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# Modelling of Impact Wear Resistance in HSLA Steels for Truck Body Applications

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## ABSTRACT

*Truck body is the main part of the vehicle, which contains several channels made up of mild steel sheets. There exists a need for the industry sector to optimize the design of dump truck body structure which allows maximizing dump truck payload capacity and simultaneously improvising the strength, reducing weight, and prolonged operational life. Two HSLA steels HARDOX 400 and A 36 are considered for the present study. Geometric Modelling of the tipper load body assembly is done using Pro-E3.0 and simulation has been done using ANSYS Workbench. The type of wear is dependent on the material hardness and coupled to the microstructure HARDOX 400 wear steel combines toughness with high hardness. In a truck body, this means that the resistance to blows and denting is better than that offered by A 36 steel and the wear resistance is higher.*

***Keywords:—*** *Truck body, Pro-E3.0, Simulation, HSLA steel, Impact wear, Abrasive, Wear rate*

## I. INTRODUCTION

HSLA steels are classified as a separate steel category, which is similar to as-rolled mild-carbon steel with enhanced mechanical properties obtained by the addition of small amounts of chromium, nickel, molybdenum, copper, nitrogen, vanadium, niobium, titanium, and zirconium [1]. The HSLA steels in sheet or plate form have low carbon content (0.05 to −0.25% C) in order to produce adequate formability and weldability, and they have manganese content up to 2.0% [1]. Handling and carrying of large quantities of materials in a truck body of varied construction upon the existing state of materials, its physical properties and required operation which is to be performed is one of the tasks taken by the mechanical and automobile engineers, which are used for carrying sand, metals, iron ore and granite blocks [2].

The wear caused by a particle impacting on a surface with a specific velocity and angle is called impact wear. This wear mode should be divided into particle erosion and abrasive impact. The particle erosion is caused by the repeated impact of very small and hard particles, less than 1 mm, travelling together with a gas or a liquid at high speed [3,4]. The abrasive impact is defined as the impact from particles with a larger size and lower velocities. The wear rate is controlled by the velocity of the particle, size of the particle, impinging angle, hardness of abrasive, toughness of the rock and the steel material [5,6]. The most important abrasives parameters affecting the wear are the mineral hardness, particle size and shape and mineralogy [7,8]. The hardness of the abrasive is the most important parameter controlling the wear. To be able to form a groove on the surface, the hardness of the abrasives has to be higher than the surface of the material. It has been indicated that a higher hardness of the material result in a higher wear resistance but this is not always true and no material will be perfect for all application. Materials with high hardness often show much better wear resistance than a softer material due to its ability to resist penetration of the abrasive particles [7, 8].

## II. EXPERIMENTAL WORK

### *2.1 Solid model for tipper body*

Three dimensional geometric Modelling of the tipper load body assembly is done using Pro-E 3.0 as per the dimensions given in Table 1. The geometric models are given in Figure 1 and 2.

### *2.1.2 Truck Body Details*

The design parameters are listed below

**Table 1: Body Specifications**

| | |
|---|---|
| Volume/load capacity | 14 cu.m |
| Dimensions: | |
| Length | 4480 mm |
| Width | 2350 mm |
| Height | 1300 mm |
| Bottom Floor thickness | 6 mm |
| Side guard thickness | 5 mm |
| Head Board thickness | 5 mm |
| Channels used for Cross Bearers: | |
| Box channel for Model | 75 mm*75 mm*4 mm |
| Channels used for Long members: | |
| C-Channel | 100 mm*50 mm*4 mm |
| Material: | A 36 and HARDOX 400 |
| Type of material carry | Sand, iron ore, boulders, coal, Road construction Material/Earth |

