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Experimental Analysis of Crash Buffer Casing for Rolling Stock of Indian Railway

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Abstract: Crash buffers are widely used in railway coaches to ensure that during sudden acceleration or deceleration they provide sufficient reduction in vibration and shock absorption. During exigencies like accidents crash buffers helps in minimizing the physical damage to coaches and human life by absorbing the shock energy. In the present work, experimental and Finite Element Analysis [FEA] had been performed on the standard railway side (crash) buffers by using the deformation element as a single component along with various design modifications in buffer casing. The four proposed modifications of conventional buffer casing were termed as S1, S2, S3 and S4. In the planned deformation of the modified buffer casings (deformation travel), it has been observed that there is around 10-20% rise in energy absorption than the conventional buffers with standard spring action. Out of four design modifications the S4 buffer has shown the maximum load and crash energy bearing ability. Energy absorption for S4 buffer increased by twice as compare to S1 samples. Results obtained exhibits the effectiveness of prototype crash buffer with modified geometry over the conventional buffers useful in minimizing the damage to railway coaches in case of accidents to a greater extent

INTRODUCTION

Indian railways are the largest railway network of the world. Everyday crores of passengers travel from one destination to another. Every train has several coaches coupled to each other through a specified coupling system. A buffer is a part of the coupling system used in the railway systems for attaching railway vehicles to one another. Major function of side buffer is to give elastic travel while applying at end of coaches. Secondly, at the curve path, its convex geometry works for the smoother running of coaches[1]. Several studies have been done for the evaluation crash worthiness of locomotives[2]. Crash buffers helps to reduce the extent of damage to coaches and its inhabitants during accidents. When we combine a standard side buffer with an energy absorbing deformation element into a single element it is known as crash buffer. The crash buffers can be mounted to all vehicles that have been designed for standard side buffers in accordance with basic design standards[3].

In the present study, an effort is made to improve the energy absorbing capacity of existing side (crash) buffers through novel design modifications. These are investigated experimentally and also studied using finite element analysis.

MATERIALS AND METHODS

Seamless pipe with Grade ASTM A106 gr.C is used with yield strength 275 MPa (minimum) and tensile strength 485 (minimum) for buffer casing. Standard buffer casing is having cylindrical geometry with 203 mm internal bore which is standard as per available railway literature. Wall thickness was also calculated as per Indian Railway literature[4]. Standard buffer elastic system (elastomer) consisted of a set of 9 pads and 8 steel plates which can provide at least 14 kJ of energy absorption and a deformation travel of 105 mm. However, the prototype buffer elastic system was fabricated using 6 pads and 5 plates with 3 kJ of energy absorption and up to 70 mm of deformation travel as per Miner's tecspak catalog. ePrototype crash buffer was scale down (4.7:1) of standard buffer with respect to less number of pads and travel. Different stages in the fabrication process of prototype crash buffer are shown in the Fig. 1a-c.

Four shape modifications of the buffer casing had been considered in the present work in order to evaluate the increase in strain energy absorption. The buffer casing for the crash buffer was designed with different shape modifications as shown in Fig. 2a-d.

The testing machine in which static test was conducted is the hydraulic press of capacity 2000 kN as shown in Fig. 3. Load is applied normally through hydraulic press on the buffer base. The free height of prototype crash buffer is 321 mm as per the reading of the scale in hydraulic press. Movement of the pressing head from the height of 321 mm to the height of 251 mm achieves 70 mm travel under the applied load of 150 kN. This 70 mm travel is the elastic travel which regains its initial height after releasing the load from 150-0 kN. As the load increases further from 150 kN then the buffer casing starts deforming and completes 50 mm travel and reaches up to 700 kN load gradually.

FE modelling of crashed buffer: FE modelling and analysis was also performed. In Fig. 4a, FE models of different parts like buffer plunger, buffer casing, locking mechanism and base Plate are shown. Assembled crash buffer is also shown in Fig. 3b. Parameters used for finite element analysis has been listed in Table 1. Boundary condition and load applied on the model for analysis is similar to what the prototype is subjected to during experimental investigation.

