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DESIGN AND STRUCTURAL ANALYSIS OF UNDER-RUN PROTECTION DEVICE FOR HEAVY COMMERCIAL VEHICLES

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*Abstract—***The Underride Protective Device (UPD) is a structure for absorbing the energy of collisions during an impact. It is essential to enhance the energy absorption characteristics of UPDs. The current project aims to design a good UPD for a heavy commercial vehicle that is effective enough to stop a passenger from falling under the rear of the truck and able to absorb a great deal of crash energy to attenuate accident severity. Also, an effective SUPD is designed to stop road users such as cyclists and pedestrians from falling under the wheels of a truck or trailer.**

Keywords **—Under-ride Protection Devices, Under-ride, Under-run, .etc.**

I. INTRODUCTION

Since the beginning of automotive history, people are scared of the consequences of accidents involving automobiles which can cause severe injuries to passengers, other motorists, pedes-trains and surroundings. Some of these injuries might heal over time However, most of the injuries cause fatality and permanent damage that raises people's attention to the safety features of the vehicles. India and many other developing countries are facing the serious problem of road accidents. The situation further worsens due to a continuous increase in vehicle traffic on the roads [4]. A study by the Transport Research Wing, Ministry of Road Transport and Highways, Government of India, states that during the year 2015, there are 95.5% of accidents involved motorized vehicles. Out of it, accident through cars and jeeps accounts for the second-largest accidents (23.6%) after two-Wheeler (28.8%). This number of fatalities is alarming and establishes a need to put efforts into the crashworthiness of smaller vehicles [3]. Underride, accidents are of three different types namely front, rear and side under-run accidents. The under-run protection devices (UPD) are the passive devices that are mounted on the front (FUPD), side (SUPD) and rear (RUPD) of heavy vehicles. Those are used to prevent small passenger cars from going underneath heavy vehicles. To avoid such accidents an under-run device has to be installed on Heavy commercial vehicles (HCV) which can reduce fatal injuries. The basic principle of an under-ride protector for tractor-trailers or straight trucks is to prevent small passenger cars from going underneath these heavy vehicles [2]. Due to the high ground clearance of the heavy vehicles and the low height of a small vehicle's rear bumper, there is an existing of a large incompatibility between them when they collided. The Rear Under-ride protection device is an attachment fixed to the rear-end chassis cross- member in an HCV which will avoid the under-running of the passenger vehicle. Most of the head injuries and consequent fatalities occur on the front side of the passenger vehicle. The rear under-run protection device prevents the vehicles from being wedged under the chassis during accidental crashes which significantly increases the safety of occupants.

This project aims to design and analyze load-absorbing structures to the rear and sides of HCV for reducing accidental severity. As there is excessive play at the rear side of the HCV and tyres are exposed, the risk of life for bikers and cyclists increases in accidental scenarios. By implementing RUPD and SUPD, the chance of entrapment of occupants under HCV can be minimized and accidental severity may drop considerably. The scope of the project is to design various possibilities for the rear and side of HCV to safeguard bikers and cyclists during accidents. A strategic material selection and structural analysis are conducted using the Finite Element Method (FEM) to check the strength and allowable deformation.

II. METHODOLOGY

The problem is taken upon the identification of the need. Further literature survey on the specified problem is done for the selection of the problem. Based on that further survey of literature is carried out to get the criteria and parameters on basis of those the designing will be carried out. On those criteria, the ideation of various possibilities was figured out. Then as fig. 1 is showing the step-by-step procedure of trial and rectification which is done throughout the design procedure to get an optimum final design once again tested for the optimum results to get the best-suited design possibility.

