: The System Overview of three gear stages

The project carried out a case study, R80 gearbox proposed by EU Reliawind as one of the generic wind turbine configurations [3]. It has a nominal power of 2 MW and a gearbox design with a transmission ratio of approximately 100. The R80 is to use a asynchronous generator with a nominal rotational speed around 1600 rpm. The turbine blades are designed to rotate at around 16 rpm. Using just this information a gearbox can be created as shown in Figure 2. Gear ratios of 6, 4 and 4.2 are selected, for one planetary and two parallel stages.

Initial results show that bending strength and pitting resistance safety factors are below the minimum recommended values of the AGMA 6006 standard [4] for stages 1 and 2. Several combinations of gear geometrical parameters are tested in order to find a conceptual stage design which meets the safety factor criteria. Table 1 shows one possible solution for three stages.

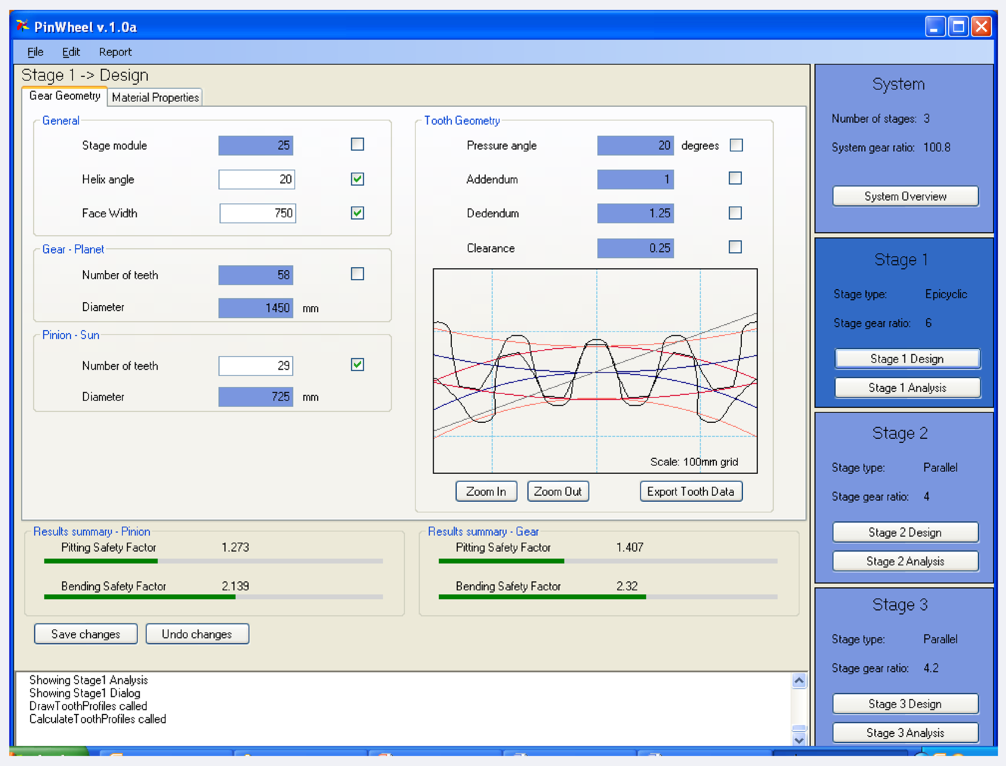

Figure 3: The Design dialog of stage one

Table 1: The updated design parameters for each gear stage

Gear Stage		Module (mm)	Helix Angle (°)	Face Width (mm)	Number of Tooth	Pitting Resistance Safety Factor	Bending Strength Safety Factor
Stage 1 (epicyclic)	Sun	25	20	750	29	1.27	2.14
	Planet Gear				58	1.41	2.32
Stage 2 (parallel)	Pinion	16	10	500	27	1.31	2.32
	Gear				108	1.42	2.71
Stage 3 (parallel)	Pinion	12	20	220	25	1.28	2.45
	Gear				105	1.39	2.85

Figure 3 shows the Design dialog for determine the gear geometry of stage one. As shown at the bottom of the window, the green bars represent the calculated results of bending and pitting safety factors, meeting the AGMA 6006 criteria. Figure 4 shows the Deign Analysis dialog which calculating derating factors for stage one design. Reports including calculations of geometry, material, and load data, stress numbers and power ratings can be generated for each stage.