Table 1: Material properties used in FEA analysis

Details	Properties	Components
Name	AISI 4130 steel, annealed at 865°C	Solid body 1 (Split1)
Model type	Linear elastic isotropic	
Default failure criterion	Max von mises stress	Buffer casing for crush buffer
Yield strength	4.6e+008 N m^{-2}	
Tensile strength	5.6e+008 N m^{-2}	
Elastic modulus	2.05e+011 N m^{-2}	
Poisson's ratio	0.285	
Mass density	7850 kg m^{-3}	
Shear modulus	8e+010 N m^{-2}	

Fig. 1(a-c): Different stages of prototype crash (end) buffer fabrication

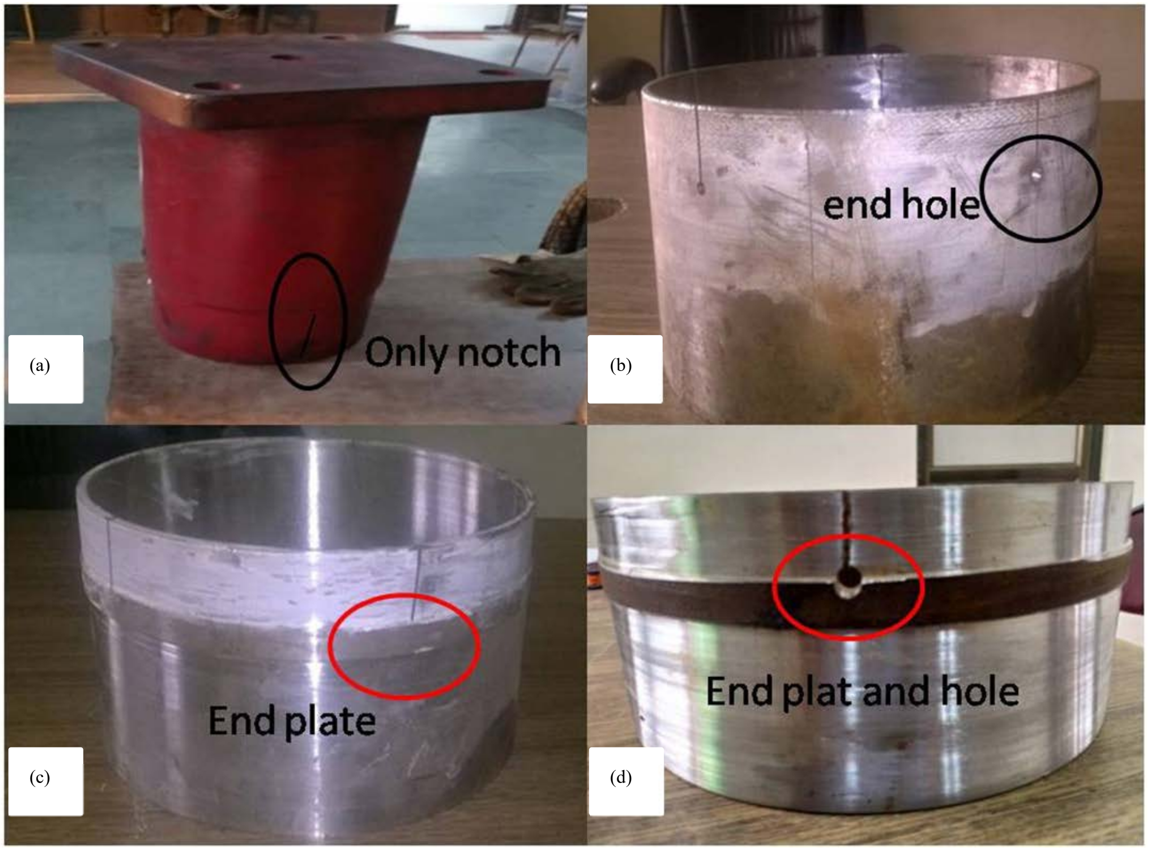

Fig. 2(a-c): Buffer casing prototype with (a) only notch (S1), (b) a hole drilled at the end of notch (S2), (c) with enhancement of 1 mm wall thickness at the notch end (S3) and (d) with enhancement of 1 mm wall thickness and a hole at the notch end (S4)

Fig. 3: Hydraulic press

RESULTS AND DISCUSSION

Testing of prototype crash buffer: In this study, prototype crash buffers were fabricated and subjected to crash testing using hydraulic press having capacity of 2000 kN load. Four different types (S1, S2, S3 and S4) of prototypes were experimentally tested and analyzed for their performance under crash condition with a maximum load of 700 kN. It has been observed that the S1 samples exhibit plastic deformation and generation of crack (Fig. 5, 6) whereas other samples S2, S3, S4 exhibit only plastic deformation and no crack generation till 700 kN of loading.