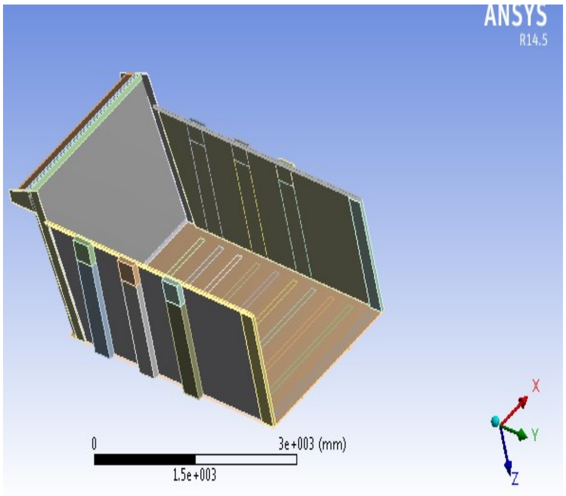


*Figure 1: Pro-E Model of A36 Tipper Body*

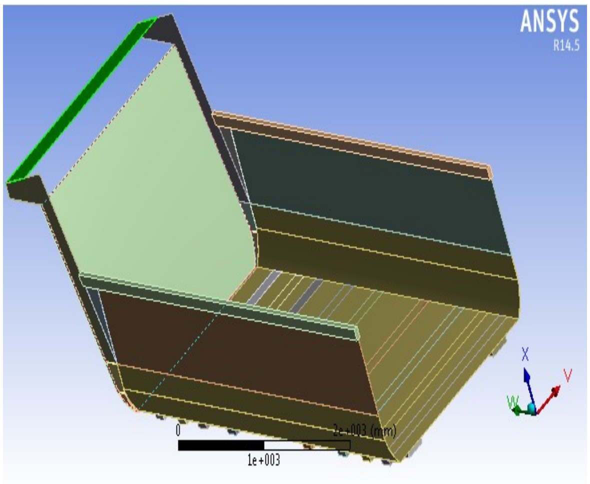


*Figure 2: Pro-E model of Hardox 400 Tipper body*

### *2.2 Material*

The study covers HARDOX 400 and A36 plates with 4 and 6mm thickness. The mechanical properties of this alloy are: yield strength is 960MPa, tensile strength is 980-1150 and % El is 12%. The chemical composition of two alloys, are given in Table. 2 The chemical composition is analyzed using an ARL-4460 Optical Emission Spectrometer.

### *2.3. Test – Impact wear*

Two tests were carried out under impact wear using lifters as per given Table 3. The second part of the test (3) focused on investigating the effect of sharp abrasives on the wear rate.

A total of 68 lifters were installed with a dimension of L30 × B27 × H29 mm, Figure 3 and 4. The lifters were placed so that the abrasives could still slide over the sample. However, the large abrasives would in some cases inhibit the sliding action according to Figure 4. The majority of wear was assumed to be caused by impact wear. In the second test the amount of abrasives and water were increase to 10 kg abrasives and 2 kg of water to create more lift. The speed was set to 27 RPM.

#### *2.3.1 Calculation of impact energy, E [mJ]*

The basic assumption is that the particles are lifted to 80% of the drum height and then fall freely. The weight of the particles has been measured to 11.06g. Note that the movement of the drum is not included in this calculation. This will affect the total impact energy depending on the impinging angle since the drum moves in an opposite direction to the abrasives hence increasing the impact energy.

$$v = \sqrt{2gh} = 3.54\ {}^{m}/_{s}$$

$$E = \frac{mv^2}{2} = 69\ mJ$$

**Table 2: Chemical Composition of Alloy (%Wt, max)**

| Alloy | C | Si | Mn | P | S | Cr | Ni | Mo | B | Fe |
|---|---|---|---|---|---|---|---|---|---|---|
| **HARDOX 400** | 0.32 | 0.7 | 1.6 | 0.025 | 0.01 | 1.4 | 1.5 | 0.6 | 0.004 | Bal |
| **A 36** | 0.29 | 0.28 | 1.3 | 0.04 | 0.05 | **Cu :** 0.2 | - | - | - | Bal |

**Table 3: Test details of Impact wear**

| Run time | Speed | Abrasives | Weight | Pre worn | Lifters |
|---|---|---|---|---|---|
| 23 hr (no change) | 27 RPM (1.13 m/s) | 16-25 mm, crushed granite | 10 Kgs | Yes (2 hr) | Yes |
| 7 hr (change every hour) | 27 RPM (1.13 m/s) | 16-25 mm, crushed granite | 10 Kgs | Yes (2 hr + 23 hr) | Yes |

The control over the impact angle proved to be more difficult than expected since the transparent lid quickly became coated with a layer of mud. As the abrasives are worn, they become smaller and the viscosity of the mixture will change due to the increase of fine particles. These two factors combined might change the flow of the mixture resulting in a different impinging angle then observed at the beginning of the test.