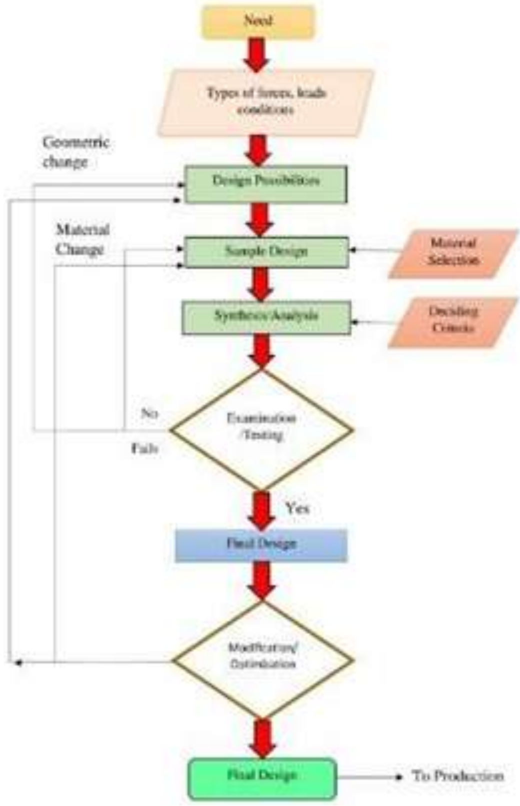

Fig. 1. Methodology Followed.

A. Material Selection

Material is the most important in making the UPD as the Properties of the material are going to decide the overall performance (Crashworthiness) of the Under run protection device. The properties of materials for a Safe UPD are,

• It should have a high strength-to-weight ratio,

• Material used should be readily available,

• Have a great shock load absorbing capacity,

• High toughness, Absorb a considerable force before explosive deformation,

In this process of selecting material for the case scenario of UPD, many research papers suggest various Grades of Mild Steel. Most of them use AISI 1020 grade of mild steel [12]. Some research papers suggest to use Fe 895 [9]. However, many researchers used existing materials already specified in technical papers. In this situation taking a look at what manufacturers are using to make a safe UPD, which is available in the market was necessary. Doing the market survey it was found that the manufacturers use two types of material according to the performance they intend. Those materials were AISI 304 Stainless steel in the case of manufacturer Jurop. It and Strenx [9][10] Using Stainless steel Grade is pretty common in manufacturing after mild steel. These materials satisfy all the above mention properties and characteristics. So, using them to design an RUPD and SUPD will be a wise choice. Also, it's important to consider the cost of the materials used in making UPD as it can be the deciding factor when the results of the analysis are calculated. For that, the number of materials required needs to be found.

Table I

Properties of the Materials [9], [11], [13]

Materials	Ultimate Stress (MPa)	Yield Stress (MPa)	Youngs Modulus (GPa)	Brinell Hardness Number
AISI 1020 ANLD.	420	350	205	111
Mild Steel	450	370	220	120
Stainless Steel AISI 304	500	190	193	123

III. DESIGN

A. Legal Requirement

As the device is concerned about Road and Road safety. It needs to abide by many Standards and guidelines. For this specific design, IS41812:2008 was followed. These are the Indian standards for designing RUPD. The design was done with strong binding with the minimum requirement of IS. Standards for SUPD were taken from the FMVSS 223/224. Reference [2] explains in-depth the SUPDs guideline. The device shall offer adequate resistance to forces applied parallel to the longitudinal axis of the vehicle, and be connected; when in the service position with the chassis side members or whatever replaces them. This requirement shall be satisfied if it is shown that both during and after the application, the horizontal distance between the rear of the device and the rear extremity of the vehicle does not exceed 400 mm at any of the points P1, P2 and P3.

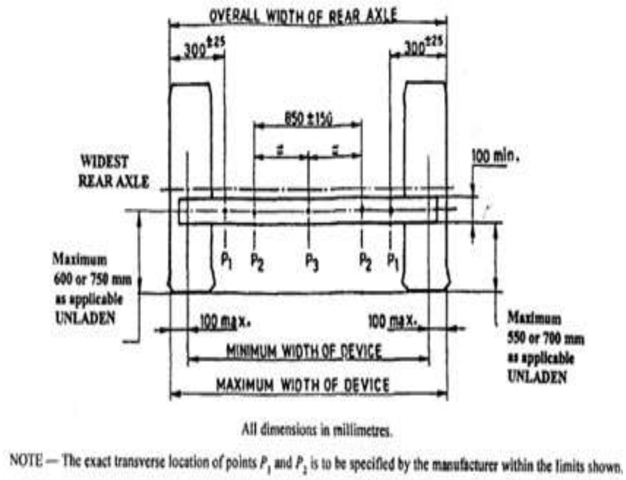

Fig. 2. IS14812:2005 RUPD Standards.