First sign of tearing at the end of notch radius appears above 1400 kN for S2 samples. Sign of tearing starts at the end of notch at 1000 kN for sample S3. For S4 samples, no tearing sign appears till 1450 kN. Thus S4 samples have more than twice the load bearing capacity of S1 samples. This has direct bearing on the strain energy absorption capacity of crash buffers.The results obtained are mainly due to various enhancements considered in the

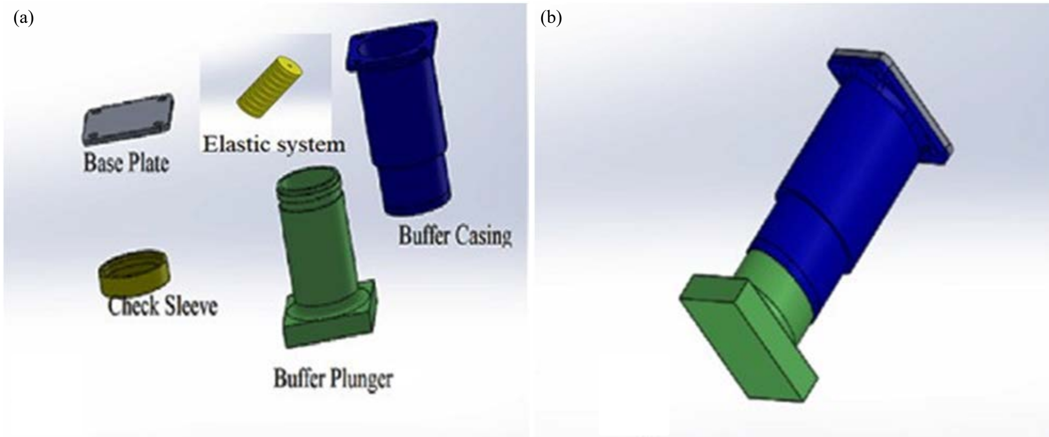

Fig. 4(a-b): Exploded view of (a) Crash buffer FE models and (b) Assembled view of crash buffer

Fig. 5: Different views of S1 sample before and after testing showing generation of crack at 700 kN of load

Table 2: Results of experimental investigation of prototype crash buffers

Sample type	Average maximum load before generation of crack (kN)	Average energy absorbed (kJ)
S1	700	32.05
S3	1000	44.35
S2	1400	60.10
S4	1450	64.57

design of crash buffer. S4 samples with a plate and hole drilled at the end of notch provides maximum load bearing capacity. Mechanisms such as crack bridging, constrained micro cracking due to redistribution of stress flow lines in the presence of circular holes results in the improvement of load bearing capacity as reported earlier[5-7]. This leads to the idea, that during collisions higher kinetic energy of the colliding rail coaches will be absorbed by the progressive deformation of the cells, allowing a comfortable ride-down deceleration of the occupants and hence minimizing fatality and damage to the vehicle.

The test results of the experimental investigation of prototype crash buffers with 6 Tecs Pac 40 kJ+5 Plates have been summarized and shown in the Table 2. Maximum energy absorption before crack generation is observed for the sample S4 which have double reinforcement of crack blunting by circular hole drilled at the tip of crack as well as the deliberate increase in plate thickness at the tip by welding a plate strip as compare to S1 samples with a simple crack (Fig. 5). Load deflection curve for S1 samples is shown in Fig. 7. For S2 samples there is an increase of nearly 37.3% of energy absorption at the point of failure as compare to S1 samples. For S3 samples there is an approximate rise of 87.5% energy absorption till the point of failure. This comparative amount of increase in the energy absorption for S2 and S3 samples as compare to S1 samples clearly signifies that the effect of increase of plate thickness ahead of crack tip is much higher in comparison to drilling hole.

