Effect of Material Yield Strength of Frontal Member in Automotive Frontal Crash

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Abstract- This paper deals with study of effect of varying yield strength of material for front longitudinal member of pick-up vehicle in frontal crash. The objective is to study maximum force carrying capacity, energy Absorption and deceleration of seat member. The model chosen for study is well correlated and open source model. The physical test to FE correlation is well achieved and this model is suitable for further study about the crash behavior of frontal structure. The aim is to run this model with different materials with different yield strength of the longitudinal member of chassis structure which is playing crucial role in frontal crash behavior.

Index Terms- Frontal Crash, Effect of Thickness, FEA, Crash

I. Introduction

The vehicle collision is a consequence of circumstances that produce abnormal operating conditions for the vehicle. Whether the collision occurs with another vehicle or with a stationary obstacle; it subjects the vehicle structure to forces and deformations. If the forces involved exceed the energy absorbing capability of the vehicle structure, occupants may be injured or killed. The vehicle structure should be sufficiently stiff in bending and torsion for proper ride and handling. It should minimize high frequency fore-aft vibrations that give rise to harshness. The structure should yield a deceleration pulse being deformable, yet stiff, front structure with crumple zones to absorb the crash kinetic energy resulting from frontal collisions by plastic deformation and prevents intrusion into the occupant compartment, especially in case of offset crashes and collisions with narrow objects such as trees. Short vehicle front ends, driven by styling considerations, present a challengingtask to the crashworthiness engineer. In addition, the automotive safety engineer is responsible for packaging the occupants, so whatever decelerations transmitted to the occupants are manageable by the interior restraints to fall within the range of human tolerance. The ultimate goal of the safety engineer is to reduce occupant harm. Typically, designers accomplish this goal using a combination of crash avoidance and crashworthiness measures.

II. Finite Element Model of Chevy Silverado

For the purpose of study an open source full vehicle model is chosen is for vehicle Silverado by Chevy Silverado. This model is released by FHWA/NHTSA National Crash Analysis Center. The model is for standard frontal impact NCAP validated model. This model is Model massed to reflect NCAP test mass (includes dummy mass and instrumentation mass. This is well correlated model with physical frontal impact test [5]

Following are few salient features of this model:

1) Model released by FHWA/NHTSA National Crash Analysis Centre
2) Silverado.2.2617kg.
3) Standard frontal NCAP validated model
4) Model massed to reflect NCAP test mass (includes dummy mass and instrumentation mass)
5) Detailed model, can be used for most impact scenarios
6) Material derived from coupon data derived coupon testing
7) Frontal impact validation into a rigid load cell wall.
8) LS DYNA is used as simulation software for the Finite Element Analysis.

This model verified against frontal NCAP test (NHTSA Test No. 5877). The crush mode of the rails and the structural members shows goodcorrelation between test and simulation.Engine and Body mount failure were observed in the NCAP test.Suspension system is modeled in greater detail.Vehicle is set to equilibrium position under gravity loading. FE model is stable in full frontal flat rigid wall simulations (Modelhas been run at 25, 30 and 35 mph to ensure stability.

