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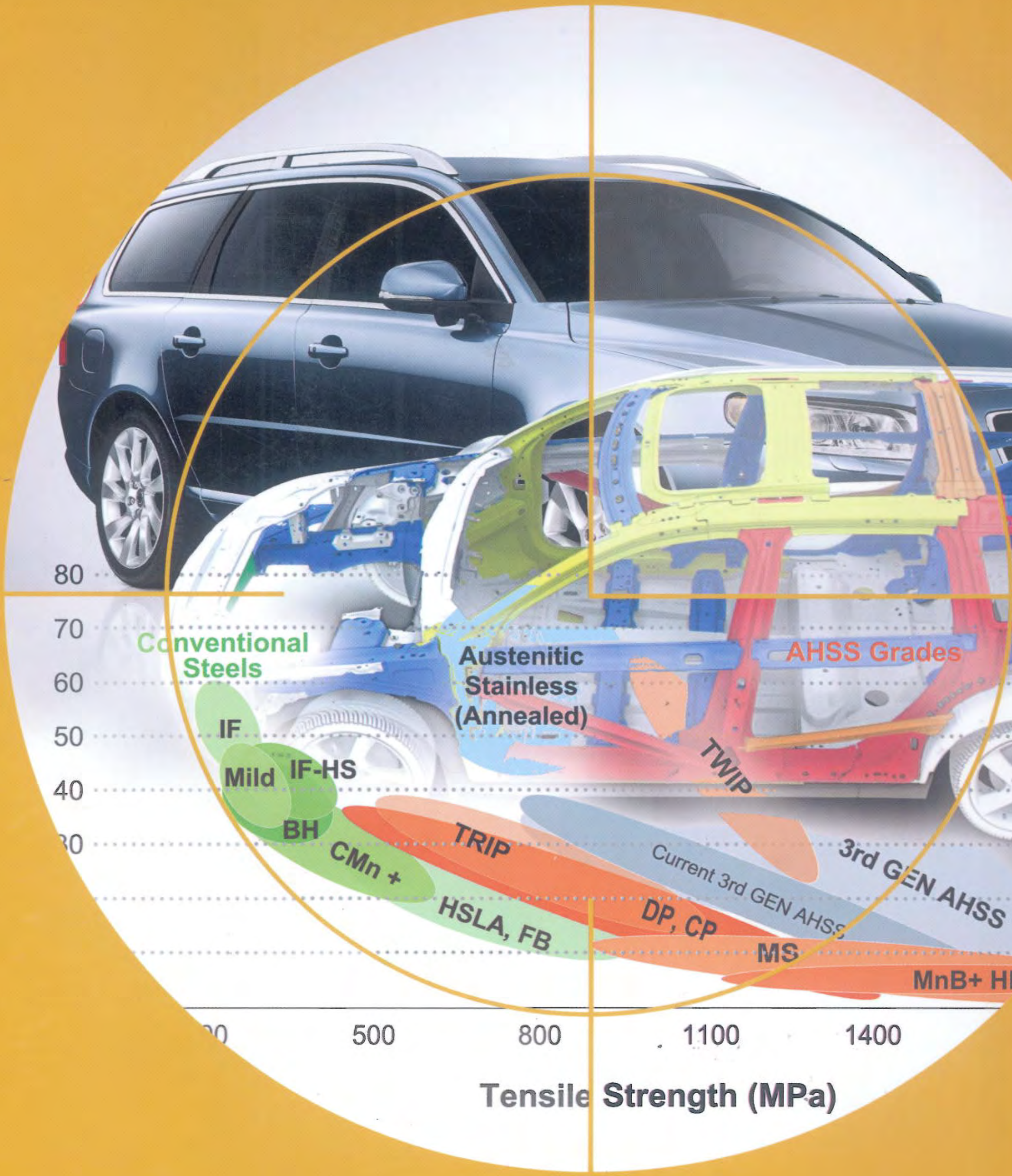

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Experimental Verification of Finite Element Analysis of a Rota Side Wagon Tippler with Strain Gauge Measurement

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Abstract

Typically, a wagon tippler operates under arduous conditions for most of its operational life. Hence, structural changes and failures are likely to occur during the operation of wagon tipplers. A complex rotational working principle of the wagon tippler complicates the analytical evaluation of its structures. This is also affected by an ever changing boundary condition of the structures during the operation. Frequent variation of load, throughout the operation while emptying the wagon makes it further complicated. Both these factors need to be seen while determining the stress level of the structures during operation. To verify the accuracy of the finite element analysis of a tippling cycle, strain gauge measurement was under taken in the wagon tippler working at site. The finite element analysis predictions of structural stresses was successfully validated as observed from the field measurements.

