Dynamic energy absorption of ultrafine-grained TWIP steel under axial impact loading

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Abstract: This research focuses on studying the dynamic energy absorption property of a microalloyed TWIP steel, which was proposed to act as a connection part between car front bumper and chassis in middle-class cars for vehicle safety. The studied TWIP steel was designed based on stacking fault energy of 25mJ/m². The as-cast steel was deformed in hot and cold rolling to 2 mm thick sheets. Subsequently, recrystallization annealing was applied to the heavily cold-worked steel at different temperatures to obtain different ultrafine grain structures. The mechanical properties were determined using tensile tests. It was observed that at 900°C, the optimal temperature for strengthening by vanadium carbide precipitation, it was too low to complete recrystallization. However, at 1000°C, an ultrafine-grained structure was formed with high yield, tensile strengths and elongation of about 700MPa, 1100MPa and 30% respectively. Accordingly, TWIP steel was used for crash analysis simulation using ANSYS Workbench R14.5. Thin-walled square columns of that steel were employed for energy absorbance during a collision regarding progressive plastic deformation. The crashworthiness criteria were studied under different impact conditions with thicknesses of 0.25, 0.5, 0.75 and 1 mm. Simulation results showed high initial peak force during the impact. Hence, a trigger mechanism of an external tapered plunger was proposed to reduce it. This combination of new material and innovative design promises enhancement car safety.

Keywords: Axial impact analysis, Energy absorption, Square column, Trigger mechanism, TWIP steel.

1 Introduction

Over the last two decades, automotive steels were undergoing an intensive development to enhance ultra-high strength property for crashworthiness. The safety regulations followed by environmental demands resulted in developing of new steels with higher strength and lower weight. These steel types are High Strength Low Alloy (HSLA), Martensitic (MS), Bake Hardened (BH), Dual Phase (DP), Transformation Induced Plasticity (TRIP), complex phase (CP) and Twinning Induced Plasticity (TWIP) steels. The last steel has gained the car manufacturers attention due to its unique mechanical properties. Hence, TWIP Steels revealed an extraordinary combination of both strength and ductility [1-7].

It was established that the predominant mode of deformation in TWIP steel, i.e., mechanical twinning, is strongly related to the stacking fault energy of the austenitic structure of the steel. The control of the stacking fault energy (SFE) is the key to induce mechanical twinning. Since,
the nomenclature of TWIP emanated from its mode of deformation, deformation twinning, where symmetric twin boundaries are formed from slipping. These boundaries resemble the act of grain boundaries of hindering dislocation motion. This gives strength to the TWIP steel in addition to increased work hardening rate [8-12].

It is noteworthy that the SFE value controls the kinetics of the mechanical twinning of the steel. It illustrates the energetic tendency for twin formation, ε-martensite transformation or pure dislocation glide [13,14]. The main factors that usually control SFE, hence defining the deformation mechanism, is the chemical composition and temperature [8,10]. A SFE of range 20-50 mJ.m⁻² deformation twinning has been observed for TWIP steel. Below 20 mJ.m⁻² Martensitic transformation is dominant rather than twining. As SFE reaches high values as in Aluminum alloys, twinning is suppressed, and pure dislocation glide takes place. The deformation twinning mechanism is mostly advantageous as it is accompanied by worthy work hardening rate [8-11].

The high strain hardening of TWIP steels is attributed to the dynamic Hall-petch effect. There are different active deformation modes in TWIP steels during deformation. Dislocation glide is the dominant mode in the early stage of deformation. Yet in the dynamic Hall-petch effect mechanical twins are observed during further straining up to certain level of saturation. The development of mechanical twins causes new crystal orientations and gradually decrease the effective glide length of dislocations, mean free path, and increase the flow stress [9,12].

Extensive work has been done on High-Mn TWIP steel over the last two decades. In an interesting review Bouaziz et. al [14] summarized a historical overview of TWIP steel. For instance, in 1888 Sir Robert Hadfield began developing the high-Mn austenitic steels. In the 1990’s, the researchers started modifying Hadfield steels by introducing new alloying elements such as aluminum. Few years later, new concept of High-Mn TWIP steel evolved to produce light weighted material. Recently, micro-alloying elements such as: Vanadium and Titanium were introduced to enhance the grain refinement and mechanical properties. In the present work, a novel TWIP steel has been designed based on a thermodynamic model for SFE calculation with a value suitable for inducing mechanical twinning during deformation. This steel is promising for safety parts in automotive applications (i.e., crashworthiness).

