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Multimode Dynamic Simulation Study of Automotive Car Seat Slider Mechanism

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ABSTRACT*: A Multibody system consists of mechanical linkages and these linkages are interconnected with Rigid Bodies or Flexible Bodies approach and due to linkages dynamic behaviour they may experience translational and rotational displacements. Multibody Dynamic analysis is used to evaluate a Multibody system. It is extensively used in Automotive, Aerospace, and Robotics domain for investigating the dynamic behaviour of the system. This study deals with design and development of new seat slider mechanism and simulation by using the Multibody Dynamics. In this study, the behaviour of seat mechanism is predicted and corrected to increase the performance of the seat mechanism. The study includes theoretical calculation, tolerance stack-up, Multibody Dynamic simulation study using ADAMS (extraction of forces) and validated with the experimental data.*

Keywords*— Seat Slider, Multibody Dynamics, friction, stiction*

I. INTRODUCTION

Today, the automotive industry is advancing very rapidly. Each year new and better automotive Components are introduced by the automotive manufacturers in view of improving passenger’s safety and comfort as well as aesthetics. Today’s global competition has prompted many automotive manufacturers to design their products based on consumer’s preference and satisfaction. The drivers comfort was as important as the functional and aesthetic design of automobiles since consumers are more and more concerned about comfortable driving and safety [1]. The Design ergonomics is an important factor to consider in designing a seat. It is basically the applications of science in human life for comfort and safety. A seat and its components are one of the significant components of a car [2]. It should be designed following the trends and modern styles of automotive design era.

In general, automobile seat manufacturer of car industries has to study car seat deformation during collision. Safety of a car driver and passenger is firstly realized to protect injury [3]. Although safety devices as safety belt and airbag can decrease harmfulness but it is not enough to avoid damage. A car seat should be considered to abate accident, especially, the frontal impact direction. The major impact load in a collision is transferred through the seat slider, so it must be ensured that the mechanism has adequate strength to withstand the load [4]. Because a car seat slider plays an important role for a car driver and passengers in order to protect them before crashing and bouncing with the equipment of a car inside. The car seat slider strength is needed to be carefully designed to meet the good properties of a car seat besides an Attractive style [5]. Numerical method for analysis of car seat strength has widely used in order to help a car seat designer testing and ensuring car seat design before production.

Multibody system analysis can be used to simulate a complex system made up of rigid bodies which are connected by mechanical joints. One of the conventional methods to analyse the dynamic motions of a system is the Euler-Lagrange equations (EL) or Newton-Euler (NE) equation. The EL equation applies energy method in order to establish the equation of motion for generalized degrees of freedom [10]. NE method is extensively used to compute the internal forces between rigid bodies. Both EL and NE are require for the solution of a number of coupled equations which equal to that of the degrees of freedom of the mechanism. The Kane method based on the virtual work theory which combines the advantages of the both NE and EL method [6].

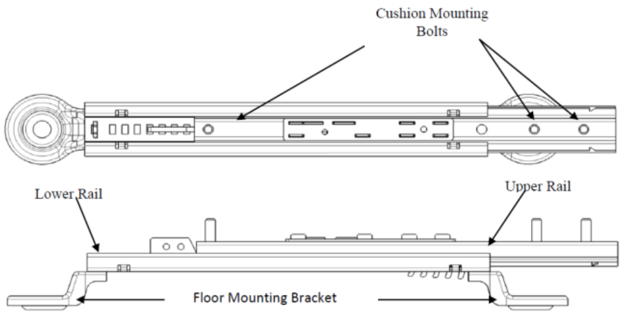
The Multibody system with motion constraint, its a common method to introduce Lagrange multipliers, but solving the mixed differential and algebraic equations (DAEs) is difficult. In order to solve DAEs there are two different approaches [7]. One is reducing the equation of motion to a state-space. The other approach is explicit expression of acceleration in terms of Kinematic variables and Time directly [8]. In this study Kane’s equation is extended and used to handle the motion constraints in multibody dynamic system.

A car Seat Slider is a major component of the seat, thus the safety is directly depends upon the strength and mechanism of the seat slider. The seat sliders are classified as T-type, W-type, and C-type according to the track profile, based on the locking mechanism as external locking and internal locking. This project aims to design and development of the new seat slider mechanism according to the customer requirement and specification. The new seat slider mechanism is validated through the Theoretical Calculations and Multibody Dynamic simulation study.