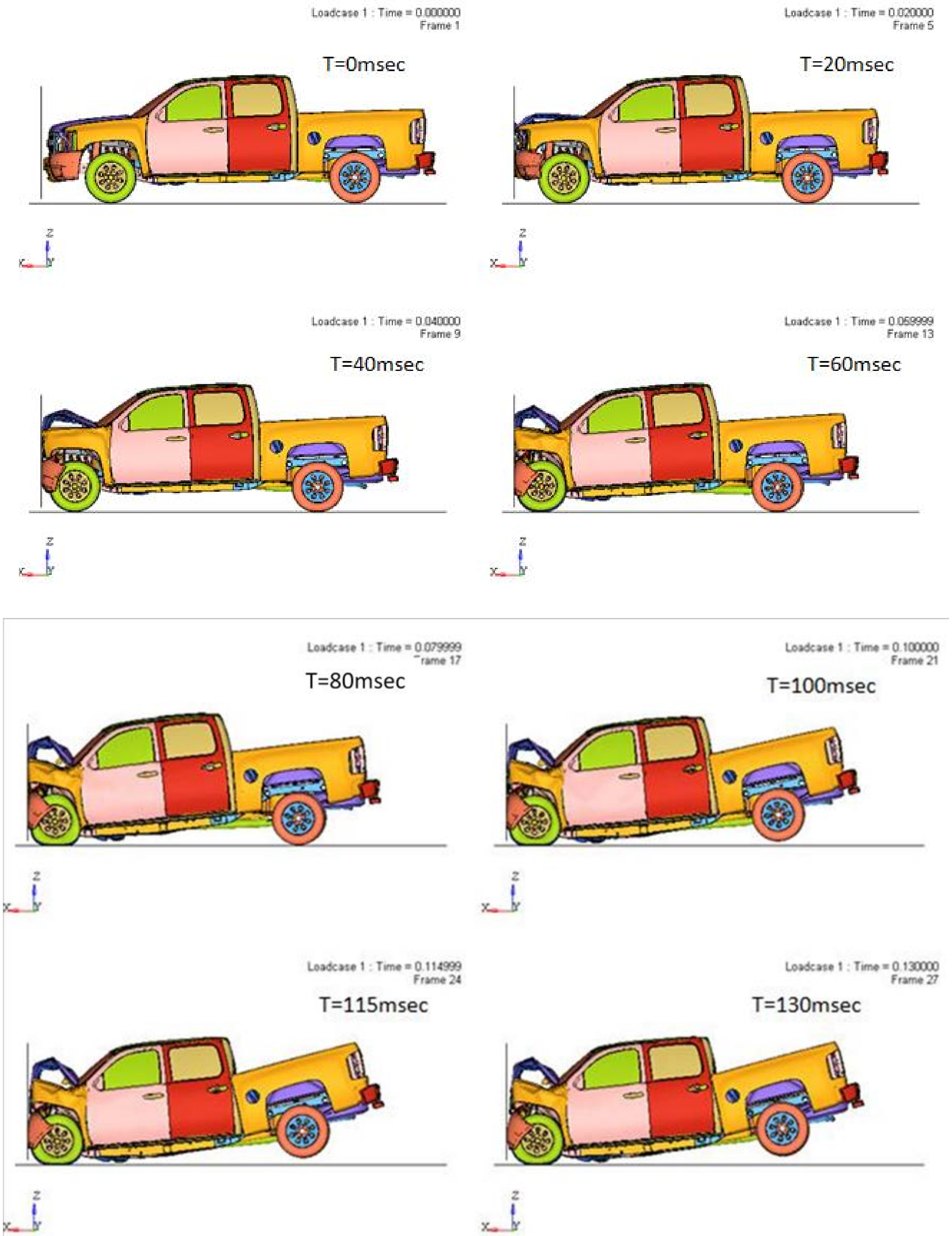
	FE Model	NCAP Test 5877
Weight (Kgs)	2617	2622
Engine Type	4.8 L V8	4.8 L V8
Tire size	P245/70R17	P245/70R17
Attitude (mm) As delivered	F – 1016	F – 929
	R – 1043	R – 1002
Wheelbase (mm)	3660	3664
CG (mm) Rearward of front wheel C/L	1664	1664
Body Style	4-door crew cab	4-door crew cab

III. Scope of the Study

The aim of this paper isto study of effect ofmaterial yield strength of the longitudinal member of chassis structure which playing crucial role in frontal crash behavior. The Effect is measured in terms overall energy absorbed by this member, Section force generated in the member and its effect on acceleration levels on seat mounting locations. For occupant safety lower the deceleration better to manage occupant decelerations with active restraint systems. Higher the declaration higher the risk of occupant fatal injuries due to sever forces getting generated in very small time. For this study the material yield strength and post yield behavior of longitudinal member of chassis structure is varied as seen in table.