Crashworthiness as described by Du Bois, Paul et al. [15], indicates the structure’s capacity to safeguard occupants in survivable smashes. Different structures were deployed all over years as energy absorbers. Amongst of all, thin-walled structures excelled as crash boxes in automotive bodies. They undergo deformation to diminish energy from crashes along with force to reduce occupants’ deceleration [16-20].

These structures are characterized by high strength-weight ratio, cheap and with a high capacity for energy absorption as they convert kinetic energy to irreversible plastic deformation energy [17]. Their behavior has also been extensively studied with different methods (analytical, experimental and numerical) as in [21-24]. This made it convenient to be implemented effortlessly in crashworthy structures.

In the current research, the designed novel TWIP steel was proposed to act as a connection part of car front bumper with chassis in middle-class car for vehicle safety. Since, the mechanical properties correlated to the microstructural evolution with the recrystallization processes have been studied to optimize the grain structure for the crashworthiness simulation by FE simulation. Understanding and predicting how the steel behaves under progressive dynamic deformation in frontal collision is the main objective of the current work. Thus The FE simulation focuses on the axial crushing condition due to its importance. Crash performance indices are used as an assessment for the material implementation in the crash structure. Furthermore, a proposed trigger mechanism is then added to reduce the initial force and increase the energy absorption.

2 State of the Art
It was established that eliminating damage to a passenger cabin in automobiles mainly depends on the material type, geometry and thickness parameters of the crash energy absorption members like the crash box. It is expected to absorb impact energy by progressive deformation regarding preferentially buckling in the axial direction into the shape of an accordion under an impact load [25]. In this research, the applied material and geometry of the crash box are TWIP steel and a square column, respectively will ensure enhanced safety performance.

2.1 Thickness optimization
The square column thickness is the main influencing factor. Greater thickness would give more mass to absorb more energy. But this means more weight which is against the trend to lower the vehicles weight. Furthermore, more thickness means higher strength and high initial peak force which is not favorable. Thus, thickness effect was studied extensively in this research.

2.2 Trigger mechanism integration
It is well known that a trigger mechanism is used with the crash box to improve the crashing behavior of the crash box through decreasing the initial peak force and increasing the energy absorption, to stabilize the force level along the crushing length. In the current study, it was found that the plain square column has a rather high initial peak force. A taper plunger is proposed to enhance crush performance. The idea of the taper is that it reduces the initial impact and initiate early buckling for progressive deformation as the effect of taper angle of plunger for aluminum was studied by Ghani, Amir RA, and M. A. Hassan [26].

3 Experimental procedure and simulation analysis

3.1 Material preparation
The designed high-Mn TWIP steel was laboratory casted using an induction melting. Subsequently, the cast ingots were undergone hot and cold deformation using a laboratory rolling mill at Materials engineering unit, University of Oulu, Finland. The cold-rolled steel sheets were annealed at different temperatures 900 and 1000 °C for different times 1, 3 and 15 min in a chamber furnace to enhance different grain structures. The chemical composition of the steels used in this study is given in Table 1. The alloy design was done regarding SFE calculation with SFE of 25 mJ/m² to induce twinning during deformation. C and Mn is added as austenite stabilizer. Cr is added to enhance corrosion resistance. With V added extra strength from precipitation occurs along with refining the microstructure.

| Steel    | C   | Si | Mn | Cr  | Ni  | Mo | V  | N  |
|----------|-----|----|----|-----|-----|----|----|----|
| NV-MnCr  | 0.28| 0.33| 7.9| 16.0| 3.3 | 1.92| 0.7| 0.226|

3.2 Microstructure analysis
The microstructures of the studied steel after annealing at different temperature and time were investigated by optical microscopy. Samples of the annealed steel have been sectioned in the normal direction. The sample surfaces were ground and mechanically polished using colloidal silica of 1 um. The final surface preparation was then achieved by an electro-etching using 69% nitric acid at a voltage of 1.1 V for 30 seconds at room temperature.

3.3 Mechanical testing
The quasi-static mechanical properties of the different grain structures of the TWIP steel were measured using a Schimadzu Autograph AG-50kNX precision universal testing machine at room temperature. Standard tensile testing specimens, were machined according to the standard ASTM
with a parallel length of 60 mm, a width of 12.5 mm and a total length of 200 mm. These samples were cut in the rolling direction. The tensile tests have been carried out at a strain rate of $10^{-3}$ s$^{-1}$.

