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Damage Evaluation of seat belt components using Finite Element Method

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Abstract

Street traffic wounds are a significant general medical issue and a main source of death and damage far and wide. Every year almost 1.2 million individuals pass on and millions more are harmed or incapacitated because of street crashes, for the most part in low-and center salary nations. Just as making tremendous social expenses for people, families and networks, street traffic wounds place an overwhelming weight on wellbeing administrations and economies.

The World report on street traffic damage avoidance, propelled mutually in 2004 by the World Health Organization and the World Bank, distinguished upgrades in street security the board and explicit activities that have prompted emotional declines in street traffic passing's and wounds in industrialized nations dynamic in street wellbeing. The utilization of safety belts, head protectors and youngster restrictions, the report appeared, has spared a huge number of lives.

The utilization of safety belts is one of the most significant moves that can be made to forestall damage in an engine vehicle crash. While safety belts don't keep crashes from occurring, they assume a significant job in decreasing the seriousness of damage to vehicle tenants associated with an impact. An inhabitant's possibility of endurance increments significantly when suitably limited.

Seat belt components damage is studied using LS Dyna which is a Finite Element Analysis tool. The development of GISSMO (Generalized Incremental Stress-State de-pendent damage Model) material is discussed in the project.

GISSMO combines the proven features of failure description provided by damage models for crash-worthiness simulations together with incremental formulation for the description of

the material instability/localization. The accurate description of instability/localization has a great influence on the results in a crash simulation. GISSMO is a phenomenological damage mechanics model which is based on experimental results and does not consider voids and cracks.

1. Introduction

Street traffic wounds are a significant general medical issue and a main source of death and damage the world over. Every year almost 1.2 million individuals bite the dust and millions more are harmed or impaired because of street crashes, generally in low-and center pay nations. Just as making tremendous social expenses for people, families and networks, street traffic wounds place an overwhelming weight on wellbeing administrations and economies. The expense to nations, a significant number of which as of now battle with monetary advancement, might be as much as 1–2% of their gross national item. As mechanization increments, forestalling street car accidents and the wounds they exact will turn into an expanding social and monetary test, especially in creating nations. If present patterns proceed, street traffic wounds will increment drastically in many pieces of the world throughout the following two decades, with the best effect falling on the most defenseless residents. The utilization of safety belts, caps and kid limitations, the report appeared, has spared a huge number of lives. The presentation of speed restricts, the making of more secure foundation, the implementation of points of confinement on blood liquor focus while driving, and upgrades in vehicle wellbeing are on the whole mediations that have been tried and over and again demonstrated to be powerful.

Retractor is a heart or main part of seat belt system. It helps to lock the webbing in case of crash events to protect the occupant by proper positioning or by holding back to seat. At the time of crash, impact force developed on the thoracic part is transferred to shoulder belt and then to seatbelt retractor. Retractor bracket takes the maximum of load and then load is transferred to the car body. The Modern retractors consist of load limiters, pretensioners and pre-pretensioners for improved comfort and more effectiveness of seat belt in reducing injury risks to occupant. In retractor assembly, apart from retractor bracket, TV Frame, Tube cover all other parts are plastic parts. Continuous efforts are being put to improve the ergonomic and performance of the Seatbelt retractor.

Figure 1 Sequence of crash

In the Automotive business there is a requirement for decrease of weight of segments so as todiminish the Energy utilization, o2 outflows and furthermore the requirement for high security, which has prompted the utilization of high-quality steels in view of their light weight and high-qualityproperties. The increasing demand for high strength steels and short development time has led to the requirement of improved predictions of the actual crash behavior in the automotive industry because a full vehicle crash test is both expensive and time consuming. Following are the material cards used in the analysis

The material models used for crash simulations are usually isotropic and is based on the Gurson, Tvergaard & Needleman or the von Mises flow method. GISSMO is the damage model which has been developed at Daimler and DYNAmore used in such crashworthiness simulations. This material modelling is mostly based on the reference of various LS-DYNA Users conferences and papers. GISSMO damage model has many numbers of parameters and curves that defines when necking and failure starts to occur. GISSMO is a phenomenological damage mechanics model which is based on experimental results and does not consider voids and cracks that are formed during the manufacturing.

