Firebrand flux

186 m

0 m

320 m

FBP X

FBP Y

FBP Z

FCS X

FCS Y

FCS Z

Fire line

Road

320 m

160 m

300 m

250 m

150 m

100 m

50 m

Forest fire simulations

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Case | Wind velocity  (m/s) | Particle velocity  (U,V,W) m/s | Ember input rate pcs/s | **Flux (pcs/m2. s)** | | |
| FCS Z | FCS Y | FCS X |
| T A | ≈1.94 | (4.2, 0.0, 2.1) | 9881 | 2.1054 | 1.562 | 0.074 |
| T B | ≈2.02 | (6.2, 0.0, 2.1) | 9881 | 1.332 | 1.499 | 0.255 |
| T C | ≈1.93 | (8.3, 0.0, 4.2) | 9042 | 1.218 | 1.120 | 0.522 |
| T D | ≈1.89 | (8.3, 0.0, 5.2) | 9042 | 1.253 | 1.341 | 0.306 |
| T E | ≈1.87 | (8.3, 0.0, 6.2) | 9042 | 1.154 | 1.196 | 0.271 |
| T F | ≈1.95 | (9.3, 0.0, 4.2) | 8907 | 1.343 | 1.230 | 0.289 |
| T G | ≈1.98 | Varied on particle | 9881 | 0.738 | 1.415 | 0.214 |
| T H | ≈2.1 | (8.3, 0.0, 2.1) | 11006 | 1.465 | 1.302 | 0.701 |
|  |  |  |  | 7.1% | 30.7% | -17.5% |
|  |  |  | Adjust the input number |  |  |  |
| TI | ≈2.13 | (8.3, 0.0, 2.1) | 14436 | 2.835 | 1.355 | 0.203 |
| TJ | ≈2.16 | (8.3, 0.0, 2.1) | 12367 | 1.392 | 1.788 | 0.752 |
| Experiment | 1.4±0.6 | NA | NA | 1.361 | 0.902 | 0.824 |
| Difference(%) |  |  |  | 2.2% | 49.5% | -09.5% |

* Lower initial horizontal velocity – results more particles accumulating on FCS Z (case T A).
* Higher initial horizontal velocity – results more particles moving away from the fire line and landing on Y, X locations. However, increasing vertical velocity results landing less firebrands on X location (TH, TD, TE, TF).
* So, TH case is being used to adjust the input composition of firebrands to get a closer value to the experiment.
* After adjusting input number according to the composition of landing flux, TI, TJ results were obtained. The TJ was obtained after adjusting the results of TI.

Total number of firebrands landed on a 1m2 area

|  |  |  |
| --- | --- | --- |
|  | Total number of firebrands(pcs)  landed on X, Y, Z | Difference with the experiment |
| Experiment | 1334 | - |
| TH | 1530 | 12.8% |
| TJ | 1771 | 24.6% |

**Oregon State University work**

1. Effect of species for firebrand generation

DF-Douglas fir, GF-Grand fir, PP- Ponderosa pine, WJ-Western Juniper

|  |  |  |
| --- | --- | --- |
| Total firebrand generation ratio (based on species) | | |
| DF/GF | DF/PP | DF/WJ |
| 1.2 | 2.0 | 2.2 |

|  |  |  |
| --- | --- | --- |
| Hot firebrand generation ratio (based on species) | | |
| DF/GF | DF/PP | DF/WJ |
| 0.5 | 4.8 | 0.8 |

**Note: Need to find a logical explanation why I use Douglas fir or Pine for the AS3959.**

Based on-

Which fuel has a closeness to Eucalyptus(Forests), Banksia(Scrub), Acacia (Mallee/Mulga) in terms of physical features, fuel MC etc.

1. Ember generation based on MC

Summary:

|  |  |  |  |
| --- | --- | --- | --- |
| **MC** | **Species** | **Number of firebrands** | **Ratio: DF/PP** |
| 40.1 | DF | 10611.4 | 2.19 |
| 41.7 | PP | 4847.2 |
|  |  |  | **Ratio: SB/PP** |
| 58.3 | PP | 4061.1 | 6.58 |
| 58.2 | SB | 26724.9 |

Note: There is no analysis about the effect of wind velocity for firebrand generation. The effect of wind is expected to be relatively small (compared to other parameters) because of the fairly wind speed.

According to Manzello et al. and Filkov et al. wind effect for firebrand generation is as below.