### 3.4 Numerical simulation

Energy absorption of an alloy is usually represented by its behavior during axial collapse of a thin-walled structure under impact loading (Drop weight test). Afterwards, the performance indicators are studied to understand and evaluate the crush performance in a better way. During this test, reaction force variation in relation to the crush distance gives an indication for crashworthiness comparisons [9].

In this study, finite element (FE) models of the thin-walled plain square column were developed using ANSYS R14.5 Workbench. The model was used to foretell the square column response towards axial impact force. The ANSYS/Explicit solver was used for the analysis. The schematic of loading arrangement can be seen in Figure 1. This solver is based on energy convergence with maximum energy error limit to be defined. The default value of 0.1 (10%) was always used.

Fixed boundary conditions are assigned to the lower plate at the end of the square column. Simultaneously, the top end is compressed by a rigid cylinder. Sweep mesh method (Quad mesh type) was used for the column as a sweepable body. The cylinder and the lower plate were modeled as rigid bodies. Slider tolerance was set for contacts as the default selection. Trajectory contact detection was also chosen with penalty formulation and tolerance 0.2. The body self-contact in addition to element self-contact was set to program controlled with frictionless body interaction. Mass scaling was also implemented to reduce the run time using a minimum CFL time step of 0.1s. Solver with double precision was selected. No erosion was allowed, and static damping was turned off (set to zero). Flanagan Belytschko method was used for hourglass damping. It helped to avoid volumetric locking and element distortion.

The square column was subjected to both static and dynamic axial loading using the plain cylinder and the tapered plunger (both assigned as rigid bodies) shown in Fig.2. During static loading, the cylinder was allowed to move 20 cm which is 80% of column length to ensure maximum effective crushing. The boundary conditions used for the cylinder were $V_x=0$, $V_z=0$, $V_y=V$ with all speed equal zero at the end of time. This ensured movement in the vertical direction only and keeping the load for into axial form. While in case of dynamic loading, a drop mass of 50 kg was specified.

![Figure 1: Schematic of finite element model of crush square column](image-url)
The column thickness optimization was a major focus point of this research so thicknesses of \( t=0.25, 0.5, 0.75 \) and 1mm of TWIP steel were studied. During the dynamic loading impact speed of 20 m/s was used for different thicknesses and different velocities. Different end time duration for different thicknesses was used to ensure the drop weight comes to rest. This was done for both the plain cylinder and the tapered plunger as a trigger mechanism.

The FE-software was validated by comparing the stress-strain curve obtained from the universal testing machine against the curve from the simulation of static tension test. The material properties inputted for the validation and the simulation was for the annealed steel at 1000\(^\circ\)C for 3 min.

![Figure 2: Schematic of the tapered plunger.](image)

### 3.4.1 Crush performance indices

In the crash analysis and assessment criteria, certain crashworthiness indices are calculated to evaluate the performance characteristics. These indices are peak Force, energy absorption, mean crushing force and crush force efficiency [6,16-19,27].

The peak force \( (F_{\text{peak}}) \) refers to the maximum load causing permanent distortion. It is of design interest for two reasons. On the one hand, city driving at low speeds where the impact is with low energy. The intended deformation of this condition must not be permanent and small as possible. While on the other hand at higher speed it has a direct effect on vehicle’s occupants. It controls the deceleration rate which causes severe injuries or death for occupant [4-5,16-19].

The energy absorption \( (E_{\text{s}}) \) which is the area under the load-displacement curve of the crash. It represents the amount of energy absorbed in the crash. It usually expressed by:

\[
E = \int_{0}^{d} f(X) dx
\]  

Where \( d \) is the effective crushing distance, \( f(x) \) is the instantaneous crash force during collision. For a certain magnitude of energy to be absorbed, a certain mass of the material must be used. Weight is still a key factor in material choice, and there is no advantage of using an extensively heavy material to absorb a large amount of energy. This was the reason why the Specific Energy Absorption (SEA) showed up to be important. The SEA is defined as the energy absorbed per unit mass of the material [9, 16-19].

\[
\text{SEA} = \frac{E}{m}
\]

Another important parameter is the mean crushing force \( (F_{\text{mean}}) \). For a definite displacement \( F_{\text{mean}} = \frac{E}{\delta} \), where \( E \) is the energy absorbed for certain displacement \( (\delta) \) [17-19].