There exists a failure criterion and also a localization criterion. In GISSMO their also exists an equation that can be used to find the total amount of energy absorbed by the material during a crash simulation. This damage model can be used similarly for other AHSS and High strength steels also.

Bridgman, Rice and Trace have demonstrated that the material disappointment is needy of the pressure state. Subsequently, the pressure state must be contemplated while describing a material's properties.When performing crashworthiness figuring's, it ought to be made to depict the pressure condition of various burden cases utilizing the invariants of the pressure tensor. Crashworthiness calculations are regularly performed on a sheet metal structure and a typical suspicion for this structure is that plane pressure wins. On the off chance that plane pressure wins, the distinctive pressure states can be particularly decided with only one parameter. The parameter is known as the triaxiality, η, and it is characterized as,

$$\eta = \frac{I_1}{\sigma_{eq}}$$

$$I_1 = \frac{\sigma_1 + \sigma_2 + \sigma_3}{3}$$

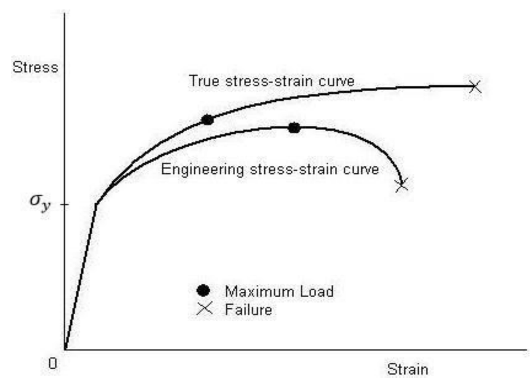
To comprehend what applications a material can be utilized for, it is important to portray its properties. To describe a material's disappointment properties, distinctive pressure states must be examined. This investigation includes breaking down the conduct during five distinctive material tests. These are one uniaxial pressure test, two diverse shear tests

Uniaxial tension test

The most major material properties can be acquired from a uniaxial elastic test. It is performed by locking one finish of the example and applying a specific burden to the opposite end. The extension of the example is estimated until its disappointment. With known beginning components of the example and the deliberate lengthening, the connection among anxiety can be gotten effectively. Underneath picture shows a schematic pressure strain relationship, got from a uniaxial malleable test. The material carries on straight flexible until the yield point σy and the connection among anxiety in the stacking heading until this point is depicted by Hooke's law and is spoken to as, σ = Eε. On the off chance that the material is stacked further, the material goes into the plastic district. Askeland depicts the separation forms that cause the recognizable plastic conduct. At the point when the material

two distinctive indented tests. These various tests are picked in light of the fact that they spread a wide range of pressure states.

is stacked into the plastic area, the yield pressure increments. This sort of treatment is called strain solidifying.



From that point, at a definitive rigidity, the solidifying of the material can never again make up for the reduction in region. From above Picture, where the commencement of diffuse necking is set apart as the most extreme burden. The conditioning that emerges after this point, is because of the building esteems. An issue with the designing qualities is that they don't consider that the measurements change during stacking. The uniaxial pressure test example is thought to misshape consistently before necking. Until this point, the building esteems may legitimately be changed over into genuine qualities with the accompanying conditions

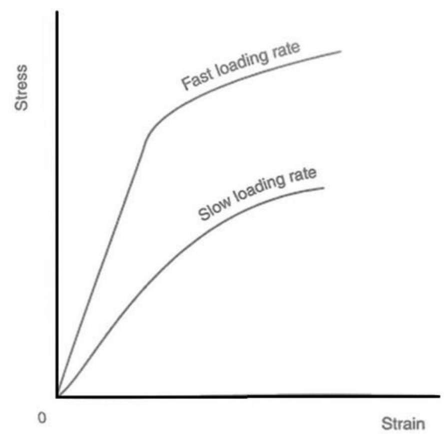
$$\varepsilon_{eng} = \int_{L_0}^{L_1} \frac{dL}{L_0} = \frac{\Delta L}{L_0}$$

$$\sigma_{eng} = \frac{F}{A_0}$$

$$\varepsilon_{true} = \int_{L_0}^{L_1} \frac{dL}{L} = \ln\left(\frac{L_1}{L_0}\right) = \ln(1 + \varepsilon_{eng})$$