No wind = > 3.22 pcs/MW.s [Douglas fir]

Wind wind(2 m/s) = > (\_\_\_)pcs/MW.s [Pitch pine]

Fuel load comparison

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Vegetation Classification | Fuel | Understorey fuel load(t/ha) | Total fuel load(t/ha) | Vegetation height(m) |
| Forest | Eucalyptus | 25 | 35 | 30 |
| Scrub | Banksia | 25 | 25 | 3 |
| Mallee/Mulga | Acacia | 8 | 8 | 3 |
| Forest | Pitch pine (pinus rigida Mill.) | 20.6±7.02 | 46.84±7.9 | 14-22 |

MC effect: Manzello’s experiments vs Oregon State University experiments-Douglas fir tree

**Oregon State University experiment**

**Manzello’s experiment**

‘it was observed that the Douglas-fir trees would only partially burn. Furthermore, at the 50% moisture content level, firebrands were not produced’

***[Firebrand generation from burning vegetation-IJW 2007]***

‘Douglas-fir trees do not produce firebrands if the moisture content is larger than 30% and no wind is applied’.

***[Firebrand generation from burning vegetation-IJW 2007]***

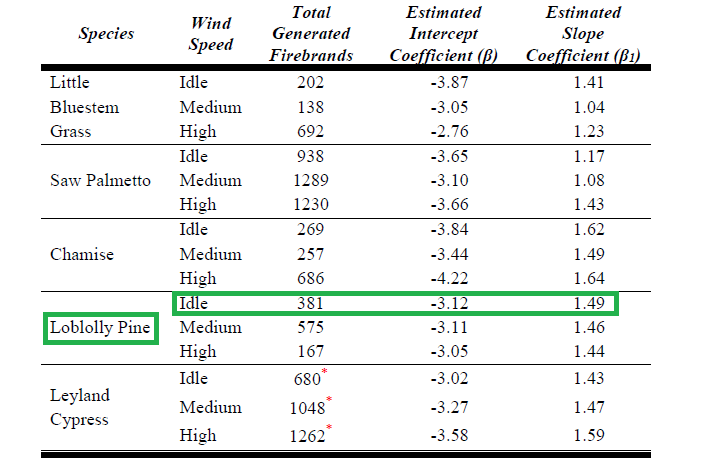
‘Douglas-fir trees do not produce firebrands if the moisture content is larger than 30% and no wind is applied’

***[Babrauskas 2002; Baker 2005]***

‘Furthermore, at the 50 % moisture content level, a significant number of firebrands were not produced. From these results, experiments were then performed using lower moisture contents. Under these conditions, the Korean Pine trees were observed to burn more intensely and copious amounts of firebrands were produced. In summary, Korean Pine trees generated firebrands only if the moisture content was maintained below 35 %, with no wind applied.’

***[Mass and size distribution of firebrands generated from burning Korean pine (Pinus koraiensis) trees-Fire and Materials 2009]***

Wind effect for firebrand generation -Babak Bahrani et al



Wind speeds

Idle – 5.36 m/d

Medium-11.17 m/s

High-18.88 m/s

**LG**-little blue stem grass

**SW**-Saw Palmetto

**CT**-Chamise tree

**LP**-Loblolly Pine

**LC**-Leyland cypress

Ember production compare to Loblolly pine

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Wind condition | LP/SG | LP/SP | LP/CT | LP/LC |
| Idle | 1.9 | 0.4 | 1.4 | 0.6 |
| Medium | 4.2 | 0.4 | 2.2 | 0.5 |
| High | 0.2 | 0.1 | 0.2 | 0.1 |

|  |  |  |  |
| --- | --- | --- | --- |
| **AS3959 fuels** |  |  | Ponderosa pine |
| Eucalyptus | Pitch pine | Douglas fir | Grand fir |
|  |  |  | Saw Palmetto |
| Acacia | Western Juniper | Loblolly pine | Chamise |
|  |  |  | Leyland Cypress |
| Banksia | Sage brush |  | Little blue stem |

Red colour: effect of MC relationships

Green colour: effect of species relation ships

Blue colour: effect of wind speed relationship

Violet colour: Similar trees in terms of height, physical appearance( foliage, branching form and size, location and soil etc.)

|  |  |
| --- | --- |
| Eucalyptus | Pitch pine |
| Acacia | Western Juniper |
| Banksia | Western Juniper |