II. METHODOLOGY

A. Conceptual Design

The design type is w-type bottom locking mechanism. In this Automotive Car Seat Slider Lock assembly consists of U-Bracket, Lock Trigger, Release Lever and spring. The Lock Trigger and Release lever are riveted to the U-Bracket which is riveted to the Upper Rail of the slider. A spring is fixed to the U-Bracket and ends of the spring are loaded on the Lock Trigger and Release Lever. The spring load holds the Lock Trigger in locked position and slider is unlocking with the help of the Towel bar. According to the customer requirements and specification a new seat slider mechanism is developed.



B. Manual Calculation

The conceptual design validated based on the manual calculation of the mechanism. Thus the strength of the each part manually calculated and the dimensions are modified by considering the weight, manufacturability and cost. The safety of the passenger is the first priority of the design. Through this the minimum force required to operate the towel bar, sliding effort, Lock breakdown strength, end stopper strength and ball stopper strength are found out corresponding dimensional changes are made according to the specification. The joints like weld, bolt and rivet strength of slider subassembly are ensured that its meets required strength. The materials for the different parts of the slider have been selected based on the stress value evolved from calculation.

C. Tolerance stack- up

The perfect mechanical part is very difficult to produce with exact dimension. In order to cope with this problem, tolerances are added to the dimensions of the part. Tolerances specify a range of accuracy for the size, shape and position of an element or feature of the part. These tolerances include dimensional tolerances and geometrical tolerances, which both influence the size and shape of the product.[10] Tolerance variations on individual dimensions lead up to a ‘tolerance stack-up’ for combined dimensions, and in essence, for the shape of the complete part. Thus it is very necessary to consider the tolerances values in each part in the slider. Mainly this concentrated on the worst case design ie, the minimum tolerances on meeting part. It is to be ensured that with this condition also the mechanism meets the required specification else changes to be taken care. Any tolerance different from the general tolerance is a cost-raising factor and should therefore be studied carefully to be sure that it is functionally necessary to implement the tolerance in the part.

D. Multibody Dynamic Simulation

1) Geometry Engines: The Multibody dynamics is a power full tool to evaluate a mechanism. After the design stages its necessary to ensure that it’s working properly as per the requirement. ADAMS is perfect tool to analyse the mechanism with actual condition. To analyse the mechanism its need to be constraint the Degrees of Freedom of the system according to working condition by giving respective joints. The Forces and the contact values assigned according to the materials which are in contact. The Software takes the model in parasolid formats. [11]This format represent the geometry with its exact boundaries, which means that its have exact surfaces. Curved surfaces are truly curved it do not contains any polygons, because of that the representations are more accurate as possible.

2) Equation of motions for Multibody system: The position of the model or body is defined from the reference frame by a set of Cartesian coordinates. The position and orientation of rigid body *i* as follows [12]

$$q_i^* = [r_i^T \; p_i^T] \quad (1)$$

where, $r_i = [\, x\, y\, z\,]^T$ are the transition coordinates and $p_i = [\, e_0 \; e_1 \; e_2 \; e_3\,]^T$ are rotational coordinates by Euler parameter. The velocity and acceleration of the body i use the angular velocities ω and acceleration α instead of time derivatives of the Euler parameters. The velocities and accelerations given by vectors

$$\dot{q}_i = [\, r_i^T \;\; \omega_i^T \;]^T \quad (2)$$

$$\ddot{q}_i = [\, \ddot{r}_i^T \quad \alpha_i^T \,]^T \; (3)$$

The equation of motion for an unconstrained body in terms of Cartesian coordinates as follows,

$$\mathrm{M}\ddot{\mathrm{q}}_{\mathrm{r}} = \mathrm{g} \; (4)$$

Where, M is the mass matrix and g is the force vector. For a constrained Multibody system the kinematic joints are described by set of algebraic constraints.

$$\varphi(q_r\,, t) = 0 \; (5)$$

Using the Lagrange Multipliers technique the constraints are added to the equations of motion. By considering second time derivative of the constraint equation

$$\begin{bmatrix} \mathrm{M} & \varphi_{\mathrm{q}}^{\mathrm{T}} \\ \varphi_{\mathrm{q}} & 0 \end{bmatrix} \begin{bmatrix} \ddot{\mathrm{q}}_{\mathrm{r}} \\ \mathrm{k} \end{bmatrix} = \begin{bmatrix} \mathrm{g} \\ \gamma \end{bmatrix} \; (6)$$