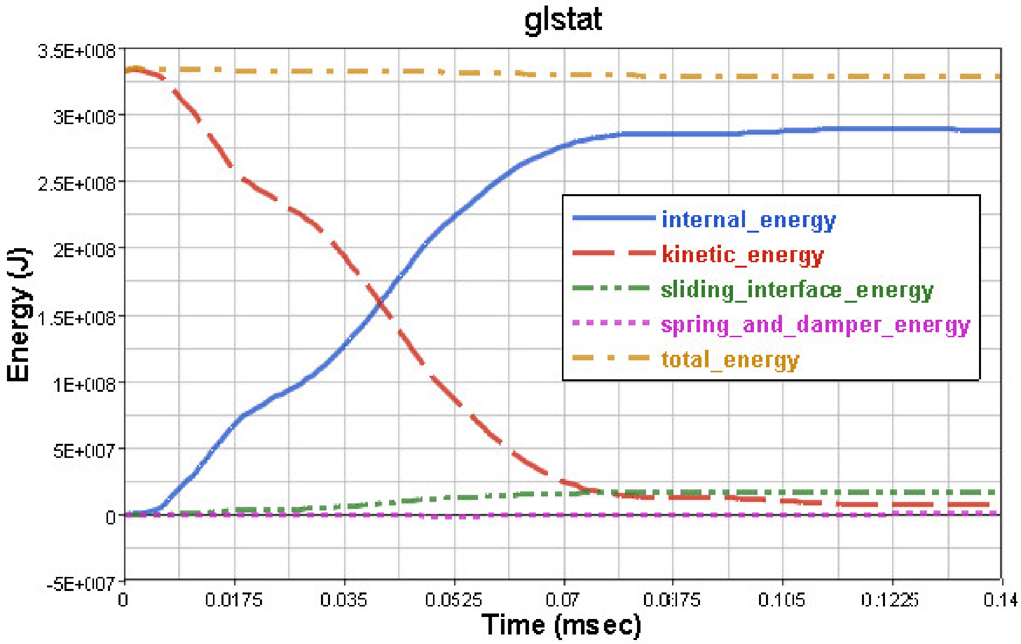
Run	Yield stress	Thickness	Ultimate stress	Elongation (%)
1	300	3 mm	370	24
2	420	3 mm	490	18
3	490	3 mm	560	14
4	550	3 mm	620	12

IV. Model Behavior during Frontal Impact.

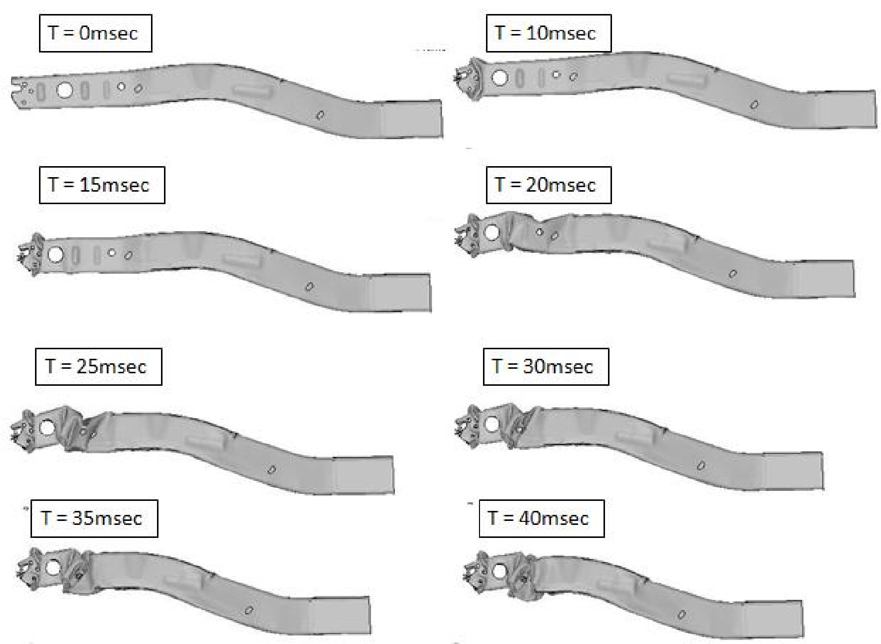


V. Energy Balance

Following diagram shows energy balance of the model. The total kinetic energy of the model is reduced over the crash duration and mostly converted into internal energy of the vehicle structure due to deformation. The sliding interface energy and spring and damper energy are lower as desired. The vehicle structure at front is designed to absorb this impact energy and longitudinal member selected for this study is playing key role in this.