Parameters for AS3959 work

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | | | | | | | **Value** | | | **Description** | |
| Ambient temperature (0C) | | | | | | | 39 | | | Similar to grass fire simulation[ref] | |
| Relative humidity (%) | | | | | | | 25 | | | Similar to grass fire simulation[ref] | |
| Wind velocity at the Fireline (m/s) | | | | | | | 11.11 [40 km/h] | | | Tweak to obtain FDI 50, 80 and 100 in AS3959-2018 | |
| 16.67 [60 km/h] | | |
| 19.44 [70 km/h] | | |
| Forest fuel  Length/diameter  (needles)(mm) | | Type1: needles | | | | | L=10 dmax= 6.35 | | | Cylindrical shape  Experimentation of underlying physics: Muller et al. | |
| Forest fuel  diameter  (twigs)  (mm) | | Stem | | | | | D=8.65 | | | Calculated from Experimental procedure, table 2: Houssami et al (Fire technology 2016). | |
| Branch level 1 | | | | | D=5.73 | | |
| Branch level 2 | | | | | D=3.068 | | |
| Branch level 3 | | | | | D=2.93 | | |
| Fuel moisture(%) | | surface | | | | | 3.84 | | | Eqn 2.58 Fire behaviour knowledge in Australia (Cruz et al) | |
| canopy | | | | | 3.84 | | |
| Fuel mass per volume (kg/m2) | Forest | over storey | | | | | 0.1 | | | AS3959-2018  Table B3:Vegetation classification and fuel load. | |
| under storey | | | | | 2.5 | | |
| Scrub | over storey | | | | | 0.0 | | |
| under storey | | | | | 2.5 | | |
| Mallee/Mulga | over storey | | | | | 0.0 | | |
| under storey | | | | | 0.8 | | |
| Drag law for static fuel | | | | | | | Haider and Levenspiel model. | | | The modified FDS 6.6.0 code will be used and it has drag law calculations according to firebrands shapes(sphere, cylinder, cubic) | |
| Canopy height max (m) | | | Forest | | | | 40 | | | AS3959-2018  Table B3:Vegetation classification and fuel load, Table 2.3 | |
| Scrub | | | | 3 | | |
| Mallee/Mulga | | | | 3 | | |
| Under storey height min (m) | | | Forest | | | | 10 | | | AS3959-2018-Fig. 2.4 (B), 2.4 (E), 2.4(F) | |
| Scrub | | | | 0 | | |
| Mallee/Mulga | | | | 0 | | |
| Firebrands  (classified into eight types of cylindrical shape, five types of cubic shape and three types of spherical shape firebrands) | | Cylindrical shape, dimensions  (cm)  (length/diameter) | | | | | Fbcy1 | 0.81 | 0.33 | | Taken from Investigation of firebrand production during prescribed fire: Filkov et al Combustion institute 2017 and processed. |
| Fbcy2 | 5.47 | 2.47 | |
| Fbcy3 | 2.49 | 1.26 | |
| Fbcy4 | 2.75 | 0.89 | |
| Fbcy5 | 1.95 | 0.80 | |
| Fbcy6 | 1.53 | 0.66 | |
| Fbcy7 | 4.59 | 0.37 | |
| Fbcy8 | 5.21 | 0.28 | |
| Cubic shape, dimensions  (cm)  (Length/width) | | | | | Fbcu1 | 0.715 | 0.5125 | |
| Fbcu2 | 2.835 | 2.265 | |
| Fbcu3 | 2.77 | 1.31 | |
| Fbcu4 | 1.66 | 1.2775 | |
| Fbcu5 | 0.835 | 0.955 | |
| Spherical shape, dimensions  (cm)(diameter) | | | | | Fbs1 | 0.515 |  | |
| Fbs2 | 1.19 |  | |
| Fbs3 | 0.93 |  | |
| Drag laws | | | | | Use Haider and Levenspiel drag models. | | | FDS 6.6.0-modified version will be modified to insert the drag model to the source code.  The drag coefficient over-rides the drag law. | |
| Density | | | | | (still finding) | | | Use same density of pitch pine. | |
| Initial temperature (0C) | | | | | 411 | | | Whadhwani et al. | |
| Fireline  (static) | | Length (m) | | | | | 100 | | | AS3959 and New Jersey prescribed fire Filkov et al 2016. | |
| Depth (m) | | | | | 2 | | |
| Magnitude (kW/m) | | Forest | | FDI50 | 23184.45 | | | Calculated based on the equations in Fire behaviour Knowledge -Cruz et al and AS3959-2018:Table B4, equations B1, B2. | |
| FDI80 | 37020.87 | | |
| FDI100 | 46781.22 | | |
| Scrub | | FDI50 | 59158.23 | | |
| FDI80 | 96624.13 | | |
| FDI100 | 116437.1 | | |
| Mallee/  Mulga | | FDI50 | 18930.63 | | |
| FDI80 | 30919.72 | | |
| FDI100 | 37259.86 | | |
| Tree trunks | | Height (m) | | | Eucalyptus | | 25 | | | Calculated based on the NJ pitch pine tree trunk height and canopy height. | |
| Banksia | | 1.8 | | |
| Acacia | | 1.8 | | |
| number | | | | | \*\* | | | Represented by non-burning obstacles. | |
| spreading | | | | | - | | | randomly | |
| Domain | | 250 mm grid size | | | | | 800 m x 200 m x 80 m  (16 ha) | | |  | |