Where k is the Lagrange multipliers vector and γ is all acceleration and velocity in the constraint equation.

$$\gamma = -(\varphi_p \dot{q}\,)_q \dot{q}_r - \varphi_u - 2\,\varphi_{qt} \dot{q}_r \; (7)$$

The differential equation that has to be solved and the obtained acceleration integrated with respect to time. Because it do not use explicit position and velocity constraints equations there may be a drift in the system constraints. In order to avoid this redundancy Baumgarte stabilization is used.

$$\begin{bmatrix} \mathrm{M} & \varphi_{\mathrm{q}}^{\mathrm{T}} \\ \varphi_{\mathrm{q}} & 0 \end{bmatrix} \begin{bmatrix} \ddot{\mathrm{q}}_{\mathrm{r}} \\ \mathrm{k} \end{bmatrix} = \begin{bmatrix} \mathrm{g} \\ \gamma - 2\mathrm{a}\varphi - \mathrm{b}^2\varphi \end{bmatrix} \quad (7)$$

Where, a and b are positive constants which give feedback control parameters for position and velocity constraint violations.

In order to start a dynamic simulation there should be some initial conditions, Positions and velocities are required. The selection of the appropriate sets plays a major role to predicting the dynamic performance of the mechanism.

3) Contact Forces: In contact mechanism there are multiple model for predicting the contact forces and georgic deformations. The hertizan theory will give better results by considering without any adhesion and discontinuity. This theory based on the impact function. [13] After choosing the impact function required stiffness, force exponent, damping and the penetration depth are to be specified according to the material and geometry. The frictional force is the important factor in contact mechanism, Coulombs friction factor shows the better results are compared to other. The frictional force instantly jumps from zero to finite, and non-zero value when the relative motion between two bodies become nonzero.[14] The dynamic coefficient is generally less than that of the static coefficient, reflecting it is easier to move something in motion than to start from the rest. The friction transition velocity should be greater than the stiction transition velocity.

4) Slider Simulation Study:

The major aim of the ADAMS simulation study is to check the functionality of the slider mechanism. Through this minimum force required to operate the Towel bar, the sliding effort has been find out. The travel of the slider and the looseness which includes free play of towel bar, horizontal, vertical and lateral looseness where find out.

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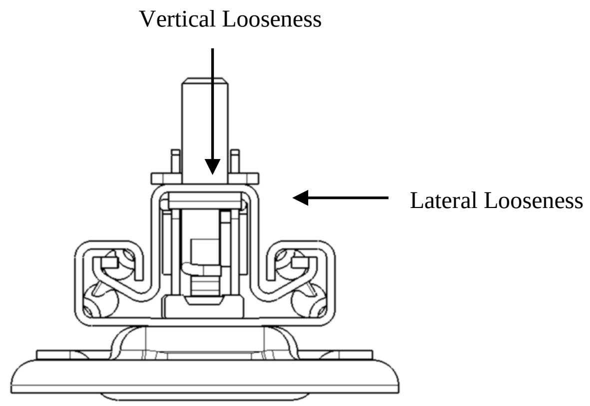
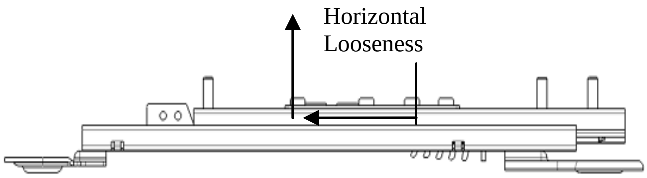


Towel Bar Operating Effort



III. RESULTS AND DSICUSIONS

The Major Problem in functionality of the mechanism comes in to the design of Trigger and its contact with the lower rail. The Unlocking and Locking should not be interfered by the lower rail. According to it the trigger tooths are modified. The strength of the required parts is calculated according to the dimension of the geometry. According to the manual calculations and tolerance stack up, following results are obtained.