In measuring this distance, any part of the vehicle which is more than 3 m above the ground when the vehicle is un-laden shall be excluded. Point P is located 300 + 25 mm from the longitudinal planes tangential to the outer edges of the wheels on the rear axle; point P2 which is located on the line joining point P1 is symmetrical to the median longitudinal plane of the vehicle at a distance from each other of 700 to 1000 mm inclusive, the exact position being specified by the manufacturer. The height above the ground of points P1 and P2 shall be defined by the vehicle manufacturer within the lines that bound the device horizontally.

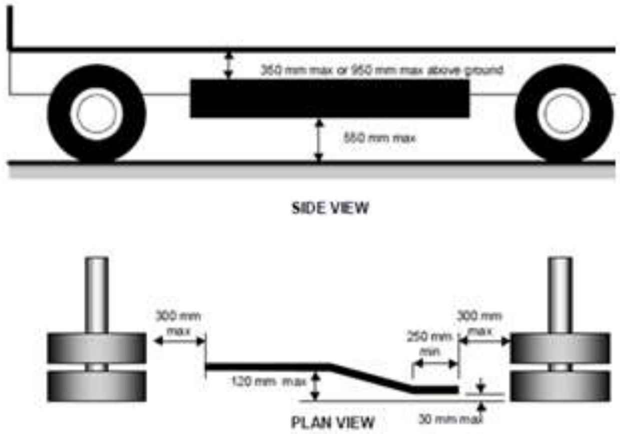

Fig. 3. FMVSS 223/224 Standard for SUPD [2].

The height shall not, however, exceed 600 mm when the vehicle is un-laden. P3 is the centre point of the straight-line joining point P2.

B. Design possibilities

Fig. 4. Survey of actual UPD.

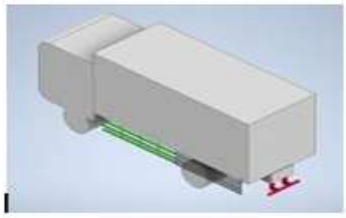

Fig. 5. Initial ideas for designs.

UPDs are in use for many decades around the world. However, its importance is very much neglected in India. Fig.4 shows in practice RUPD and SUPD. Which are nowhere near providing any safety. Reference [17] contents dimensions were used for the rough guidance of setting the size of the SUPD and RUPD accordingly and IS 14812:2005 were used to design them. For comparative studies existing RUPD and SUPD are modelled with different iterations of possibility made. Fig.5 Shows design thoughts from which the current design is inspired. These designs are fulfilling the IS standards So adding new elements to the design can be done to improve the design and to do a comparative study of the possibilities made.

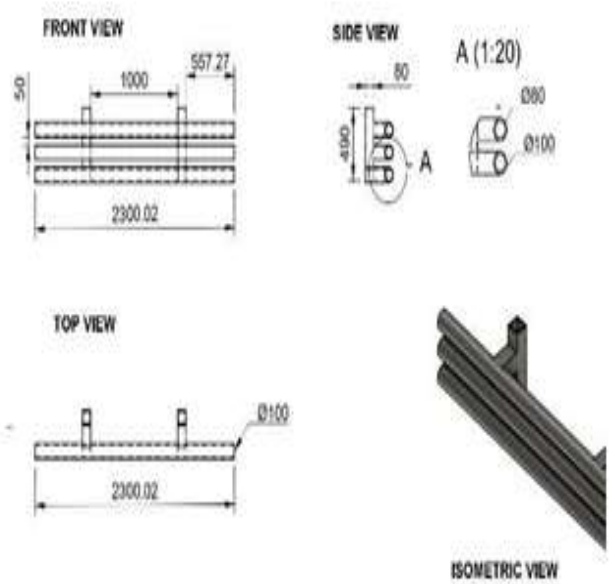

Fig. 6. Existing RUPD Design.