FE analysis of buffer casing part model: FE models of S1, S2, S3 and S4 prototype crash buffers were generated and subjected to a high load of 1500 kN. Von Mises stresses and deformation of the FE models was evaluated

Fig. 6(a-f): Prototype samples of buffer casing (a, b) S2, (c, d) S3 and (e, f) S4 before and after application of 700 kN

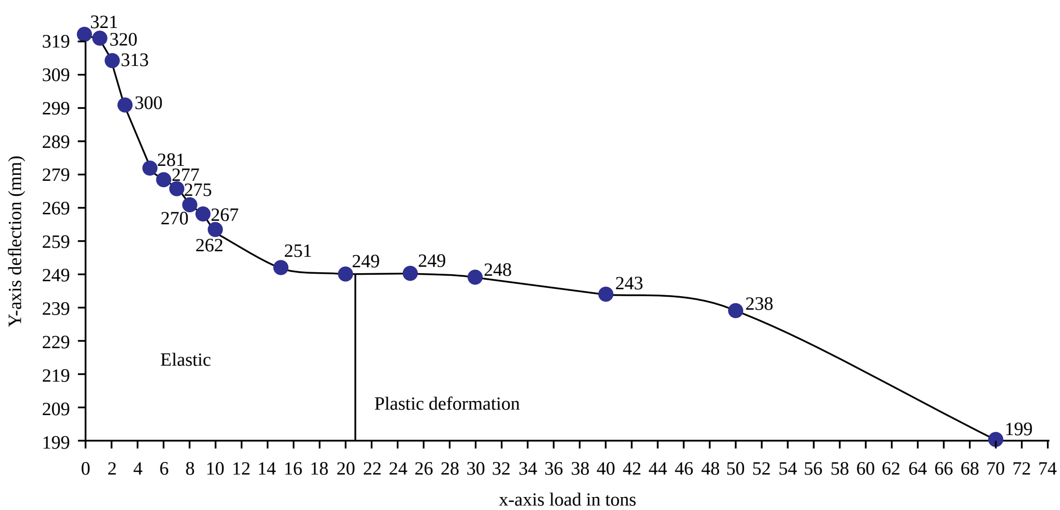

Fig. 7: Load vs. deflection curve for S1 sample

and analyzed as shown in Fig. 7. Studies have given different results which are discussed in the case studies of the FEA modelling of the crashed buffer.

Figure 8 gives the compilation of FEM analysis of the crash buffer models. This comparison shows the load bearing capacity of the crash buffers with different notch