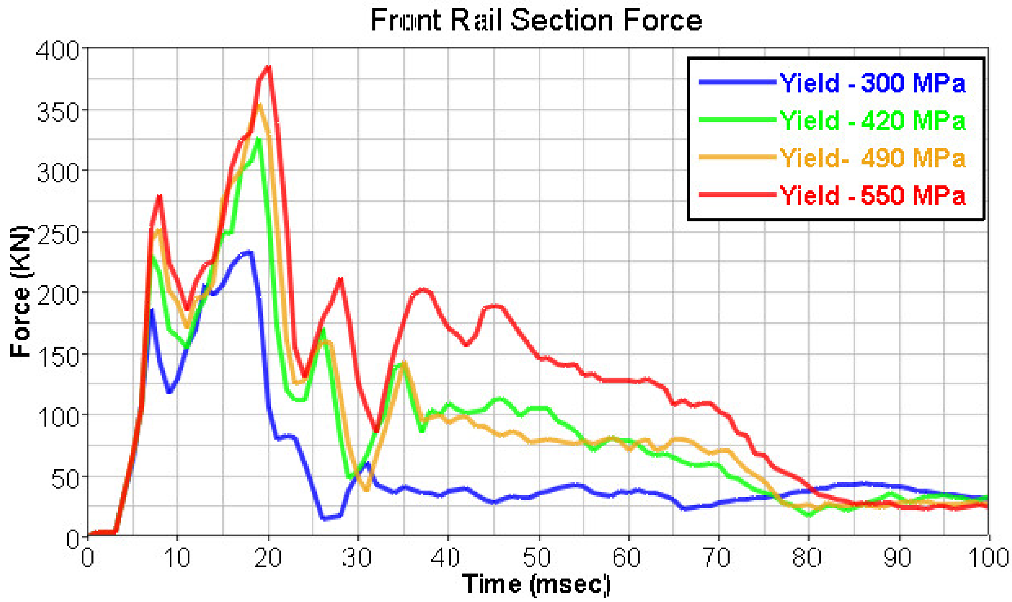
VI. Deformed Shape of Front Rail



This is the front longitudinal member for which material is varied to study the effect of material yield strength. This member is deformed during the crash event initiating a collapse at 25 milliseconds. Maximum resistance is offered before the collapse is function of thickness, geometry and material.

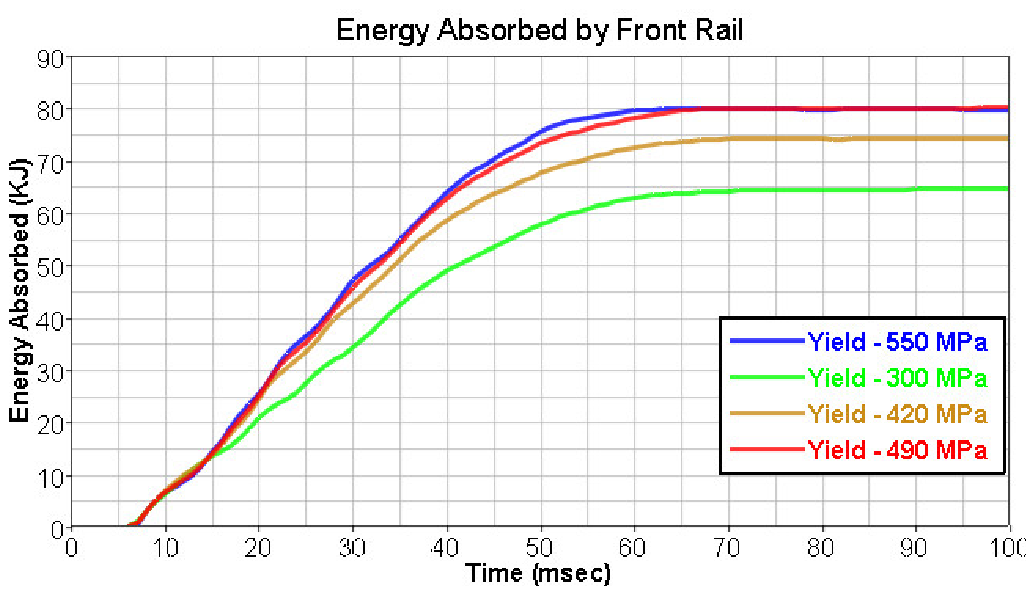
VII. Section forces comparison with respect to varying thickness

As seen from the comparison of results it is evident that as material yield of front rail is increased the ability to take force by front rail is increased.