Strain rate dependency

There are various materials in a vehicle, each with its own properties. Usually the reaction of the material is needy of the stacking rate, i.e the strain rate. A strain rate subordinate material could have properties appeared in beneath chart. In any case, the distinction of Young's modulus, i.e the slant for the flexible conduct, is little for metals. Indicated that the higher strain rates the material is exposed to, the more grounded it carries on. To comprehend if a material will show this conduct or not, it is important to know how the material has been treated preceding that. There are a couple of elements that are considered to choose if the material, right now, is strain rate subordinate. Right off the bat, it relies upon which materials the steel is made of. It additionally relies upon the warm treatment that the steel has been experienced to. The temperature of the material is additionally significant factor to know.



Damage mechanics

Harm is a highest piece of the material properties while thinking about material disappointment. This idea accepts development of voids in the material. The harm spoke to by, D, is essentially a measure for the decrease of the cross-segment zone concerning the up and coming void as demonstrated as follows

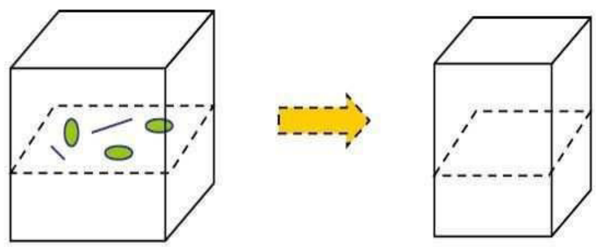


Figure 2The current section area and the effective section area

Above picture shows the general segment territory including miniaturized scale absconds and the decreased, effective, cross segment zone. In the event thatan is representant current segment zone, i.e. the cross-segment territory including the zone of the voids, and Aeff will speak to the successful cross segment region, for example the cross-segment zone barring the region of the voids, Lemaitre and Chaboche characterize the harm parameter

$$D = 1 - \frac{A_{eff}}{A} = \frac{A_{defect}}{A}$$

At the point when the harm is equivalents to 1, the material fizzles. The decrease of the cross segment will affect the pressure used to show the worldwide reaction. The meaning of σtrue, together other condition above gives Lemaitre's plan which is a fundamental connection to hold harm to the anxieties together

$$\sigma_{eff} = \frac{F}{A_{eff}} = \frac{\sigma_{true}}{1 - D} \Rightarrow \sigma_{true} = (1 - D)\sigma_{eff}$$

This is essential harm hypothesis and the basic hypothesis for the distinctive disappointment models. One regular contrast between the models is that the harm development. Liang Xue guarantees that one of the most generally utilized and least complex methods for portraying the harm development is the Johnson Cook model that yields

$$\dot{D} = \frac{\dot{\varepsilon_p}}{\varepsilon_f}$$

Material failure

While concentrating material disappointment, it is imperative to know how the material model assesses material disappointment. A large portion of the models are strain based, that imply that disappointment don't happen during pressure of the segment. There are two strategies to play out this. The principal technique is a disappointment criterion. A disappointment criterion predicts a point of disappointment yet doesn't show the real disappointment conduct in the model. If the harm of a component surpasses a specific wellbeing esteem, the component is wiped out. A disappointment criterion is likewise characterized as a disappointment model which doesn't couple harm with pressure. The subsequent technique is disappointment model, which rather than simply wiping out the component, attempts to dissect practically the burst way and lower the stacking limit of a component constantly in relation to its harm parameter, i.e. couple the harm and genuine worry to discover disappointment of material.

