Modelling and Simulation of Chilean Needle Grass Spread during Slashing

Lj. Erakovic[a], A. Subic[a], B. Abu-Hijleh[a] and D. McLaren[b]

[a] School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University, Melbourne, e-mail: s3030035@student.rmit.edu.au

[b] Department of Primary Industry, Keith Turnbull Research Institute, PO Box 48, Frankston 3199 and CRC for Australian Weed Management.

Abstract: Chilean Needle Grass has been described as being potentially the worst environmental weed of native grasslands in South-eastern Australia and its potential distribution has been estimated to be more than 41 million ha. This research involves experiments as well as modeling and simulation of the flow and spreading of Chilean Needle Grass during slashing. Fluent, Computational Fluid Dynamic package (CFD) is employed to investigate the inherent complexities of the slashing process using a virtual slasher model and simulating the slashing process and spreading of Chilean Needle Grass involving also blade mechanics. This approach aims to develop new slasher designs capable of reducing Chilean Needle Grass spread. High accuracy of the simulations is realized through validation with experimental data. Tuft method and pressure profile measurements were performed in the wind tunnel, these experiments resulting in data about the flow pressure patterns inside the slasher deck unit. The real slashing process of Chilean Needle Grass was performed in the field, the slashing action was visualized using dyes and digital video filming while the spreading of the slashed grass was carefully mapped. These experiments helped achieve a reliable CAD-CFD slasher model, which appears to be the most effective method of analyzing the slashing process to date. The main benefit of the developed computational models is in greatly reduced trial time and the possibility of investigating a wide range of data including the effect of different slasher geometries on the spreading levels. These simulations assist the investigation into the effects of various slasher blades and deck geometries and the influence that dimensions, density, shape and other Chilean Needle Grass properties have on the slashing process and on the flow inside the slasher deck. These simulations and experiments also clarify the problem of hygiene and deficiencies of present designs, which cause attaching of grass and seeds to the slasher and subsequent spreading.

Keywords: *Simulation; CFD; Slashing; Chilean Needle Grass*

1.INTRODUCTION

Chilean needle grass was accidentally introduced to Australia and New Zealand from South America in the late 1920's (Slay, 2002). Today it has been proclaimed a Weed of National Significance as it is threatening native grasslands and productive pastures throughout significant regions of south-eastern Australia (Slay, 2002). It is anticipated that it will be declared a noxious weed throughout much of Australia in the near future. The potential distribution of Chilean needle grass in Australia has been estimated to be more than 41 million ha (McLaren, Stajsic and Gardener, 1998). This wild plant has been described as being potentially the worst environmental weed of native grasslands in South-eastern Australia. Slashing is done for many reasons. It aims to reduce plant biomass and fire risk, improve driver safety by improving roadside visibility, reduce or prevent Chilean needle grass flowering and its spread into neighboring properties and reduce its spread into rare and endangered remnant grasslands. Slashing is only one of the approaches that are used for reducing the Chilean needle grass spread. The spread of Chilean needle grass infestation throughout Australia is aided by the seed's ability to attach itself to, and be spread by animals, man and machinery.

The slashing process appears to be one of inducement of the Chilean needle grass infestation. Slashing actively disperses seeds, scattering them around the slasher deck during the performance of the slashing process and carrying them if machinery is not kept clean. Simulations and experiments aim to investigate the following concepts:

- The flow inside the slasher deck;

-The influences that the slasher geometry and seed properties have on the flow and the spreading of the seeds;

-The deficiencies of present designs from a hygiene point of view – where and how the seeds are attached and the best course of action to resolve the problem.

This approach should result in improved slasher design with reduced spreading characteristics, which are reflected in reduced spreading area around the slasher deck and enhanced hygiene aspect of design.

This research will set up a good base for further examinations and improvements of the slashing process.

The number of published works concerning this subject is limited. The most significant progress has been made by Hagen, Chon and Amano in 2002 when Computational Fluid Dynamic (CFD) was wisely employed to simulate the mowing process.

This project will contribute to understanding the inherent complexities of the slashing process by developing a virtual slasher model, which will enable simulation of slashing action and related Chilean needle grass spread. The virtual model is based on a simplified CAD model, which is transferred into the CFD interface where the simulation is performed. The accuracy of data attained with a virtual model was determined through comparison with field experimental data and data obtained in the wind tunnel so that the reliability of the CAD–CFD slasher model is validated. This model will allow detailed and accurate simulation of the slashing process, greatly reduced trial time, the investigation into the effects of various slasher blade geometries and the influence that dimension, density, shape and other seed properties have on the slashing process and on the flow inside the slasher deck.