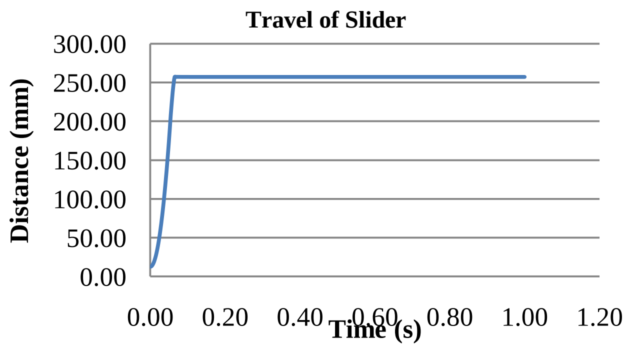


Fig 1: Travel of slider

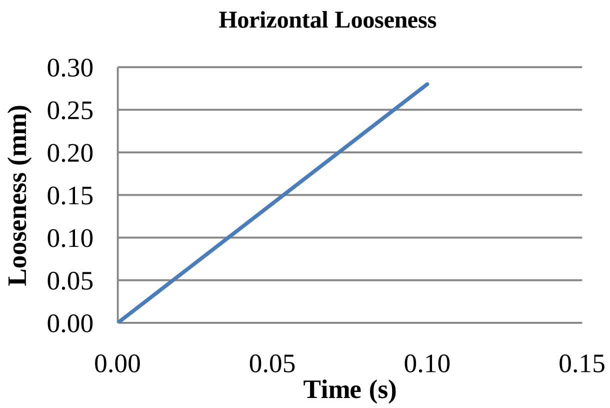


Fig 2: Horizontal Looseness

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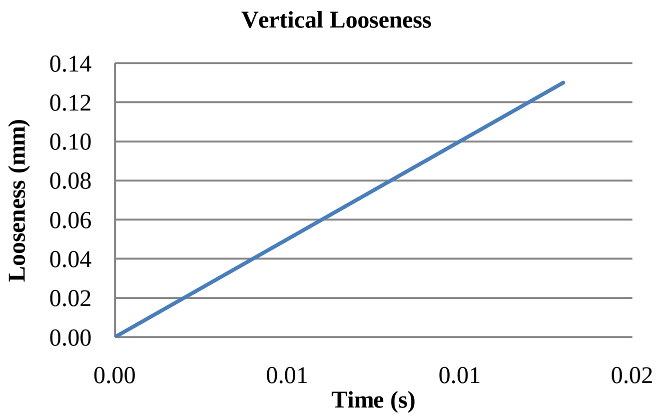