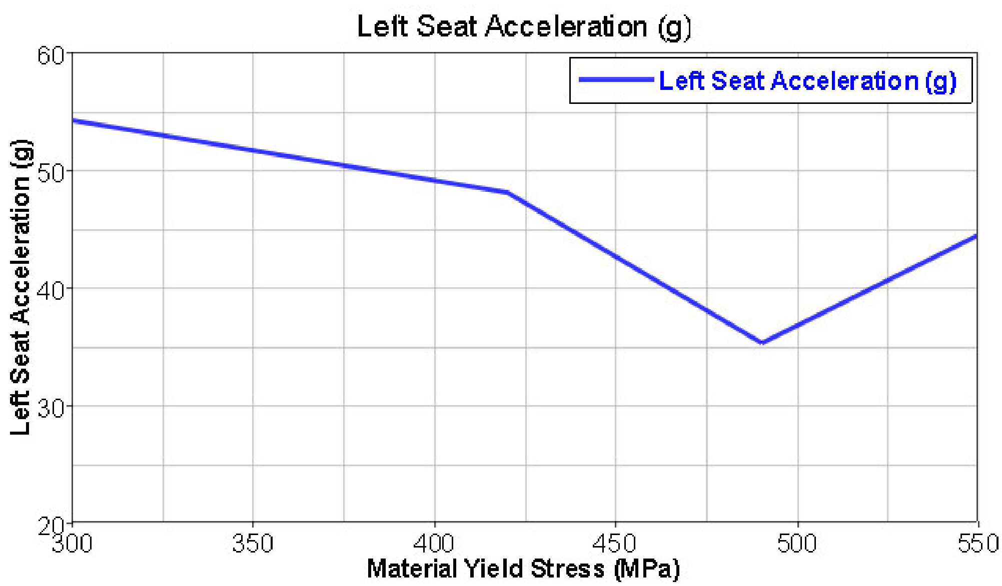
VIII. Energy Absorption comparison with respect to varying yield of material

This is plot of Energy Absorption by front rail for different material yield strengths. As material yield strength of front rail is increased there is increase in energy absorption capacity. Also it is indicating increasing yield strength after certain limit the energy absorption capacity is not increasing. So there is limit to Energy absorption capacity of the rail with increase in material yield strength and further increase may give stiff response from the rail.



IX. Acceleration comparison with respect to varying Material Yield

The acceleration for left seat is monitored in this case and it is showing interesting trend. The acceleration is high at when material with lowest yield i.e.300 MPa isused and gradually decreases with increase in yield of material used for front longitudinal member used up to and again sharply rises with material yield of 550Mpa.With lower yield the front rail's giving up with less force and residual forces are transferred further towards passenger compartment, resulting higher deceleration ofleft seat. So with material of yield of 490 MPait appears to be optimum design with relatively lower acceleration of the left seat as well as fairly good force and energy absorption capability. Also the gain in energy absorption from 490 MPa to 550 MPa is relatively less.



X. Conclusion and further study

With lower yield material for the front rail, it is giving up with less force and residual forces are transferred further towards passenger compartment, resulting higher deceleration of left seat. So with material with yield of 490 MPa it appears to be optimum design with relatively lower acceleration of the left seat as well as fairly good force and energy absorption capability. Also the gain in energy absorption from 490 MPa to 550 MPa is less or negligible along with adverse effect of increase in deceleration of the seat.

With this study it is evident that along with thickness of front longitudinal rail the yields strength and post yield material properties have significant bearing on the crash behavior of vehicle. Further study can be taken with different geometrical shapes with varying moment of inertia for frontal longitudinal members with the same thickness and yield of material

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