LS-DYNA

The capacities of LS-DYNA are numerous and not many among them are static and dynamic calculations, material disappointment investigation and split spread to give some examples. LSDYNA's express settling procedure is broadly utilized in the car business. One explanation behind this is it predicts the vehicle's conduct and its impact upon the tenants during crash. To run a reenactment, a ".key" document is important. The key-document is a content that contains a progression of catchphrases in it. The catchphrases illuminate the solver about how the reenactment should be carried out, for example, which geometry, material model, limit conditions, time step, and so on that are vital. The watchwords that will be utilized are *MAT 024, which will show the elasto-plastic conduct, and *MAT ADD EROSION, which will demonstrate material disappointment.

*MAT 024

*MAT 024 model is with elasto-plastic conduct and depends on von Mises yield criteria which is utilized to show the material conduct until where unsteadiness happens. The info parameters considered in the *MAT 024 card are essentially Young's modulus, the mass thickness, Poisson's proportion and the solidifying of the material. The solidifying bend will just cover the stacking way until shakiness begins. Furthermore, the model backings progressively complex material conducts additionally in which the material is strain rate subordinate, i.e. a viscos-plastic model. Rather than actualizing one solidifying bend, a table characterizing distinctive strain rates which are associated with a specific solidifying bend must be executed to catch the conduct in detail. Notwithstanding, *MAT 024's properties are not fit for communicating the material conduct past the purpose of uniform extension. To have the option to get that piece of the conduct, the *MAT ADD EROSION watchword must be utilized.

*MAT ADD EROSION

Material models in LS-DYNA don't permit material disappointment. The *MAT ADD

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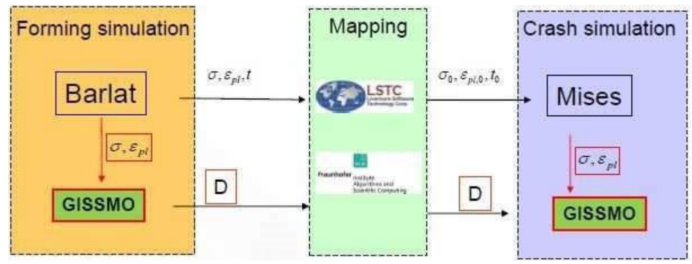
EROSION card gives a choice to add these properties to other material models. The watchword incorporates choices to actualize GISSMO. LS-DYNA User's Manual Volume II , gives a point by point portrayal of the info parameters, however a couple of the most significant and basic parameters are exhibited in beneath table. These are the parameters that must be recognized through turned around designing technique with an improvement programming, LS-OPT.

GISSMO

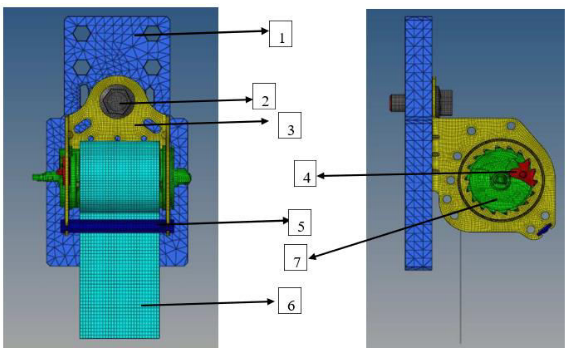
Center has been to improve the forecast of split inception and engendering. To accomplish this, Daimler and DYNAmore have discovered a way where it is conceivable to decide and aggregate the pre-harm caused during the sheet metal shaping to the accident investigation. The tricky part has they confronted is an anisotropic yield criterion for example Slope or Balart is utilized for the shaping procedure and an isotropic yield criterion for example von Mises is utilized during crash recreations. A harm model that is appropriate for both the strategies needs to accurately foresee harm paying little heed to the standard utilized. GISSMO has been created to fill all the holes by empowering mapping of harm and different history parameters from the shaping reproduction to the accident reenactment, as demonstrated as follows.