Both parts of the second test were carried out using 10 kg of 16-25mm crushed granite combined with 2 kg of water. In the first part the machine ran for 23 hours with no change of abrasives and in the second part the machine ran for 7 hours with change of abrasives every hour. The latter part would ensure a controlled impact angle during the whole test and a better understanding of how the wear rate changes with sharp abrasives or worn abrasives. The samples were weighted both before and after testing.

*Figure 3: The Drum with a Total 68 Lifters Assembled*

*Figure 4: Lifters Hindering the Sliding of Abrasive Particles*

The holders used in the second test had also been used and worn in the first test. This could create some problems when using an unworn sample since the height difference might create a higher wear on the edges. To reduce this problem the samples were worn in the drum for 2 hours and then cleaned and weighted. Before starting the second test the height of the edge between sample and holder were investigated and the distance between each pair of lifters.

## III. Results

### *3.1 Simulation using ANSYS Workbench*

The developed geometric models as given in figure 1 and 2 are imported in the stl file format (stereo lithographic file) into ANSYS Workbench for conducting the simulation studies. The simulation studies have been conducted for A 36 and HARDOX 400 steel as the details given in Table 4.

**Table 4: Material Property Details of HSLA Steels for Simulation Studies**

| **Property** | **A 36** | **HARDOX 400** |
|---|---|---|
| Density | 7800 kg/m$^3$ | 7476.57 kg/mm$^3$ |
| Volume | 698771509 mm$^3$ | 509832376 mm$^3$ |
| Mass m = density x volume | 698771506 x 7800 = 5450.42 kg | 509832376 x 7476.57 = 3810.27 kg |

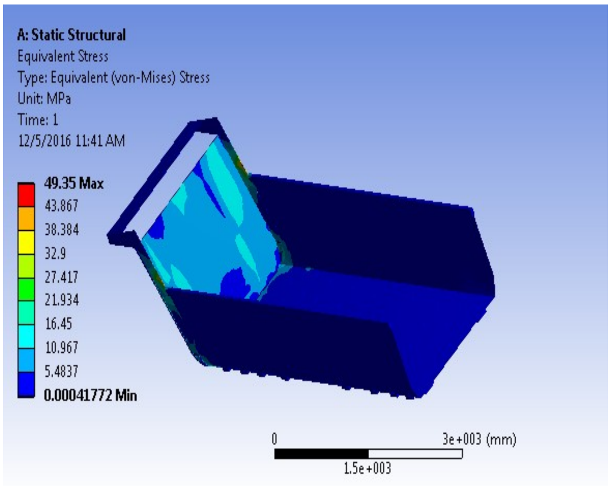


*Figure 5: Head Stress Developed in HARDOX 400 Tipper Body*

The simulation studies are conducted for measuring the side stress, head stress and bottom stress developed during the performance of the tipper body. The results are given in Table 5. Figure 5 is giving the information about the head stress developed during simulation studies for Hardox 400 alloy tipper body.

Table 5 is giving the information regarding the maximum stresses developed in static load condition for A 36 and Hardox 400 alloy tipper body. For predetermined carrying load the maximum stresses developed in Hardox 400 alloy tipper body are less compared to A 36. From these simulation studies the load carrying capacity of the Hardox 400 tipper body is more. Reduction in 30% tipper body weight is observed for Hardox 400 tipper body from the geometric models.

Reduction in tipper weight = (Tipper weight of Hardox 400 - Tipper weight of A 36) / Tipper weight of Hardox 400)

= (5450.42 - 3810.27) /5450.42

= 30.1%

**Table 5: Stress Developed During the Simulation Studies**

| Material | Bottom Stress, MPa | Head Stress, MPa | Side Stress, MPa |
|---|---|---|---|
| A 36 | 201.78 | 153.26 | 727 |
| Hardox 400 | 14.817 | 49.35 | 486.97 |

