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# Design and Development of Work Tool Attachment

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***Abstract*—Ripping of hard and frozen ground is commonly done by using an Earthmoving machine with rear-mounted work tool that are usually a permanent part of the machine. Ripping is an attractive alternative to drilling and blasting with explosives. In this project, a multi-shank work tool attached to an earthmoving machine is subjected to failures (weld cracks near carriage assembly) thus resulting in less machine operation time. This project deals with the design and development of the existing work tool subjected to failures so as to reduce stresses at critical areas by incorporating new design changes.**

***Index Terms*—Design, Development, work tool, Analysis.**

## I. INTRODUCTION

The **work tool** in this project is a long claw-like device attached to the back of an earthmoving machine. The work tool can come as a single (single shank/giant) or in groups of two or more (multi shank). Usually, a single shank is preferred for heavy ripping. The work tool shank is fitted with a replaceable tungsten steel alloy tip. Ripping rock breaks the ground surface rock or pavement into small rubble easy to handle and transport, which can then be removed so grading can take place.

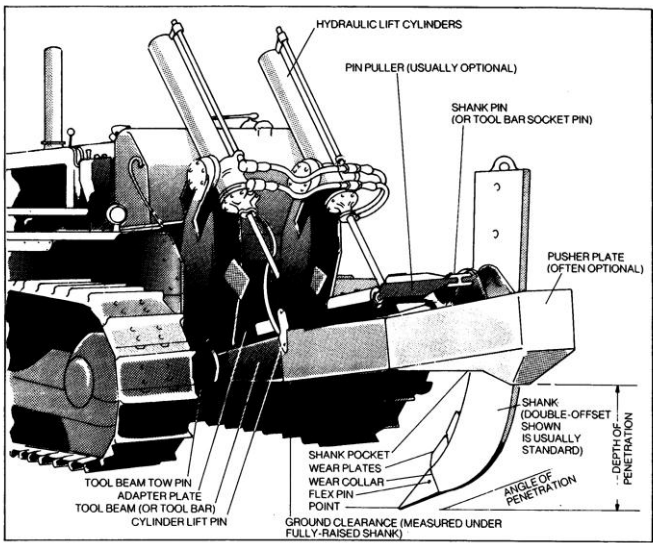


**Figure 1: Work Tool Attachment**

The multi shank Work Tool attachment subjected to weld cracks consist of the following main parts: Mounting Group with lift and tilt hydraulics cylinder options, Carriage assembly (where failures occur), Tooth Group with cutting teeth and Frame Group as shown in Figure 1.

Working principle of the Work Tool attachment:

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The Work Tool cutting teeth is forced to penetrate into the ground with the help of hydraulic pressure. When the force exerted by hydraulic mechanism exceeds the compressive strength of the rock mass, then it causes a shear failure of the rock. As the machine moves the drawbar pull causes tensile breakage of the rocks. If the rock mass is fractured, the rock fails when the drawbar pull exceeds the cohesion between the fractured blocks or rocks. Sometimes pre-fracturing of the much consolidated rock mass is necessary for the efficient ripping operation. The economical speed of the work tool attachment when maximum drawbar pull is available is around 2 to 3 km/hr. The speed more than above causes more power consumption and more wear and tear in the cutting teeth. This will also generate excessive heat and will cause low production.

## II. METHODOLOGY AND OBJECTIVE

### *A. Problem Definition*

The field issues reported on the Work Tool attachment are on the carriage assembly area where most of the weld cracks were present with very low life. The current project work deals with the static load condition and with the Work Tool attachment at lift cylinder with the maximum stroke condition.

### *B. Objective*

To reduce stresses in critical areas of the Work Tool Carriage assembly by providing temporary field fixes by adding structure to existing carriage and permanent production fixes by modifying, removing, adding plates to the carriage assembly without changing the castings and pin locations.

### *C. Methodology*

The first task is to conduct a baseline Finite Element Analysis (FEA) by applying unit load (of 1 KN) conditions to the simplified current Work Tool attachment. Later, this baseline FEA model will be used for validating new design changes (developed as field and production fixes) by using unit load conditions to witness reduced stress patterns. FEA study is performed using Pro/Mechanica (Creo/ Simulate).