2. NUMERICAL STUDY

Finite element Model Building of seatbelt retractor

Finite element modelling of retractor model remains same as FE model building of Anchor plate. To begin with retractor CAD model in CADPART or IGES format is imported into the preprocessor tool that is. Seatbelt assembly contains main parts such as Frame, Spindle, Bracket, Tie plate, Thread head, Lock dog, etc. The Meshed parts of seatbelt assembly are as shown below. The blue colored part is support plate used to support frame from bending when its being loaded. Bolt of 22mm Flange head us used to hold frame to car assembly. For the Simulation Bolt is considered as rigid part. Frame, Tie plate, Lock dog are meshed with the Hex elements and Spindle, Support plate are meshed with tetrahedral elements. Webbing is meshed with shell elements.



1.Support Plate
2.Bolt
3.Retractor Frame
4.Lockdog
5. Tie Plate
6. Webbing
7. Spindle

Material Definition

Deformable materials are used for Frame and Tie plate. Spindle, Lock dog, Bolt and fixture are modelled with rigid material as shown below.

Part	Material	LS-Dyna material card	Density Tones/mm3	Young's Modulus MPa	Yield Strength MPa	Ultimate Strength MPa	% Elongation
Frame, Tie plate	SPFH590	*MAT_PIECEWISE_LINEAR_PLASISITY and MAT_ADD_EROSION	7.850e-09	210000.0	550	660	20
Spindle, Bolt and Support Plate	Steel Rigid	*MAT_RIGID	2.950e-09	71000.0	-	- -	-

Load and boundary condition

Below shown picture shows the loading direction of the Seatbelt retractor assembly. Displacement of 100mm for 100ms is applied on the webbing and the load is transferred to the spindle on which the webbing is being wounded. The load from spindle is transferred to the frame through Lock dog which engages to teeth of frame.