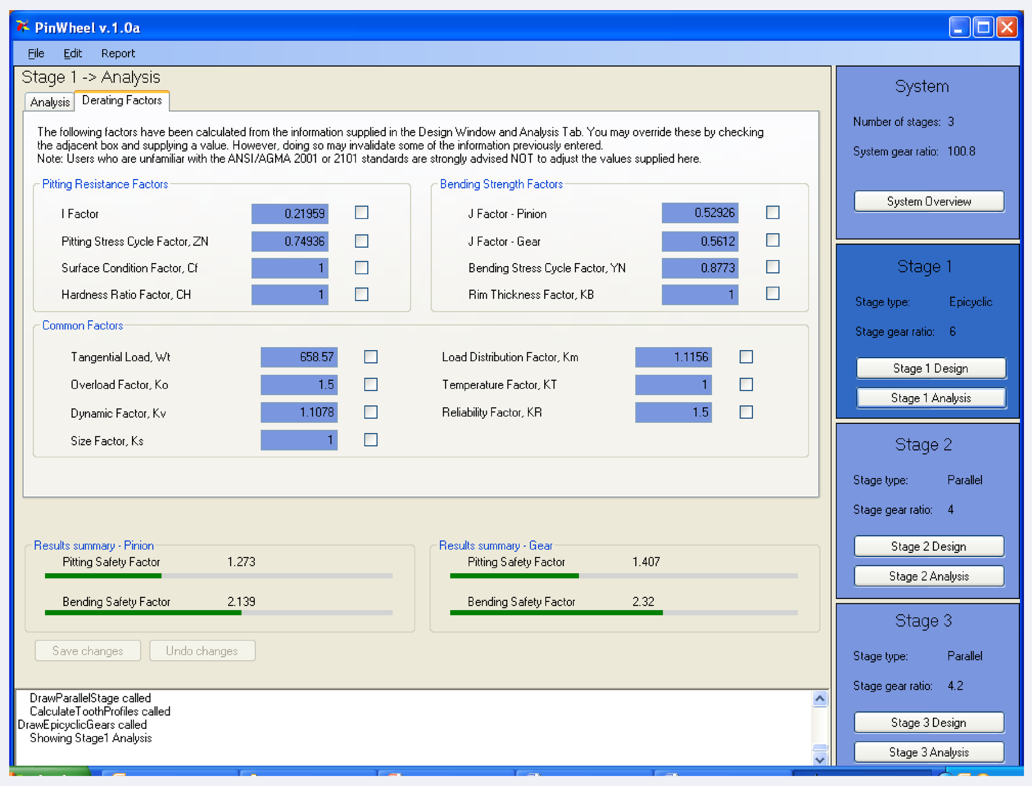

Figure 4: The Design Analysis dialog of stage one

Conclusions

The software tool developed provides effective means to design wind turbine gearboxes in the early stage of design development. This software could be used among the members of a wind turbine design team to aid concept design integration.

References:

1. AGMA. *ANSI/AGMA 2001-D04;* Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth. 2001.
2. AGMA. *AGMA 908-B89 Information Sheet*, Geometry factors for Determining the Pitting Resistance and Bending Strength of Spur, Helical and Herringbone Gear Teeth. 1989.
3. K. Smolders, H. Long, Y. Feng and P.J. Tavner. Reliability Analysis and Prediction of Wind Turbine Gearboxes. *The EWEC 2010 Scientific Track*. Poland, 2010.
4. AGMA. *ANSI/AGMA/AWEA 6006-A03*. Design and Specification of Gearboxes for Wind Turbines. 2003.

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