## III. FINITE ELEMENT STUDY BY USING CREO/ SIMULATE

Steps in preparing a typical FEA model (Figure 2) for solution using CREO / SIMULATE (formerly called Pro/ MECHANICA) :

1. Identify the model type
2. Specify the material properties, model constraints, and applied loads
3. Discretize the geometry to produce a finite element mesh
4. Solve the system of equations
5. Compute items of interest from the solution variables

6. Display and critically review results and, if necessary, repeat the analysis

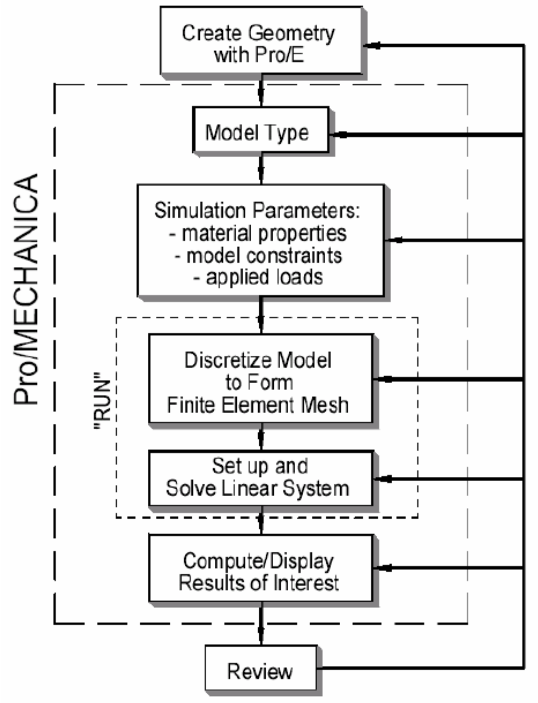


**Figure 2: Typical FEA Steps**

*A. Simplified Model Geometry:*

The existing model geometry is simplified for further design validation using Creo/Simulate. Part of the model simplification process, the existing solid geometry is simplified and proper connectivity (weld contact areas) are ensured as bonded interface.

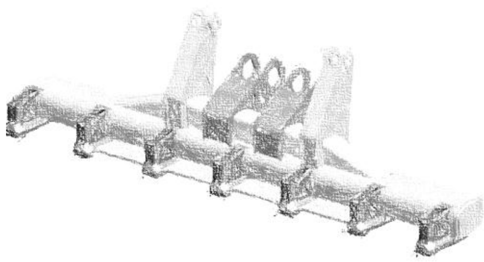

**Figure 3: Baseline Design of Carriage Assembly**

Pins, Link assemblies and cylinders are modeled as beam elements in Creo/Simulate & appropriate beam releases are provided per the component function.

*B. Material Properties*

Consistent sets of Units used: Forces – N (Newton); Stress as N/mm^2 or MPa
Material assigned: Steel
Material properties: Yield Strength: MIN 290 MPa; Tensile Strength: MIN 435 MPa

*C. Discretization*

The entire Work Tool arrangement is meshed by following the sequence of meshing by the breakdown of part, sub-assembly, group and arrangement levels.
Element Type used in Meshing: Solid type.

*D. Boundary and Load Conditions*

All Degree Of Freedom at connection between top link and frame and lower link and frame are constrained.

The baseline FEA Model is loaded with unit load of 1 KN at the tip of center, extreme right and left.

Links, Cylinders and Pins are replaced with beams of appropriate cross sections.

Beam releases are provided to Pins as shown in Figure 4. This enables the pin to rotate along X-direction only.

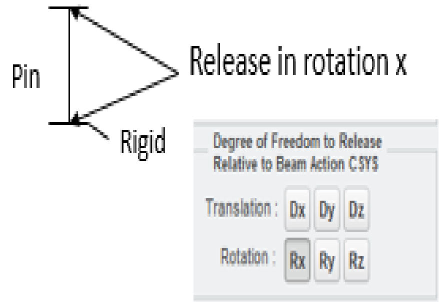


**Figure 4: Beam release for Pins**

Beam releases are provided to Links and Cylinders as shown in Figure 5. This enables the link & cylinder to rotate in all x, y & z directions and translate in y & z direction (translation restraints in x-direction).