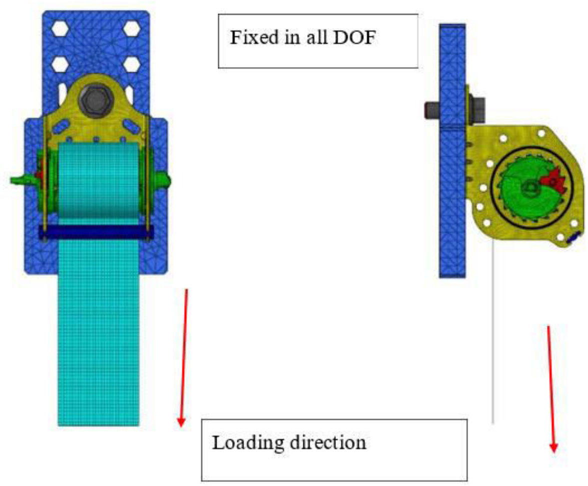


Figure 3Loading Direction

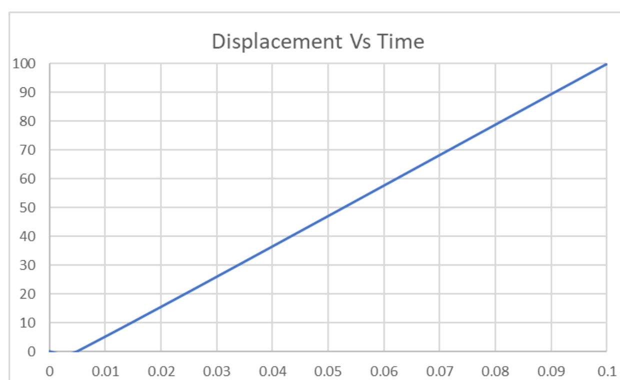


Figure 4 Loading Rate

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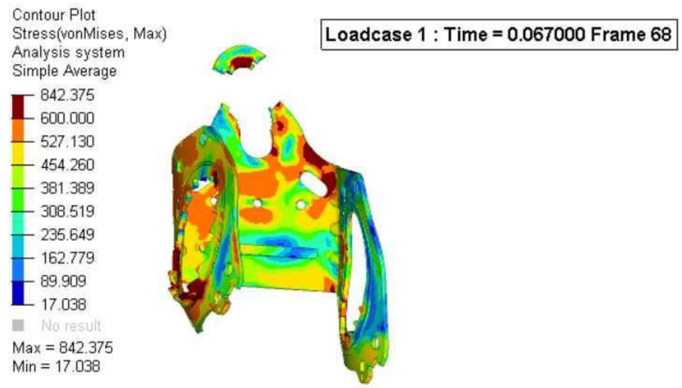
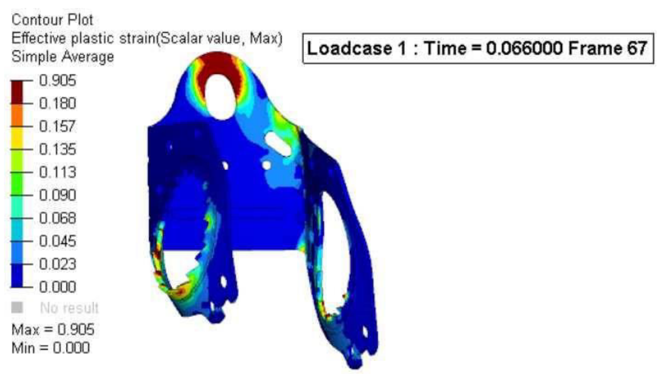
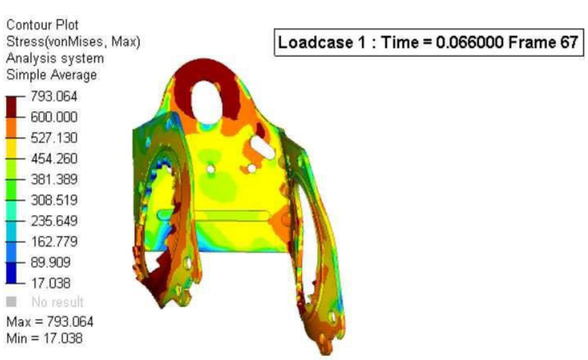
Results: Retractor strength simulation

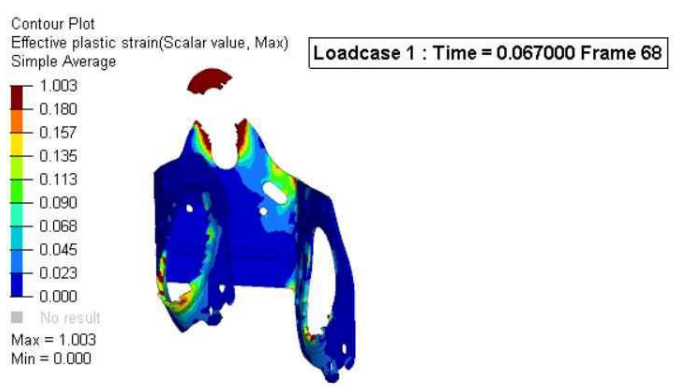
D3plot and Binout files are loaded to Hyper view which is a post processor tool which helps us to read the results. Below are stress and strain plots of the

retractor frame. The frame fails at 20.886kN load. The Load is extracted from the webbing at the time of failure. The stress and strains developed on the frame just before the failure and after the failure are shown below. The Brown color in the below stress and strain contour shows the stress and strains developed more than the Tensile stress and nominal strain values. It helps designer to work on to improve their design to achieve the desired failure load. For the Material used for the simulation has 600MPa Tensile strength and has 18% of failure strain. When the elements attain failure, strain values the elements gets deleted automatically and this gives us almost actual results









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Experimental test setup for Retractor Assembly

The setup consists of a Seatbelt assembly mounted to Fixture and fixture mounted on the table. The table is fixed to the ground. For testing of the Retractor Frame strength, initially the fixtures are developed to mount the test specimen into the machine. Testing is carried out as per the automotive standard. Below figure shows the test setup for tensile strength analysis. Firstly, the tensile strength fixture is fixed at the solid base mounted on the table. Retractor Assembly is tightened on the fixture. Webbing from the seatbelt is mounted to fixture to test the strength of retractor assembly.

