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Modeling and Simulation for the Drivetrain of Reversal Stubble-breaking Rototiller

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Abstract

Rototiller was one kind of agriculture machinery which was widely used in the country side, and traditional corotation stubble-breaking rototillers exsisted the deficiencies in narrow work width, high energy-consumption, poor vegetation coverage and soil-breaking performance. Aiming at the shortage of traditional rototillers, a reversal stubble-breaking rototiller was designed in this paper. On the basis of expounding the structure and working principle of the rototiller drivetrain, the virtual prototype model of the rototiller transmission was established by using SolidWorks, and its movement simulation was made by applying ADAMS, the simulation results in different engine speed of 65.685rad/s and 98.99rad/s showed that the rotating direction of each gear was in accordance with the real situation, the maximum rotational speed error between the simulation and theoretic calculation of the transmission was 1.02%, and the established virtual prototype had higher precision, which provided a prerequisite for dynamics analysis and optimization design of the drivetrain of reversal stubble-breaking rototiller.

Keywords: *rototiller drivetrain, SolidWorks, ADAMS, virtual prototype, simulation analysis*

1. Introduction

The resource of crops straw was rich in China, how to utilize straw rationally and effectively had become a common topic in present-day society. Along with the strict implementation of the regulations of banning to burn straw and with rising in agricultural mechanization levels in our country, straw-returning directly would be one of the most effective means and methods for processing straw in the long periods from now on. Nowdays, the stubble-breaking rototiller was the main machinery for crops straw-returning, and its working performance would impact directly on quality and efficiency of straw-returning. According to the certain degree deficiencies of traditional corotation stubble-breaking rototillers in vegetation coverage, soil-breaking, roughness and other aspects [1], a reversal stubble-breaking rototiller with better cultivating quality was designed in the paper, and virtual prototype modeling and simulation research for the type of rototiller was carried out, which had important practical value and practical significance for the optimization design of rototiller structure and improving its working performance.

2. Composition and Working Principle of the Drivetrain of Reversal Stubble-breaking Rototiller

The drivetrain of reversal stubble-breaking rototiller composed chiefly of a pair of bevel gears, four cylindric gears in side gearbox and a cutter axle. The deferent power of engine was transmitted directly to the driving bevel gear through the drive shaft, under the action of the driving bevel gear, the driven bevel gear made the driving gear in side gearbox revolve synchronously, then the gear power was transmitted to the cutter axial gear through two middle gears in side gearbox, finally, it could drive the cutter axle and blades installed in the cutter axle in reverse, and realized the purpose of ploughing back the chopped and scattered straw on the surface of the earth. Through the joint action of the transmission gears, while realizing the purpose of slowing engine speed down and increasing its torque, it could change the rotating direction of the cutter axle, and improve the effect of ploughing back the straw.

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3. Virtual Prototype Modeling for the Drivetrain of Reversal Stubble-breaking Rototiller

3.1. Selection of Modeling Software

In order to research the dynamic characteristics of the drivetrain of reversal stubble-breaking rototiller, optimize to design the system, it was necessary to build a virtual prototype model and carry out the kinematics simulation for rototiller drivetrain. SolidWorks software was the first 3D CAD system based on Windows in the world, it was of three characteristics: (1) powerful functions, (2) easy study and use, and (3) technology innovation, it could provide different design scheme, reduce the errors in the design process and improve product quality[2]. ADAMS software was a virtual prototype analysis software developed by American MDI company, users could use this software for statics, kinematics and dynamics analysis of the virtual machine system very conveniently [3-6]. According to the actual need of modeling and simulation for the rototiller drivetrain in the article, we selected the two kinds of software mentioned above as tools for modeling and simulation, through establishing each part model of the drivetrain and assembling them in SolidWorks environment, then importing it into ADAMS for virtual simulation analysis, which could lay the foundations of the optimization design for the drivetrain of reversal stubble-breaking rototiller.

3.2. SolidWorks Modeling of the Rototiller Drivetrain Part

After entering the drawing environment of SolidWorks software, we first drew a bevel gear. In the new menu, we selected "a single component drawing", and clicked the "toolbox"in the interface, after we selected standards spur bevel gear from gear folder, meanwhile, the generated spur bevel gears had parametric characteristics, we could generate the bevel gear we needed by changing the parameters such as the number of modulus and teeth. With reference to the bevel gear structure parameters of the drivetrain of reversal stubble-breaking rototiller used currently, we first established a driving bevel gear with module m for 6, teeth z for 14, pressure angle α for 20° and a driven bevel gear with module m for 6, teeth z for 30, pressure angle α for 20° in the paper, then entered into parts assembly environment interface, and assembled the established driving bevel gear and driven bevel gear into a pair of meshing in SolidWorks, the assembly situation was shown in Figure 1, at last we saved it by the file type of Parasolid (*. x_t).