The final aim of the project is to redesign slasher technology with improved dissemination characteristics, which will reduce the spreading of Chilean needle grass.

2. SLASHER MODEL

There are numerous ways of creating CAD models suitable for meshing using a program called Gambit (Fluent 2001). Choice of solution approach depends mostly on a CAD program used for creation. CAD models transferred from Solid Works into Gambit appear to have a lot of problems caused by the doubled transfer of object geometry. Therefore the most suitable approach is to take relevant geometry coordinates from the transferred CAD model and create completely new model using Gambit drawing tools.

For a successful simulation in the CFD package, it is necessary to create a simplified model without the influence of excess geometry, which has no effect on the slashing process. Figure 1 shows the real slasher model with all existing geometry including nuts, bolts, ribs etc. Figure 2 shows the simplified model, modified in order to achieve reasonable speed of the calculating process and high accuracy of attained data.

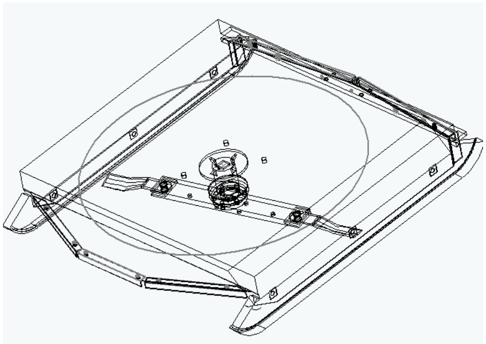

Figure1. Real slasher geometry

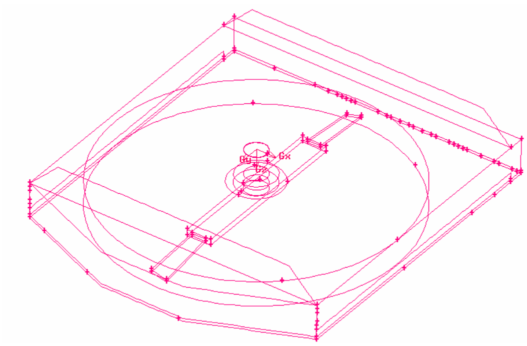

Figure2. Simplified slasher geometry

The rate and quality of results are directly influenced by the technique of mesh generation. Advanced meshing quality which is reflected in smaller spacing of the mesh nodes does not necessarily mean better results, but it slows down the computing process. Hence, it is imperative to attain optimal solution, which guarantees high quality of results and very small time usage. Poorest mash quality is generated in gaps where highly skewed cells are created. These problematic areas can be solved with minimal changes in geometry or by generating a higher quality mesh in that region or both.

There are several changes in general geometry and they are visible, especially at the front and back part of the slasher deck (figure 2). They are made in order to facilitate the mesh generating process and to improve mesh quality.

3. EXPERIMENTAL TESTS AND VALIDATION

In order to verify the validity of the CFD model, numerous tests were performed.

3.1 Experiments in the field.

These experiments involve slashing of dyed Chilean needle grass which expands:

-investigation of the spreading during the slashing process by using digital video filming;

-inspecting and analysing the hygiene aspect on the top of the slasher;

-mapping of the slashed grass that falls outside the slashing strip.

3.1.1 Filming of the slashing process

Fluorescent dye enables improved visualisation of the slashing process and filming of the motion of the grass, which escapes the slasher deck. This test shows highest outlet velocities on the front left part of the slasher and comparably high velocities in the entire frontal outlet area. Rear and side outlets appear not to have significant outflow of grass which points to lower velocities and possible reversed flows caused by negative pressure gradient relative to external pressure. Looking from the top of the slasher, the blades rotate in a counter-clockwise direction.

3.1.2 Inspecting and analysing the hygiene aspect

Throughout the performance of the slashing process it is clearly shown that vast number of Chilean needle grass seeds fall on the top of the slasher deck. During transport and further slashing the seeds are being spread to other grasslands. A very high percentage of these seeds escape the deck in the front outlet.

3.1.3 Mapping of the slashed grass

Dyed grass is also used for better visualisation of slashed parts that fall outside the slashing strip. This result points out that much of the slashed grass falls out on the left hand side and that is in harmony with the highest velocities on the front left part outlet.

Most of the grass components fall within 1 meter from both sides of the slasher while the rest falls within 2 meters distance.

This mapping test should be used to validate the improved slasher model but it can also be used to validate the virtual slasher model. Velocities on the outlets of the slasher can be compared with distances. Also a new virtual model can be developed which will be capable of simulating the spreading of the slashed grass that falls outside the slasher's deck.

