Section 4

IMPULSE AND FORCE DURATION TO REPLACE ENERGY AND FORCE AS FRANGIBILITY CRITERIA

Ben Griffiths

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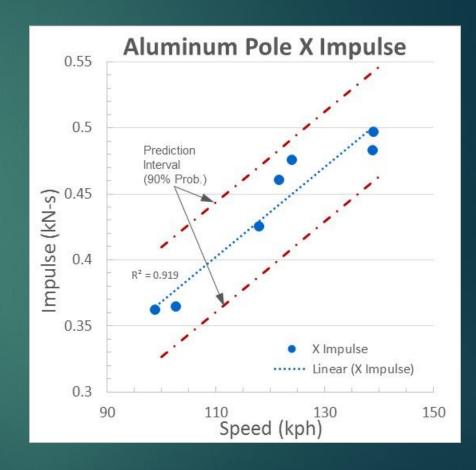
Recommendations

- Replace energy criteria with impulse
- Research force duration criteria as a possible alternative to peak force

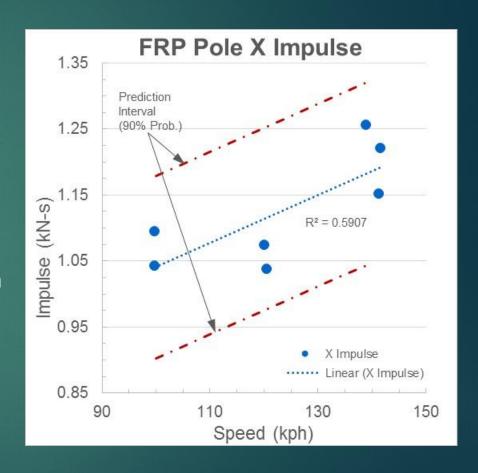
► ICAO

- ► "4.1.1 Impact may affect flight safety in three ways:
 - a) the aircraft may lose momentum;
 - b) the aircraft may change direction; and
 - c) the aircraft may suffer structural damage."
- "4.1.2 The amount of momentum lost is mathematically governed by the integral of force over time."

- ► Aluminum poles
 - Relatively small variation
 - Clear correlation to Speed
 - Prediction interval @ 140 kph: 0.504 kN-s ± 8.2%

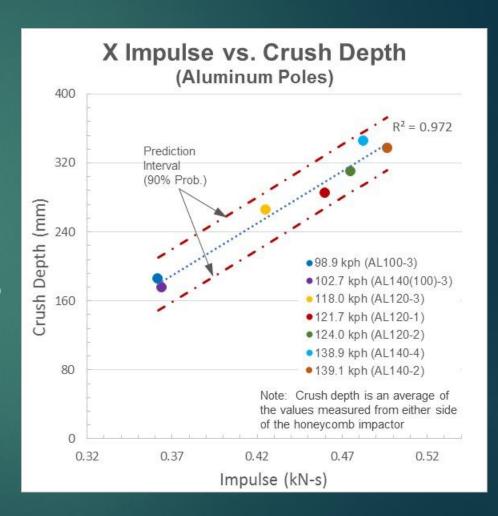


- ► FRP poles
 - Relatively small variation
 - Some correlation to Speed
 - More of the variation is due to sources other than speed
 - Prediction interval @ 140 kph: 1.186 kN-s ± 11.67%



Impulse

- ► Aluminum poles
 - Relatively small variation
 - Clear correlation to Crush Depth
 - Prediction interval @ 0.504 kN-s: 352 mm ± 8.4%



Energy (Work) vs Impulse

▶ Review

- ▶ Energy (Work)
 - Work done on pole is not accurately represented because of impactor crush
 - Energy calculation only applicable to the X-direction

▶ Impulse

- ▶ Does not require an estimate of impactor displacement
- ▶ Can be applied in multiple directions
- ▶ Directly related to change in momentum of the aircraft
- Correlation to impactor crush (wing damage)
- ► Limit for energy at 140 kph can be directly applied to impulse criteria

Shane Shurtliff, P.E.

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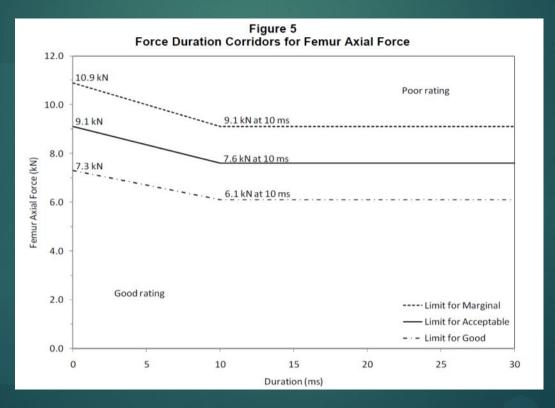
Proposed Criteria