Then comes the Crush Force Efficiency (CFE). It relates the mean and peak forces as they are directly related to the deceleration affecting the occupants. It is the most convenient method of
quantifying the deceleration the passenger feels. It is a ratio between the mean force to the peak force. As this ratio tends to unity minimum deceleration occurs which is an ideal absorber. It is then that the absorber is crushing approximately to the peak load. On the contrary, if the ratio is near zero this is an indication of rapid acceleration change [6, 16].

\[
\eta = \frac{F_{\text{mean}}}{F_{\text{peak}}}
\]  

(3)

4 Results and discussion

4.1 Microstructure observation

Typical microstructures of the annealed TWIP steel at 900 °C for different time are shown in Figure 3. At 900 °C for 1 min, the microstructural features are similar to those in a cold deformed structure, i.e., distorted grains with zones of high density of deformation bands, which are visible as dark regions, as shown in Figure 3(a). With increasing the annealing time to 3 min, the microstructure undergoes partial recrystallization, as shown in Figure 3(b). After 15 min annealing, a fully recrystallized structure with fine grains is promoted, as shown in Figure 3(c).

![Figure 3](image1)

Figure 3: Optical microstructures of the studied steel after recrystallization annealing at 900 °C for a different time: (a) 1 min, (b) 3 min and (c) 15 min.

Similarly, distorted grains with high density of deformation bands, dark zones, can be seen in the annealed structure at 1000 °C for 1 min, as shown in Figure 4(a). However, fully recrystallized structures have been promoted with longer annealing time, 3 and 15 min, as shown in Figure 4(b) and (c), respectively.

![Figure 4](image2)

Figure 4: Optical microstructures of the studied steel after recrystallization annealing at 1000 °C for a different time: (a) 1 min, (b) 3 min and (c) 15 min.

4.2 Tensile test

The tensile flow stress curves of the TWIP steel with different grain structures, see Figure 3 and 4, are shown in Figure 5. It can be observed that the quasi-static mechanical properties characterized by high yield strengths (830–1225 MPa) and quite high engineering tensile strengths between 1050 and 1400 MPa for the grain structures promoting at 900 °C. It is apparent from the microstructural observations in Figure 3 that the annealing treatment at 900 °C for 1 min
is not sufficient to induce a fully recovered structure. Therefore, the flow curve of the corresponding structure is accompanied by a low ductility of 9% as well as a low strain hardening exponent of 0.04. Upon increasing the annealing time to 3 min, vanadium carbide (VC) precipitates are strongly formed inside the structure. These precipitates have a significant effect on the strengthening of the material due to increasing the yield strength to 950 MPa with a moderate ductility. After 15 min of annealing, the structure underwent partial recrystallization through to the influence of the VC precipitates. Consequently, high YS and UTS of 830 and 1070 MPa, respectively, are enhanced with a high ductility of 35%.

With increasing the annealing temperature to 1000 °C, the mechanical properties are dramatically changed with increasing the annealing time from 1 to 15 min, as shown from the flow curves in Figure 5(b). The temperature of (VC) carbide dissolution has been calculated according to the following equation [28].

\[ \log[V][C] = 4.237 - 6157/T \]

Where [V], [C] are the concentrations of respective elements in weight percent, and T is the absolute temperature (in K). The estimated dissolution temperature of VC precipitates is 972 °C. Hence, the effect of the VC precipitate on the recrystallization process of the concerned TWIP steel is sluggish at 1000 °C due to the dissolution of the carbides.

The enhanced ultrafine-grained structure of average grain size ~ 2 μm at 1000 °C for 3 min showed a significant high YS and TS strengths, 814 and 1080 MPa, with a high ductility of 32%. This is attributed to the grain refinement along with the activate deformation mechanism, mechanical twinning during tensile straining. After prolonged annealing of 15 min at 1000 °C, the structure consists of fine new austenite grains with a grain size of ~ 6 μm. The YS has been decreased to 600 MPa with increasing the ductility to 40%.

![Figure 5: Quasi-static tensile stress strain curve for different time of recrystallization heat treatment at (a) 900 °C (b) 1000 °C](image)

The extracted tensile mechanical properties from the flow curves in Figure 5 are shown in Table 2. It can be seen that the strain hardening parameter n, i.e., the Hollomon exponent, increases with the annealing time at both annealing temperatures. For instance, the n-value increases from 0.20 to 0.31 with increasing the annealing time from 1 to 15 min at 1000 °C.