3.2 Wind tunnel experiments

These will be used to investigate flow patterns using the tuft method and pressure measurements inside the deck.

3.2.1 Tuft method

This enables comparative visualisation of vector profiles of absolute velocities located near the internal horizontal walls. This method clearly points to recirculation and stagnation zones. Stagnations zones are detected at the top front and top back corners, while the recirculation zone is detected on the top horizontal wall above the rotating blades (Figure 3). The experiment was performed in the wind tunnel and the images were taken from the bottom through the glass floor so as to obtain a stationary view of the deck and maximal rotational speed. Velocity profiles attained from CFD analysis are consistent with the tuft method results.

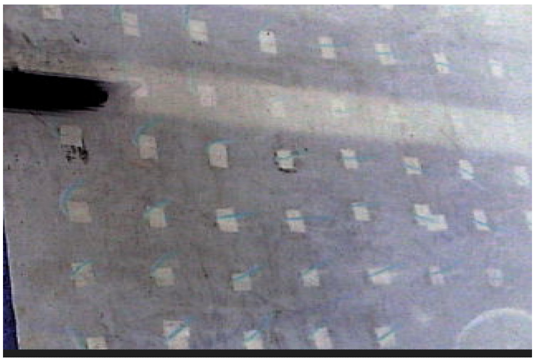

Figure 3 Recirculation zone detected by the tuft method on the horizontal top wall above the rotating blades.

3.2.2 Pressure measurements

Pressure measurements were performed in the wind tunnel 15 mm above ground surface level and for rotational speeds of 93rad/sec and 122 rad/sec. Values were recorded for every 10 cm distance so a pressure map is obtained (Figure 4). This map can be used for comparison with CFD results.

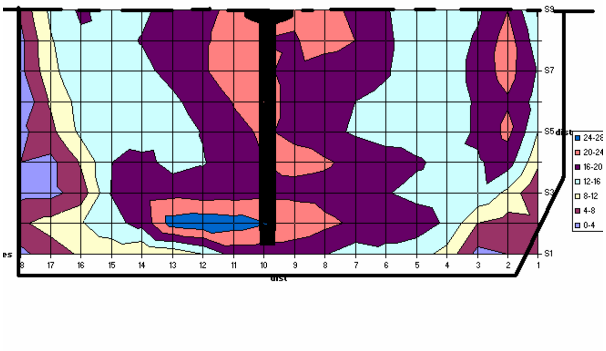

Figure 4 Distribution of pressure obtained in wind tunnel 15 mm above the ground level and for one simetrical side of the deck.

4. SIMULATIONS AND ANALYSIS OF THE SLASHING PROCESS

The slashing process is simulated by using a "Sliding Mesh". The overall volume of a slasher is divided into two parts, which are in contact via a geometrically identical interface. The first volume V_1 (figure 5) includes the complete volume of the slasher deck from which interface volume is deducted. Deducting shaft and blade volumes from the interface volume obtains the second volume V_2, (figure 6). These two defined volumes combine to create a sliding mesh (figure 7), which is connected via the interface. The internal volume V_2 is defined as a moving mesh which rotates about the vertical z-axis coordinate at given rotational speed.

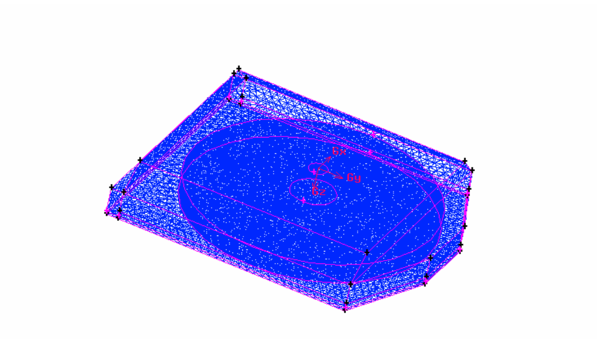

Figure 5. Mesh generated for the volume V_1

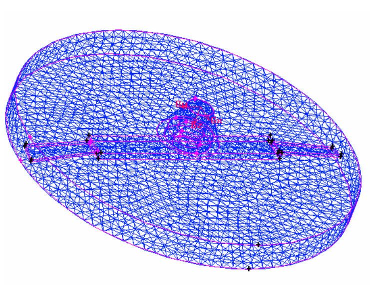

Figure 6. Mesh generated for the volume V_2

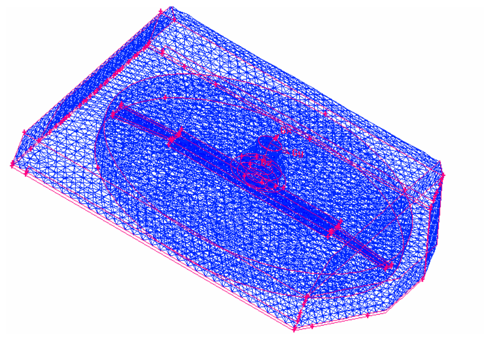

Figure 7. Mesh generated for the final model capable of simulating the slashing process.