 Calculating force duration is a process which analyzes the duration in which a force is applied

Force Duration Examp	le				
(Does not include any real test d	ata)				
Analysis Process	Raw Data		Force Duration Sort		
1) Time step obtained from DAQ sampling rate (20 kHz ⇒ 0.00005 sec timestep)	Time	Force Value	Duration	Force Value	
2) Force values sorted greatest to least	S	kN	S	kN	
3) Assign one time step to each force data point to get duration	0	0	0.00005	10.6	4
4) Example shows that 7 out of the 20 data points are above 5 kN	0.00005	0.05	0.0001	10.5	_
5a) Duration = (Number of data points above 5 kN) x (timestep)	0.0001	0.5	0.00015	7.5	4 Above 5
5b) Duration = 7 x 0.00005 = 0.00035 sec	0.00015	1.6	0.0002	7.4	
6) Force is greater than 5 kN for 0.00035 sec	0.0002	2.8	0.00025	6.9	
12 10 8 SkN Raw Data Force Duration Sort	0.00025	6.9	0.0003	6.5	
	0.0003	6.5	0.00035	6.5	
	0.00035	7.4	0.0004	4.6	
	0.0004	6.5	0.00045	4.6	
	0.00045	10.6	0.0005		
	0.0005	10.5	0.00055		
	0.00055	4.6	0.0006	2.8	1
	0.0006	7.5	0.00065		_
	0.00065	4.6	0.0007	2.1	
	0.0007	4.2	0.00075	1.6	i
	0.00075	4.5	0.0008	_	
	0.0008	2.2	0.00085	0.5	,
0 0.0002 0.0004 0.0006 0.0008 0.001 0.0012	0.00085	2.1	0.0009	0.05	,
Time (s)	0.0009	1	0.00095	0)
	0.00095	0	0.0010	0	

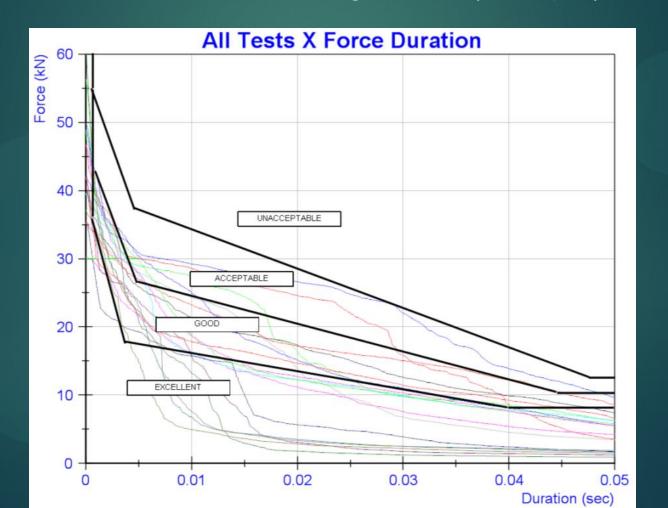
Proposed Criteria

The automobile industry uses force duration in many different areas of testing, but most commonly in human injury ratings



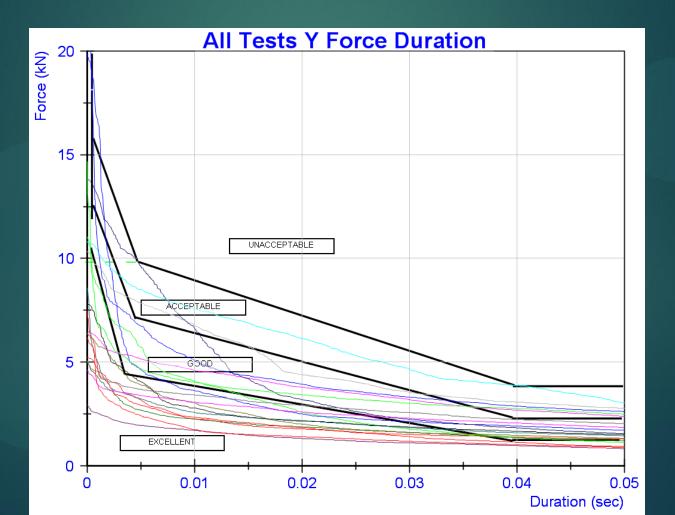
Proposed Criteria

X-Axis Force Duration Rating Criteria (Example)



Proposed Criteria

Y-Axis Force Duration Rating Criteria (Example)



- Impulse eliminates uncertainties in impactor displacement
- Impulse can be applied in all directions
- Impulse is directly related to aircraft momentum
- Impulse can be correlated to level of wing damage
- Force duration criteria can potentially provide a correlation between force levels and wing damage
- Rating criteria can be used for both impulse and force duration

- Replace energy criteria with impulse
- Research force duration criteria as a possible alternative to peak force