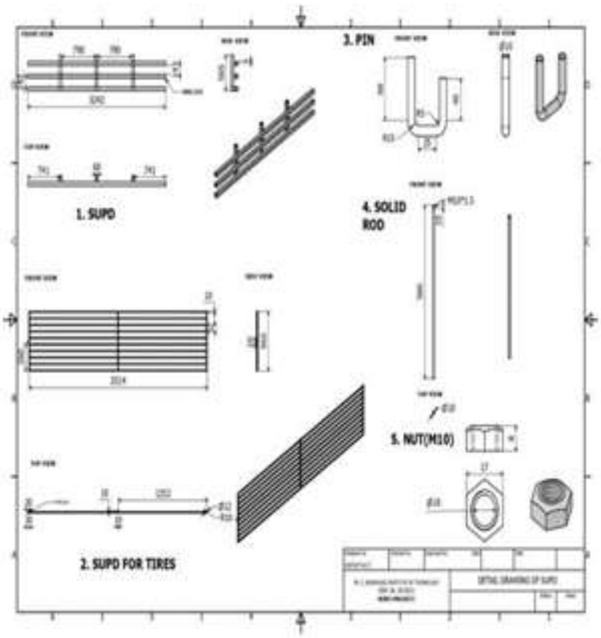

Fig. 7. Design possibility of RUPD P1.

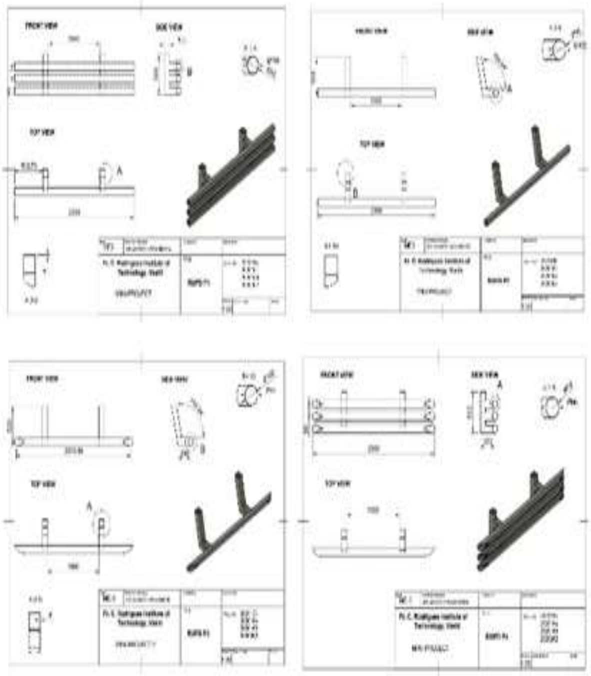

Fig. 8. Design of SUPD.

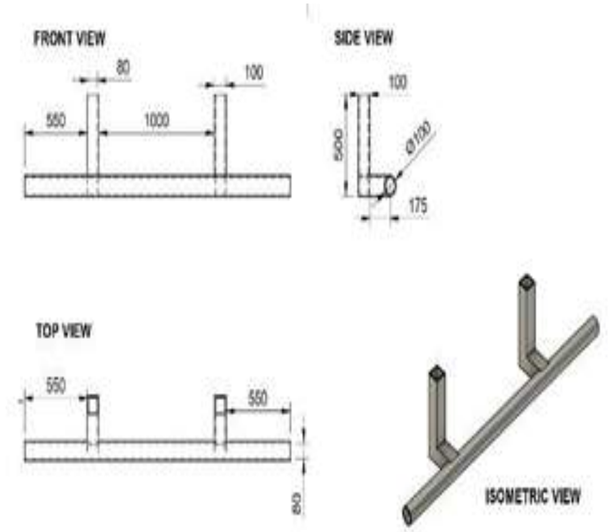

Fig 9. Design Possibilities P1, P2, P3, P4 from left respectively.