It is well known that the value of n reveals the plasticity property of the material. The higher n-value means higher plasticity could be expected without failure. Thus, the n-value could be used a good indicator for the deformation of a material under a crash state. Also, it reflects the strain-
hardening rate and is an indicator of the deformation mechanism [29]. The area under the flow curve represents the absorbed energy during the plastic deformation by the material. Thus, the enhanced structure at prolonged annealing time, 15 min, at 1000 °C displayed the highest absorbed energy of 355 MJ/m³.

Table 2: Mechanical properties of the studied TWIP steel at different times different annealing temperatures 900 °C and 1000 °C for 1, 3 and 15 min.

| Recrystallization Temp. | 900 °C | 1000 °C |
|-------------------------|--------|---------|
| Recrystallization Time  | 1 min  | 3 min   | 15 min | 1 min  | 3 min   | 15 min |
| Yield Stress (MPa)      | 1225   | 944     | 832    | 948    | 814     | 625    |
| UTS (MPa)               | 1327   | 1208    | 1068   | 1120   | 1083    | 980.5  |
| Ductility %             | 9      | 16      | 35     | 22     | 32      | 40     |
| Strain-Hardening exp.(n)| 0.04   | 0.12    | 0.25   | 0.20   | 0.23    | 0.31   |
| Strength Coeff.(K) (MPa)| 1557   | 1748    | 1871   | 1781   | 1914    | 1913   |
| Energy absorbed (MJ/m³) | 119    | 194     | 315    | 235    | 310     | 355    |

4.3 Simulation results

4.3.1 Software validation

The software was validated using the tension test. The mechanical properties were implemented in the model using the multilinear isotropic hardening material model. The tension test was then conducted by using the same geometry as the experimental sample and giving a displacement with time sufficient enough to ensure quasi-static conditions. It can be seen in Figure 6 that the curves obtained from experimental tension test machine nearly fits the one obtained from the simulation. Furthermore, the relative error between the 2 curves until the tensile strength, as the simulation involves no failure, is about 1.5 %.

Figure 6: Simulation and experimental of tension test

4.3.2 Static loading simulation

Figure 7 demonstrates the static response of the column with a plain compressing plunger at different thicknesses. It can be seen that all specimens exhibit high Initial Peak Force (IPF) then by lower alternating mean forces. It is obvious that the lowest thickness had the lowest IPF with a smoother rise than the others. Figure 8 illustrates the deformed shapes of the material with different thickness. The 0.25mm thick column although had lowest IPF, it showed three locations of progressive buckling with small folding lengths. Its buckling initiated at the bottom end followed by the upper end then another small fold at the middle due to its very low thickness. While as the thickness increased the progressive buckling started to appear, at 0.5mm when buckling initiated it was on the whole length causing the column to bend over itself. This appeared
on the curve by sudden drop after the IPF and not any peaks appeared. Then after the thickness increased progressive buckling started to appear with a small number of folds due to the materials’ high strength and the ratio of height to thickness causes the fold to be with a limited number. This is also evident from the number of peaks on the curve of the static response.

Figure 7: Static response with flat plunger

Figure 8: Deformed shapes of TWIP steel with different thickness (a)0.25mm (b)0.5mm (c)0.75mm (d)1 mm under axial static loading

On the other hand, when the tapered plunger was introduced the static response was as seen in Figure 9 and the deformed shapes are in Figure 10. It is apparent that all samples did not have progressive buckling extensively, yet small fluctuation with a moderate mean. This mean is near the IPF in all samples making them approaching the ideal impact absorber where the mean force equal to IPF. This is considerably seen in the column with 0.25 mm thickness.

Figure 9: Static response with tapered plunger

The IPF values were also reduced significantly at about 23% at the 1mm thickness to lower percentages for lower thicknesses. This was a result of the tapered ending lowering the wall’s
bending resistance. What is more to add the rise time or distance for the IPF was delayed this will allow better deceleration feeling for the occupants’ safety. Furthermore, it can be seen that also the plunger smoothened the first impact (initial peak force), it reduced the number of folds due to the delayed buckling.

Figure 10: Deformed shapes of TWIP steel under tapered plunger with different thickness (a)0.25mm (b)0.5mm (c)0.75mm (d)1 mm under axial static loading

4.3.3 Dynamic simulation
The results are after adding the 50kg mass to the plunger as drop weight. The initial speed was fixed to study the effect of different thickness. The results of the flat plunger are shown in Figure 11.