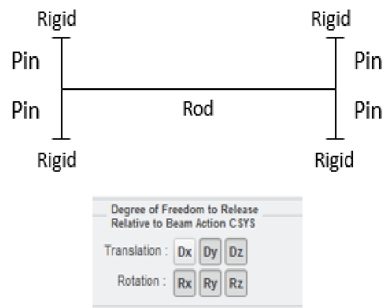


**Figure 5: Beam release for Links & Cylinders**

Thus, after defining all the loads, constraints and boundary conditions, the baseline building of the Work Tool arrangement is completed.

*E. Baseline Analysis*

The Baseline FEA analysis was carried with the above conditions successfully. The entire Work Tool arrangement is meshed by following the sequence of meshing by the breakdown of part, sub-assembly, group and arrangement levels.
Element Type used in Meshing: Solid type.

*F. Design Solutions*

Two concepts (doubler plate – Figure 6 & stiffener plate – Figure 7) were evaluated as temporary field fixes against the baseline design. The Stiffener plate idea resulted in reduced stress patterns.

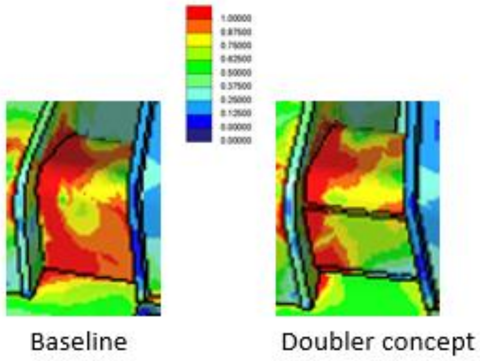


**Figure 6: FEA results of Doubler Concept**

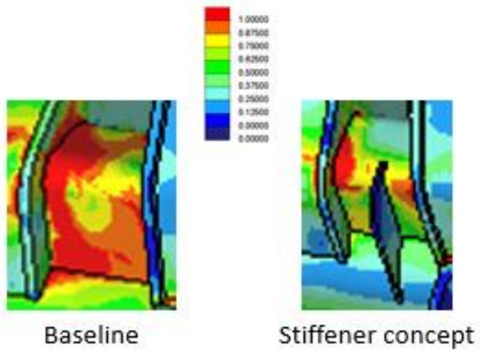


**Figure 7: FEA results of Stiffener Concept**

As part of the permanent production fix, following carriage assembly design (Figure 8) was developed for the multi shank work tool attachment.

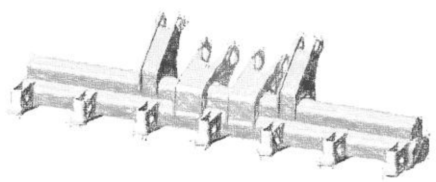

**Figure 8: New Production Design of Carriage Assembly**

Further Finite Element Analysis (FEA) was carried on the new production design of carriage assembly and comparative study with the baseline design showed improved stress pattern as captured in Figure 9.

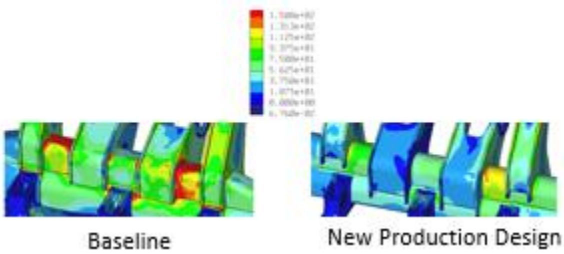


**Figure 9: FEA results of Production Design**

## IV. Conclusion

The baseline FEA results of the current work tool attachment design was compared with the new design concepts developed as temporary & production solutions. It is observed that higher stress areas of the baseline designs are reduced with those new design proposals provided in two phases as field and production fixes.

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