Fig. 8 shows the detailed components of the new design for SUPD by referring FMVSS standards. It consists of a total of 5 components assembled. Major of them is SUPD and SUPD for Tires. Along with these possibilities, more 2 possibilities have been done and an Analysis of those for crashworthiness is done on Ansys. All the models are created using Fusion 360 software.

IV. RESULTS

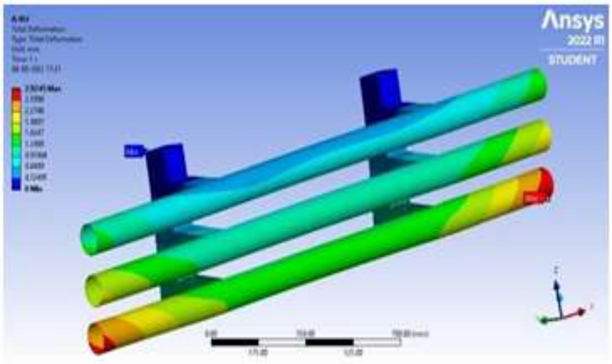

Fig. 10. RUPD P1 Model showing Total Deformation for Mild Steel.

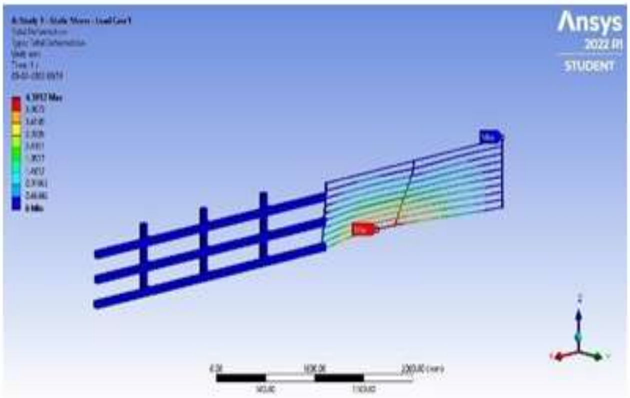

Fig. 11. SUPD model showing equivalent stresses.

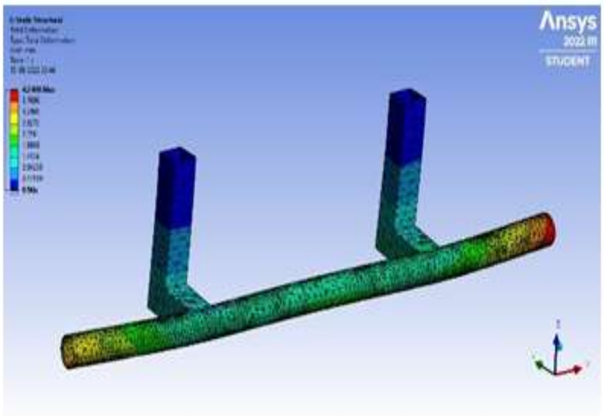

Fig. 12. Existing RUPD model total deformation.

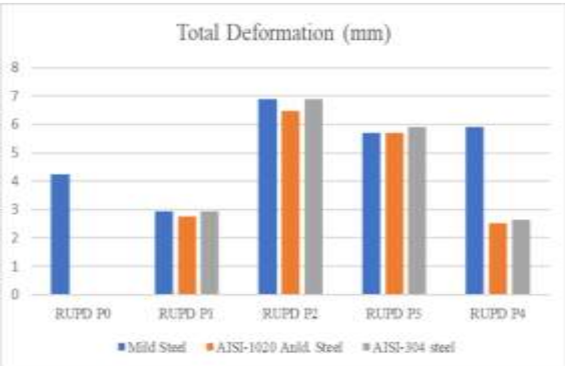

Fig.13.Graph showing Total Deformation (in mm).