The process of obtaining results through CFD simulation is very long and tedious. For simulations that use the sliding mesh it is recommended that the process commences with a rotating speed that is 10% of the real rotating speed. After the first round of results the speed should be gradually increased until the desired number of rotations is reached. The results obtained through the CFD method are achieved for a rotational speed of 122 rad/s which is the real speed of slashing.

Figure 8. represents a contour diagram of Static Pressure (Ps) on the reference plane, which is placed 15 mm above ground level. This plane lays below the level at which the blades rotate. Figure 9 shows blades which rotate in a counter-clockwise direction. Figures 8 and 9 are related and the position of the blades reflects the contour diagram of the static pressure on the reference plane. Figure 8 shows that the Ps is the least below the position of the blades. This is logical taking into account that the rotating blades cause upward air movement. Higher values of Ps at the perimeters of the reference plane are the results of the movement of outside air in the deck. This is caused by negative pressure gradient relative to external pressure.

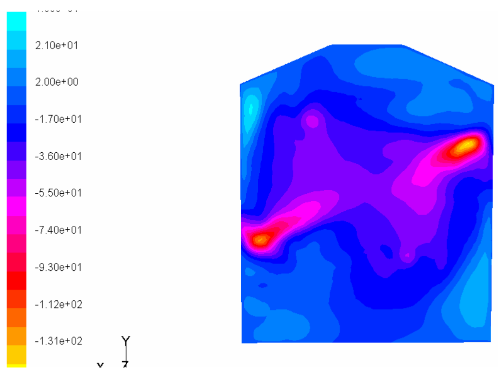

Figure 8. Contour diagram of static pressure on the reverence plane.

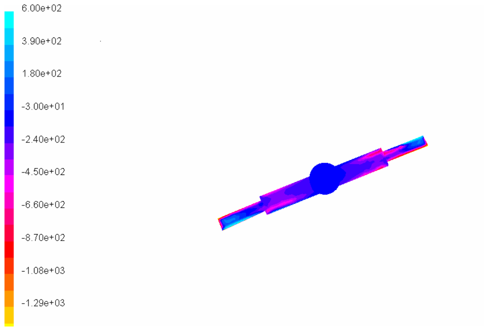

Figure 9. Contour diagram of static pressure on the rotating blades.

5. CONCLUSION

A real slasher model was transferred to a Gambit interface and a simplified virtual model appropriate for meshing and attaining quality results for a minimum usage time was created. Relevant results suitable for validation of the virtual model are obtained in the field tests and wind tunnel tests. CFD simulations are performed and validation of the virtual model is approved by using field tests and wind tunnel tests data. The deficiencies of the slasher deck design, that helps seed collecting on the deck top were detected. A concept that should prevent this collection process has been developed and it is in the final process of examination. A validated CFD model will be used to investigate new blade and deck design and to reduce Chilean needle grass spreading.

Due to inherent difficulties relating to exploration of the slashing process this approach appears to be the most suitable solution.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

Slay, M. W. A., Chilean Needle Grass Control in Hawke's Bay, 2002.

McLaren D.A., V.Stajsic, and M.R. Gardener, The distribution and impact of South\North American stipoid grasses 13(2):62-70, 1998.

Hagen P. A., W. Chon and R.S.Amano, " Experimental Study of Aerodynamics Around Rotating Blades in a

Hagen P. A., W. Chon and R.S. Amano " Experimental Study of Aerodynamics Around Rotating Blades in a Lawnmower Deck," *ASME Fluids* Quebec, Canada. Paper FEDSM2002-31315, 2002.

R.S. Amano, W. Chon and K.F.Neusen, Counter Rotating Blades in a Double-Spindle Deck," *FEDSM98-5278,* FED-Vol.245, Washington, DC, 1998.

W. Chon and R.S. Amano, "Experimental Study of Aerodynamics Around Co-Rotating Blades in a Lawnmower deck," *ASME International Mechanical Engineering Congress & Exposition,* 1999.

W. Chon and R.S. Amano, "Experimental Study of Two-Phase Flow Around Double Co-Rotating Blades in a Lawnmower deck," *ASME National Heat Transfer Conference,* Pittsburgh, PA, 2000.

[8] Fluent user guide, Fluent Inc. 2001