Fig 3: Vertical Looseness

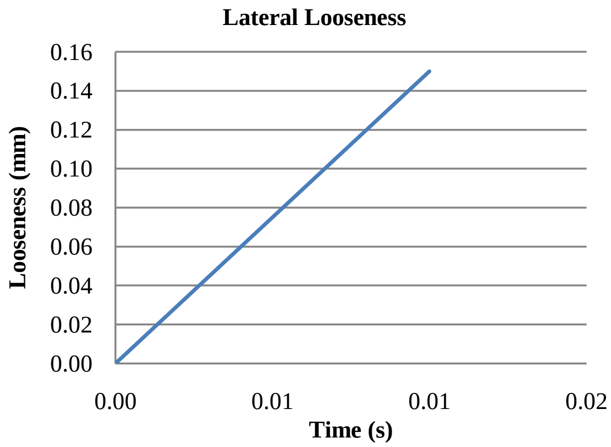

Fig 4: Lateral Looseness

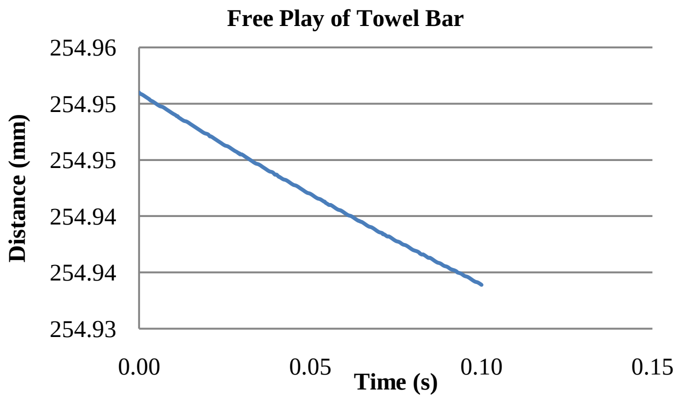

Figure 5: Free Play

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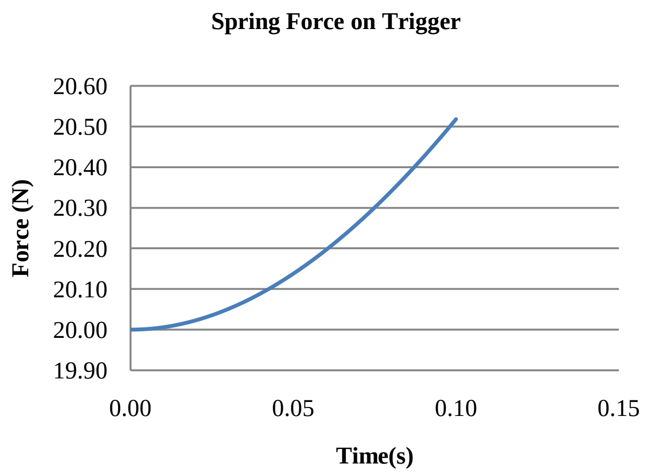

Fig 6: Spring Force on Trigger

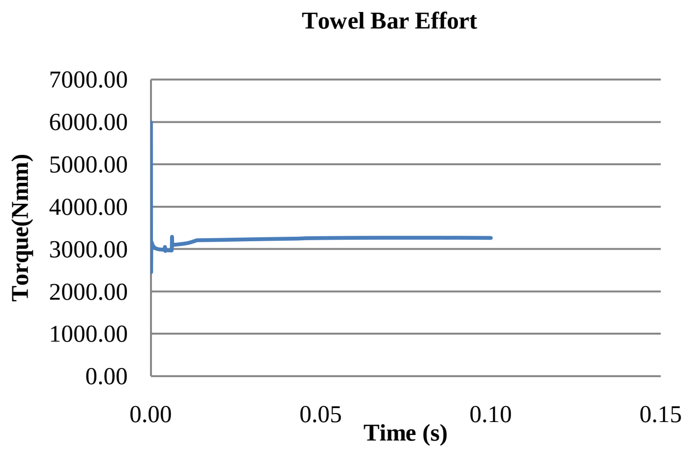

Fig 7: Towel Bar Effort

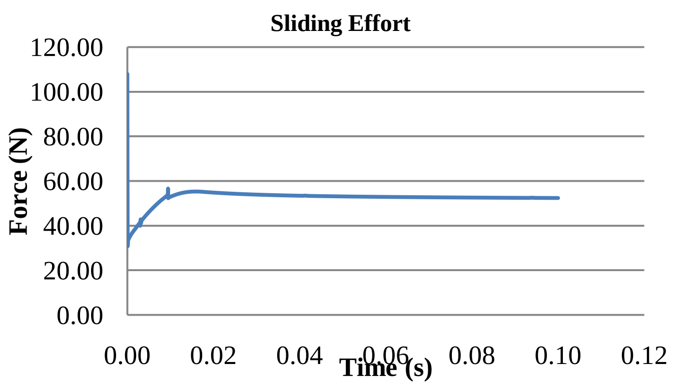

Fig 8: Sliding Effort

TABLE I
RESULT VALIDATION

Sl No	Functionality	Experimental Results	ADAMS Result	% of Error
1.	Travel or stroke of the slider (mm)	257	248	.74
2.	Horizontal Looseness(mm)	0.3	0.28	7.14
3.	Vertical Looseness(mm)	0.2	0.15	33
4.	Lateral Looseness(mm)	0.2	0.17	17.6
5.	Free play of Towel bar(mm)	0.65	0.58	12
6.	Spring Force on the Trigger(N)	20-25	19-20.5	4.7
7	Towel Bar Operating Effort (N)	30	22	36
8.	Sliding Effort (N)	58	55	5.4

The Results from the ADAMS simulation and the experimental results for this particular Design are correlated. The ADAMS simulation values are almost matching with experimental values. The percentage of the error are maximum on Towel Bar operating effort around 36% . The above deviation may be because of the contact profiles of the geometry and the frictional value variation. Multibody Dynamic simulation helps to validate the product before the prototype. MBD simulation study helped to reduce the time to market as well as cost for prototype and experimental testing cost of the product.

IV. CONCLUSION

The seat slider mechanism is simulated in ADAMS and modelled according to the real condition. The result from the ADAMS simulation study is validated from the experimental results. The percentage of the error is less than 50% of the experimental results. Thus MBD simulation study can be utilized to check the product validation and thus the errors are rectified and corrected in the design phase itself.

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