Modeling process of cylindrical gears was similar to that of bevel gears, after selecting standards spur cylindrical gear from gear folder, the generated spur cylindrical gears also had parametric characteristics, at the time, we could generate the cylindrical gear we needed by changing the parameters such as the number of modulus and teeth. According to the spur cylindrical gear structure parameters of the drivetrain of reversal stubble-breaking rototiller, after establishing a driving gear in side gearbox with module m for 7, teeth z for 15, pressure angle α for 20° and two middle gear 1 and 2 in side gearbox with module m for 7, teeth z for 23, pressure angle α for 20° and a cutter axial gear with module m for 7, teeth z for 22, pressure angle α for 20°, we entered into the assembly environment of parts and components for general assembly, Virtual assembly drawing of the drivetrain of reversal stubble-breaking rototiller was shown in Figure 2, in this diagram, the driving gear in side gearbox was coaxial with the driven bevel gear, and middle gear 1 engaged externally with the driving gear, while the cutter axial gear engaged externally with middle gear 2.

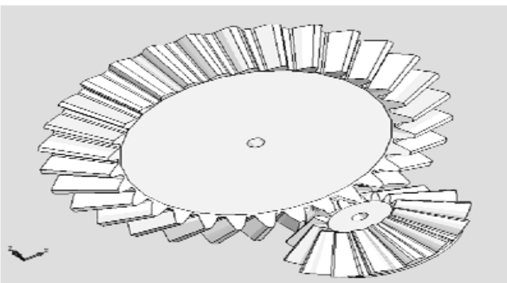

Figure 1. Meshing Model of the Driving and Driven Bevel Gear

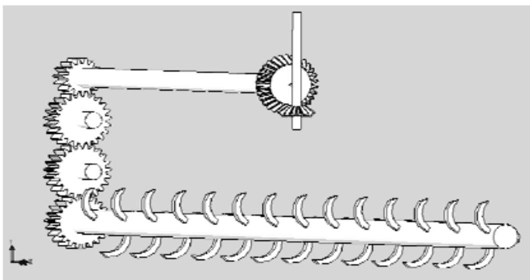

Figure 2. Virtual Assembly Drawing of the Drivetrain of Reversal Stubble-breaking rototiller

4. Simulation Result Analysis of Virtual Prototype Model in ADAMDS
4.1. Import of Virtual Prototype Model

After opening the ADAMS/View window, we imported the parts assembly body of the rototiller drivetrain into ADAMS, and by selecting some function modules such as “Joint”, ”Marker” and ”Gear” in ADAMS, we could add the gear pair between each pair of meshing gears, and impose restrictions on it in order to produce interaction between each pair of gears [7-10]. Virtual prototype for the drivetrain of reversal stubble-breaking rototiller with all added constraints was shown in Figure 3.

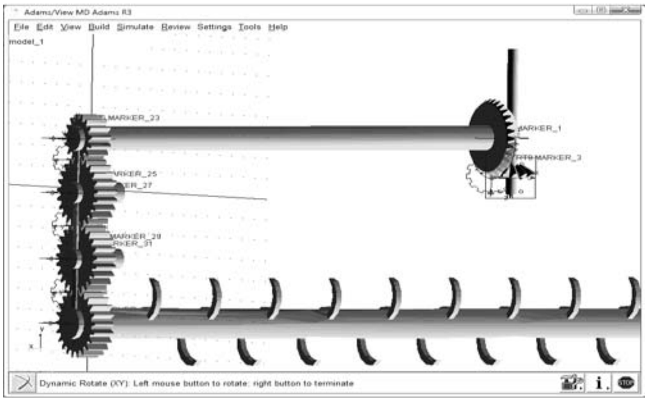

Figure 3. Virtual Prototype for the Drivetrain of Reversal Stubble-breaking Rototiller with All Constraints

4.2. Simulation Result Analysis

After clicking on the simulation icon in ADAMS, and setting up engine simulation speed, the simulation termination time and step length, we could click "start" button to relize the kinematic simulation of rototiller drivetrain. When engine simulation speed was 65.685 rad/s and 98.99 rad/s, simulation termination time was 100s and simulation step length was 1000 steps, we made a kinematic simulation on the established virtual prototype for the drivetrain of reversal stubble-breaking rototiller, the rotational speed simulation graph of each drivetrain gear was respectively shown in Figure 4 and Figure 5.