### *3.2 Wear Rate for 23 Hour Testing*

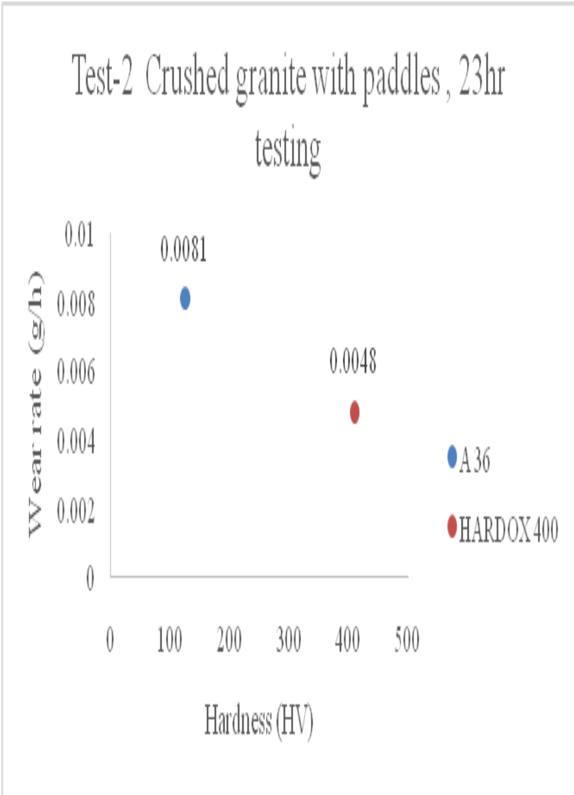


*Figure 6: Test-2 Crushed granite with paddles, 23hr testing*

The A 36 steel grade has the highest wear rate, 0.008 g/h as compared to HARDOX 400 during as shown in Figure 6.

### *3.2.1 Relative Service Life*

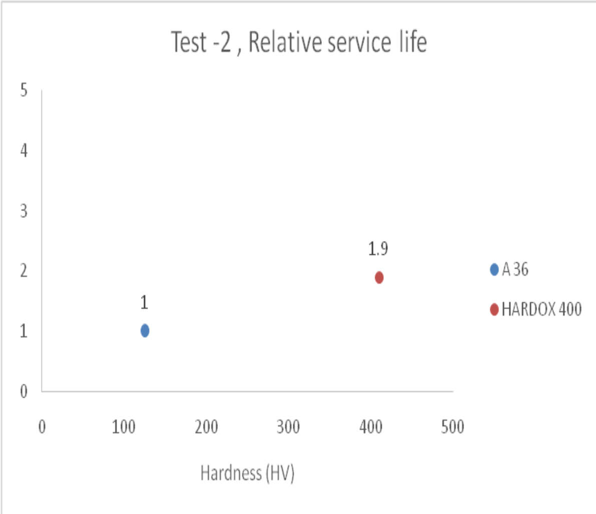


*Figure 7: Test -2, Relative Service Life*

The result show in Figure 7 a potential increase in lifetime by up to 1.5-2 times, when upgrading to the hardest material, HARDOX 400 from A 36.

### *3.3 Wear rate for 7 hr testing*

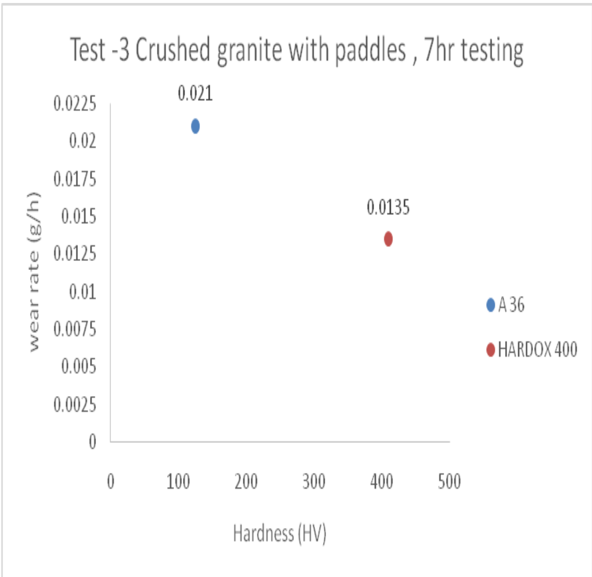


*Figure 8: Test-3 Crushed granite with paddles, 7hr testing*

The A 36 steel grade has the highest wear rate, 0.02 g/h as compared to HARDOX 400 i.e. 0.0135 during Test as shown in Figure 8.