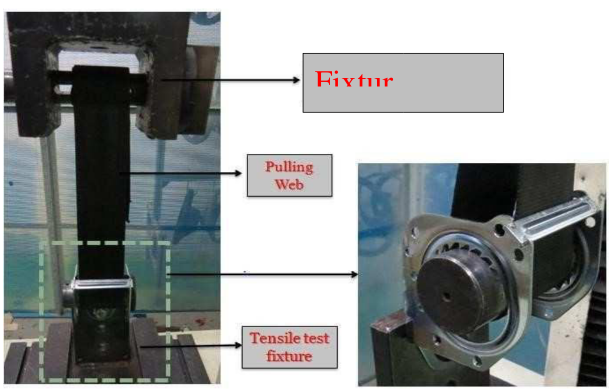

Figure 5Retractor test set up

Strength Testing machine is connected across the computer, pulling force with respect to time and Frame displacement is noted. This helps to plot force v/s Time curve for the Anchor plate. Total of thirty samples are considered for experimental study and all of them show the same failure mode and have difference in the failure load this might be due to manufacturing defects and variations in set up. Tested parts and the failure load data of all thirty tests is as shown below.

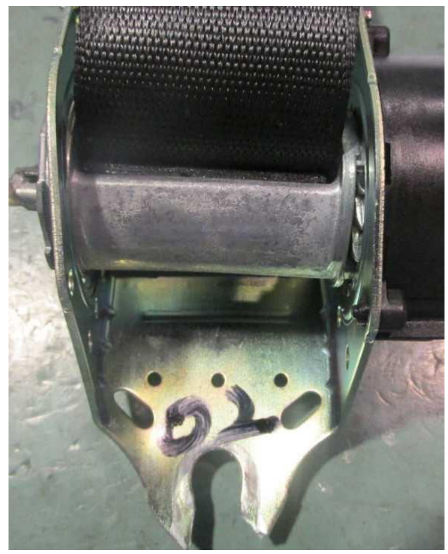

Figure 6Retractor components after testing

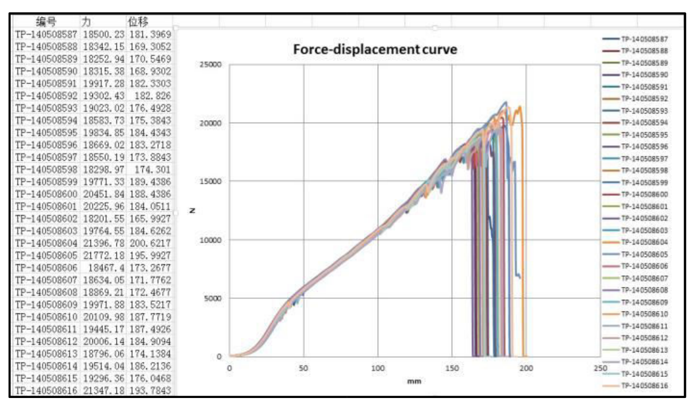

Figure 7Test results

Comparison and discussion of experimental results and finite elemental results

Every Numerical calculation should be justified by the test results before its trusted. Retractor frame strength calculation numerically says 20.886kN. In case of all 30 tests failure mode remains same that is the Frame fails around bolting region. Failure loads for all test cases vary in the range of 18kN to 21kN. There is always a variation from test to simulation because of many factors. Both test and simulation results are almost same and can be trusted and design can be taken further.

3. CONCLUSION AND SCOPE FOR FUTURE WORK

Conclusion

A numerical and experimental method has been developed to investigate tensile strength of Anchor plate and retractor assembly.

GISSMO material was developed with damage card to predict the material failure after yield point till failure.

GISSMO material played important role in the analysis to predict failure. In case of two-point curve material data failure of components has to be done by grey spot method and it's not that accurate to predict failure.

In case of GISSMO material the elements reaching failure, strain delete themselves and give exact failure of the component. In this study numerical calculations match with the test results.

Scope for future work

In this simulation we have not considered entire seatbelt assembly components for the simulation. In future we should consider all the components to replicate the actual. We have to model spindle with the hexahedral elements to consider spindle failure modes in simulation. In case of angular pulls the failure, mode shifts from bolting region to spindle failure or other modes. We should consider to model GISSMO model for spindle and other components also.

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