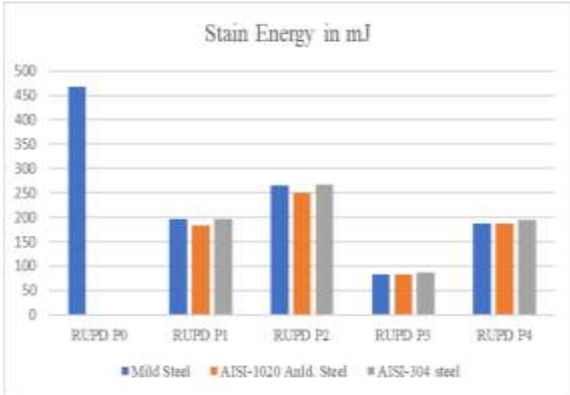

Fig.14.Graph showing Strain Energy (in MJ).

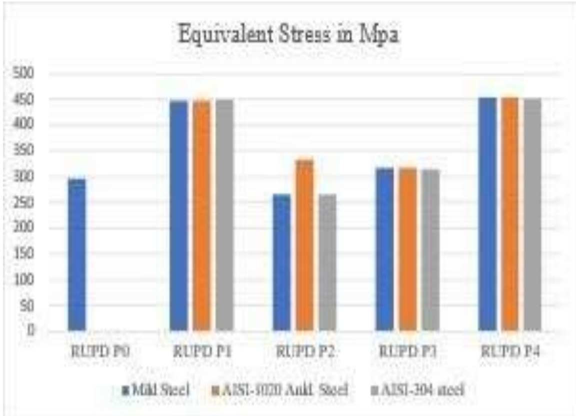

Fig.15.Graph showing Equivalent Stress (in Mpa).

For SUPD proposed design, the Selection is done by compiling material which satisfies the conditions. It showed that using AISI 1020 ANLD steel is once again well-suited for the SUPD.

Table I
Table showing values of selection of Parameters for RUPD P4

RUPD P1	**Selection Parameter**				
	Total Deformation (mm)	***Strain Energy (MJ)***		***Stress (von-messes) MPa***	
		mini	max	mini	max
Mild Steel	2.5323	2.35e-5	187.41	0.22146	453.53
AISI 304 Stainless Steel	2.6228	2.43e-5	194.24	0.21181	451.87
AISI 1020 ANLD Steel	2.5323	2.35e-5	187.41	0.22146	453.53

V. CONCLUSION

RUPD and SUPD for rear and side underride accidents are designed. While designing it is found that Weight to strength factor and energy absorption are the key design principles used for developing Rear Under run Protection devices and Side Under run Protection Devices. Designing a safe RUPD and SUPD can reduce the severity of accidents. It is mandatory to comply with standards established by the governing body. In the case of RUPD, these standards are listed by IS 14812:2005, which are very similar to their American counterparts FMVSS 223/224. For SUPD, Dimensions are from the research published by the IIHS and Volpe in. The design complies with IS 14812:2005 standard. These stated the margins of the design. However, to completely constrain boundary conditions of UPDs the dimensions of HCV were also considered [17]. Completing the design constraints, three materials were identified as per the characteristics required which have a high potential of making UPDs. The RUPD P1 and SUPD new design are selected with material AISI 1020 ANLD steel. As it has shown the best overall characteristics which fit the parameters set.

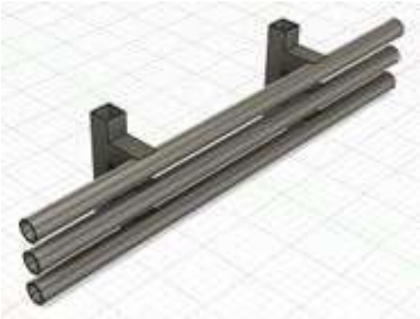

Fig.16.SelectedRUPDP1Design

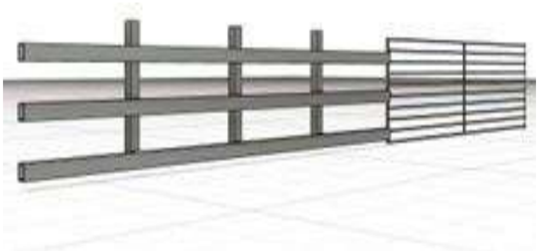

Fig.17.SelectedSUPDDesign

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