### *3.3.1 Relative Service Life*

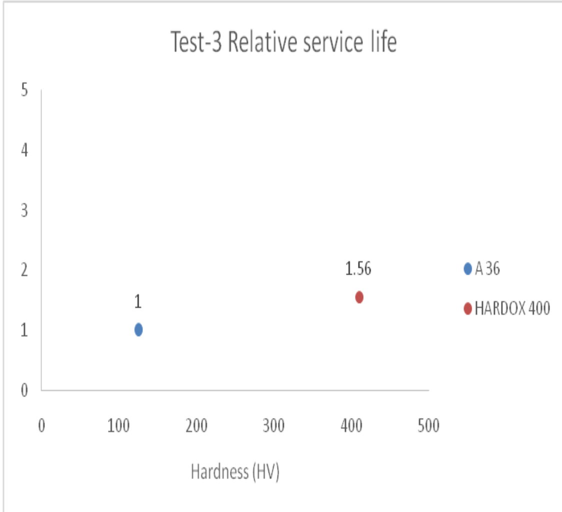


*Figure 9: Test-3 Relative Service Life*

The result show in Figure 9 a potential increase in lifetime by up to 1.5-2 times, when upgrading to the hardest material, HARDOX 400 from A 36.

### *3.4 Topographic Investigation- SEM*

Direction of the drum is from right to left. Impact angle is assumed to be around 90 degrees. Embedded abrasive materials were observed on all the samples. The harder material HARDOX 400 showed a smoother surface as shown in Figure 10. Deep craters could be found in A 36 as depicted in Figure 11. The harder steel grades show lower number of craters. These were probable form in the beginning of testing by the sharp abrasives.

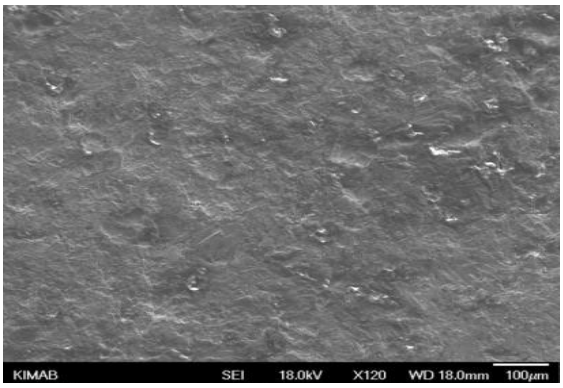


*Figure 10: HARDOX 400 shows less deformed surface*

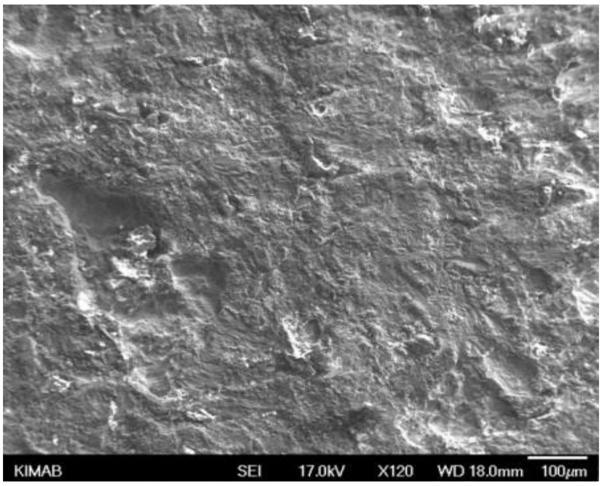


*Figure 11: SEM images of A36 showing deep craters*

## IV. CONCLUSIONS

HARDOX in truck bodies HARDOX hard steel combines toughness with good wear and impact resistance compared to A 36 steel, that the resistance to blows and denting is better. HARDOX 400 impact wear is high and uniform. This means that the steel can withstand wear and impact very effectively. The harder HARDOX 400 steel grades show lower number of craters. So, large items can be loaded into the body without causing serious permanent dents. The impact wear at two different service times will be uniformly distributed, and the increased useful life will thus result in better overall economy of the body. Reduction in 30% tipper body weight is observed for Hardox 400 tipper body from the geometric models.

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