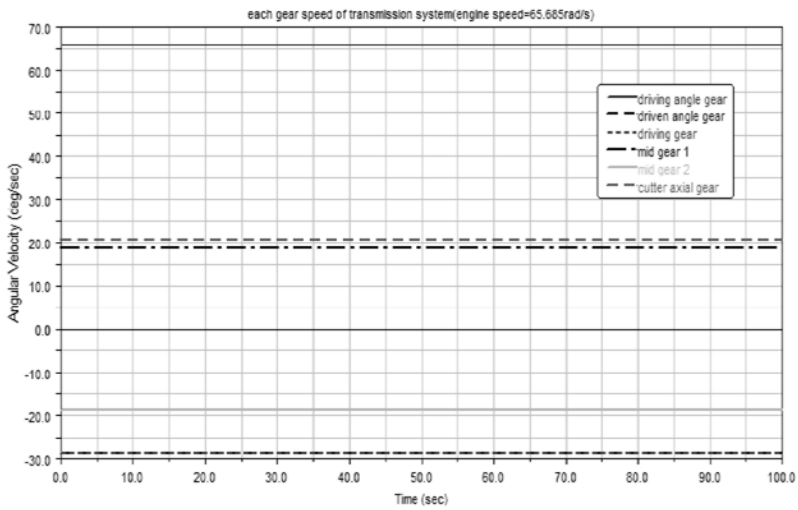

Figure 4. The Rotational Speed Simulation Graph of Each Drivetrain Gear at Engine Speed of 65.685rad/s

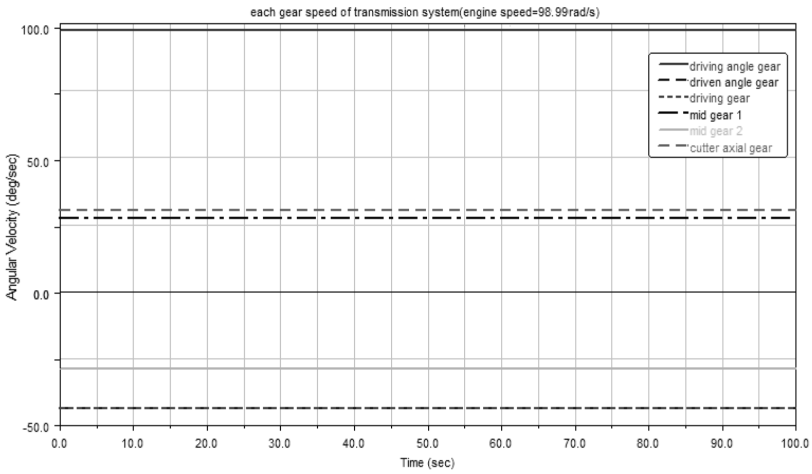

Figure 5. The Rotational Speed Simulation Graph of Each Drivetrain Gear at Engine Speed of 98.99rad/s

From Figure 4 we could obtain that the rotational speed ratio of the driving bevel gear and driven bevel gear was 65.69/28.93 = 2.271, that of the driving gear in side gearbox and middle gear 1 was 28.93/18.8 = 1.539, and that of middle gear 2 in side gearbox and cutter axial gear was 18.92/20.69 = 0.914, from Figure 5 we also could obtain that the rotational speed ratio of the driving and driven bevel gear was 98.99/43.6 = 2.27, that of the driving gear and middle gear 1 was 43.6/28.34 = 1.538, and that of middle gear 2 and cutter axial gear was 28.52/31.18= 0.915, according to the setted gear parameters in establishing virtual prototype of the rototiller drivetrain, we knew that the transmission ratio of the driving and driven bevel gear was 33/14 = 2.143, that of the driving gear and middle gear 1 was 23/15 = 1.533, and that of middle gear 2 and cutter axial gear was 22/23 = 0.957, through the calculation, we obtained the maximum rotational speed error of virtual prototype meshing gears in the two simulation speed mentioned above was (2.271–2.143)/2.143 = 5.97%, the maximum error of the whole transmission simulation speed was (3.175–3.143)/3.143 = 1.02%, in the above formula, 3.175 and 3.143 were respectively general rotational speed ratio and transmission ratio of rototiller drivetrain gears at engine speed of 65.685 rad/s, which showed the established virtual prototype of the rototiller drivetrain had a higher precision. Because all of the transmission gears meshed externally with each other, we could also see from Figure 4 and Figure 5 that the rotating direction of external meshed gears was exactly opposite, the cutter axle and blades installed in it kept reverse state, which was consistent with the actual situation.

5. Conclusion

By using the parameterized modeling method of SolidWorks, and according to the actual conditions of the drivetrain of reversal stubble-breaking rototiller, fast modeling and precise assembly for transmission parts could easily be realized, which would shorten the design time of virtual prototype greatly; After the assembly body of transmission parts being imported into ADAMS, and reasonable constraints being added on it, movement simulation of the rototiller virtual prototype could be carried out; The simulation results at engine speed of 65.685 rad/s and 98.99rad/s showed that the rotating direction of each gear was consistent with the actual situation, the maximum rotational speed error of external meshing gears during the whole simulation process was 5.97%, the maximum simulation speed error of the whole transmission was 1.02%, which indicated that the established virtual prototype of the rototiller drivetrain had a higher precision.

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