Figure 11: The dynamic response of TWIP steel columns to a speed of 20m/s at different thickness under axial impact

As the simulation was conducted as a freefall test, each column stops the drop weight after certain distance as in the dynamic response curve. Their deformation is also shown in Figure 12. From the deformed shapes and the dynamic response, the effect of high strength material can be seen. Whatever the thickness there is a rise in IPF then sudden decrease after the first impact wave. The 1mm and 0.75mm did not continue the deformation as they could withstand the energy of the impactor. While at 0.5 mm progressive buckling along with amalgamate deformation started to appear and it continued with 0.25mm. The difference in the response between each thickness and its successor in terms of IPF is nearly double. This means near double the thickness, double the resulting IPF. Nearly same as the crushed length.

As the proposed trigger mechanism of a tapered plunger was implemented also with 50 kg. The results turn out to be as in Figure 13. The plunger decreased the IPF with about 13% for the 1mm thickness with a lower percentage for the other thickness. In the meanwhile, the most apparent benefit from the tapered plunger is increased displacement and also widening
of the area under force-displacement curve by increase energy absorption. This also made the IPF rise more smooth gradually and enhanced the mean force to be near to the peak force. The deformed columns can be seen in Figure 14.

![Deformed columns of TWIP steel at 20m/s with tapered plunger](image)

**Figure 12:** Deformed columns of TWIP steel at 20m/s with (a) t=0.25mm (b) t=0.5mm (c) t=0.75mm (d) t=1mm under axial impact

From the deformed structure, we can see the effect of the plunger on enhancing the progressive buckling and decreasing the wall bending resistance to lower the IPF. By increasing the number of folds, the rate of IPF rise became slower, and the curve becomes wider with higher energy capacity. The crashworthiness indices are summarized in Table 3.

![Dynamic response of TWIP steel columns to a speed of 20m/s at different thickness with tapered plunger](image)

**Figure 13:** The dynamic response of TWIP steel columns to a speed of 20m/s at different thickness with tapered plunger

![Deformed columns of TWIP steel at 20m/s using tapered plunger](image)

**Figure 14:** Deformed columns of TWIP steel at 20m/s using tapered plunger with (a) t=0.25mm (b) t=0.5mm (c) t=0.75mm (d) t=1mm under axial impact
Table 3: Crashworthiness indices for TWIP steel columns with flat and tapered plunger at different thicknesses

| Thickness (mm) | Peak crush force (N) | Crush efficiency | Energy absorption (kJ) |
|---------------|----------------------|------------------|------------------------|
|               | Flat                 | Tapered          | Flat                   | Tapered               |
| 0.25          | 41167                | 38942            | 0.567                  | 0.563                 | 4.24 | 3.84 |
| 0.5           | 88072                | 79204            | 0.455                  | 0.405                 | 3.807 | 4.004 |
| 0.75          | 130380               | 113230           | 0.4672                 | 0.414546              | 2.9 | 4.233 |
| 1             | 177930               | 159680           | 0.6375                 | 0.74                 | 3.864 | 6.423 |

General trend force-displacement curve is usually used to study the crashworthiness effectiveness as mentioned in Xintao [5], Christopher [6], Markus [9], Tong [17] and Xiang [18]. However, it was difficult to make quantitative comparison due to the presence of new material. As for experimental results, a stock of the material must be present along with appropriate manufacturing technique to manufacture the required columns seamlessly without and welding.

5 Conclusion

In this work, Recrystallized TWIP steel mechanical properties at different conditions of time temperature have been determined. The alloy design regarding stacking fault energy along with the deformation mechanism and heat treatment yielded a promising steel candidate for automotive applications. Its superior strength combined with ductility was decided to be best used for crashworthiness applications. A FE-model was constructed to examine the crush performance when TWIP steel is implemented in standard square columns under axial impact load. Due to the high strength of the alloy, it showed rather high IPF which can be reduced by using thinner gauge steels resulting in lower weight as a gained profit. Afterwards, an external tapered plunger was applied to put a trigger mechanism to lower the IPF. It was found that the plunger showed a substantial improvement of IPF especially at the thickest column. The CFE along with the energy absorption was not quite enhanced except for the 1mm thickness during dynamic loading. While in static loading IPF decrease is more significant along with CFE. Finally, TWIP steel is attracting automakers to down gauge steels resulting in lower weight as a gained profit. Further trigger mechanisms must be studied. If thinner thicknesses were to be used some other factor regarding flexural rigidity of the car body and the noise along with low speed impact must be studied. Upon the current results, the author thinks that the best place to implement this TWIP steel is as reinforcement to the passengers’ cabinet as it will absorb energy while maintaining structural integrity due to its high strength.

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