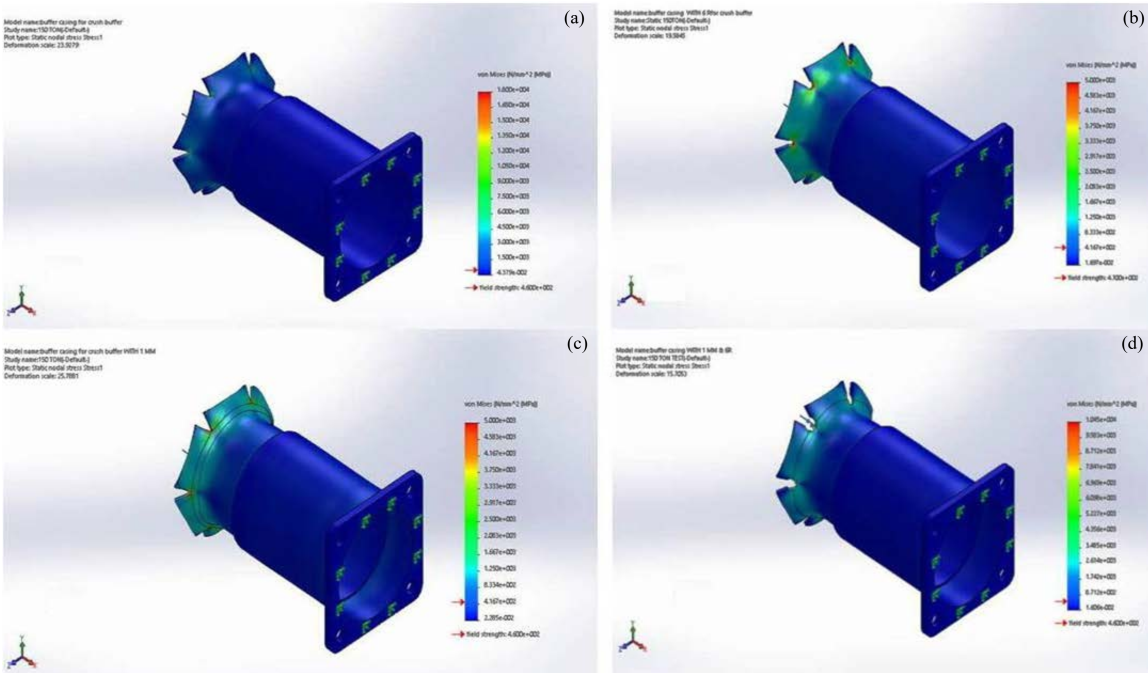

Fig. 8(a-d): Von mises stresses observed in prototype crash buffer samples (a) S1, (b) S2, (c) S3 and (d) S4 subjected to 1500 kN

Table 3: Comparison of load bearing capacity with different notches

	FEA results for different shape of casing at applied load of 1500 kN			
Description	Notch without radius results S1	Notch with 6 mm radius results S2	Notch with 1 mm wall thickness increment results S3	Notch with 6R and 1 mm wall thickness increment results S4
Maximum stress (Mpa)	21281.3	11156.5	26695.3	10454
Maximum displacement (mm)	1.97	2.38	1.82	2.93
Maximum strain	0.044	0.03539	0.0339	0.03017

design (S1, S2, S3 and S4). It has been observed that prototypes S2, S3 and S4 exhibit better load bearing capacity as compare to S1 i.e. the generation of lower stress at similar load has been observed. Crash element with shape S4 exhibits lowest Von Mises stress generation under the given load as compare to other proto types in accordance with the experimental results discussed earlier. This is basically due to double reinforcement at the notch tip i.e. presence of crack tip blunting circular hole supported by addition plate welded at the crack tip. These two enhancements help to increase the load bearing capacity of the crash buffers.

FE results are in agreement with the experimental results. It can also be concluded that the generation of crack will help in enhancement of strain energy absorption and directional movement of plunger in the casing during crash type situation. Further it can also be concluded that the effect of circular notch generation at the end of notch crack tip (S2) is better as compare to enhancement by welding plate or increasing the thickness of plate at the notch tip (S3) when load bearing capacity is to be evaluated. Crash element of the crash buffer prevents the overloading of the railway vehicle, its structure and components during strong impacts and collision events. High load peaks and accelerations are also avoided at that time.

Results of the Finite Element Analysis (FEA) of the prototype crash buffer samples are being reported in Table 3. S4 type crash buffers exhibit the lowest stress and strain generation under the same load as experienced by the other crash buffers. So the crash buffer samples S4 with notch and supportive end plate are preferred crash buffers as compare to S1, S2 and S3 samples. FEA results are in coherence with experimental results.

CONCLUSIONS

The main aim of this study was to perform experimental and finite element analysis of the modified prototypes of standard buffer casing by considering the deformation element into single component to be used as crash buffer. Four different proposed designs of crash buffer casings S1, S2, S3 and S4 were fabricated and investigated for their load bearing capacities. Generation of crack, crack tip blunting by circular notch at the tip and welding a plate at the crack tip are the different modifications considered in buffer casing for analysis. It was observed that Buffer casing samples with notch tip blunted by circular hole and thicker plate welded at notch tip (S4) were able to bear maximum load of 1450 kN before exhibiting the crack generation as compare to other samples. S1 samples failed at a load slightly above 700 kN. Highest and lowest energy absorption was exhibited by S4 and S1 samples respectively. S4 samples were able to absorb nearly twice the energy absorbed by S1 samples. However, there is nearly 7.5% increase of energy absorption in S4 samples as compare to S3 samples. So, both S3 and S4 samples are preferred for crash buffers. Improvement in energy absorption is mainly due to crack bridging, constrained crack propagation due to redistribution of stress flow lines in the presence of circular holes and supportive end plates which resulted in the improvement of load bearing capacity. FEA results were in coherence with experimental results.

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