Keywords: Wagon tipplers, Finite element analysis, Strain measurement

INTRODUCTION

The demand for power generation is increasing day-by-day. To meet this requirement, the Government of India is planning to substantially increase the power generation in the country. Under the current 12th Five Year Plan of Government of India, the target is to reach 79690 MW units of power generating capacity. Though in recent years, power generation from non-conventional resources is also being encouraged in India, but power generation using coal (Thermal Power plant) is still the most economical source of power (66600 MW out of proposed 79690 MW) in the country.

With the release of coal blocks by Government of India to private sector and the public sector enterprise, Coal India- coal based thermal power continue to be the dominant source of power generation in the country. Many companies are adding new capacities by expanding their existing sites or by setting up new generation capacities in green field locations. In a typical thermal power plant in India, the transportation of coal is done essentially by rail wagons which are unloaded with the help of wagon tipplers. While a wagon tippler is a vital equipment and plays an important role in a CHP (Coal Handling Plant) in a thermal power plant, it is also a critical equipment in unloading of wagons carrying raw materials in Steel Plants, Cement Plants, Port and in the non ferrous metals industry.

Wagon Tippler structure experiences varying loads during tippling as the material in the wagon starts falling in the hopper after certain angle(beyond 15° tippling). It means that the structure has to meet varying load and various boundary conditions during the entire tippling cycle. This induces varying stress levels in the structure during operation. The wagon tippler is designed to address this varying load & stress levels. These are done through engineering calculations and are supported by Finite Element Analysis (FEA). However, these are based on calculations and assumptions.

In order to ascertain the correctness of these, it is essential that stress at different angles of tipping is captured in actual working condition. Hence to capture all these changing loads & boundary conditions, analysis for the following load cases was considered:-

1. Cradle is resting on ground(4 points of contact with the ground) with loaded wagon of 110 T (tonnes)
2. Wagon is resting on side support and cradle. Wagon Tippler is rotated by 5°. Wagon weight at this point is 110 T
3. Wagon is resting on side support and cradle.

Wagon Tippler is rotated by 90°. Wagon weight is 92 T (due to evacuation of coal) at this point.

4. The wagon is resting on side beam and clamped-in position by top clamp when the wagon tippler is rotated by 135°. Wagon weight is 35 T (totally emptied) at this stage.

The strain gauges were applied at selected points and the strain & Stress levels were calculated during the consecutive tips. Results obtained from field measurements were used to verify and validate the FE Analysis calculations and assumptions.

BRIEF DESCRIPTION OF THE WAGON TIPPLER

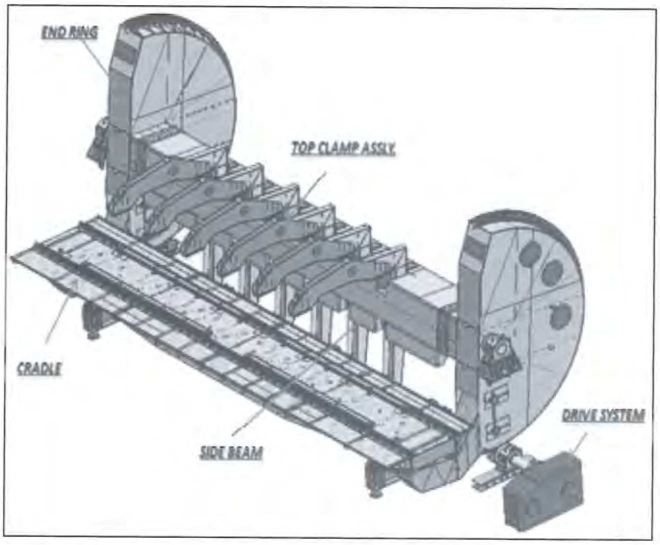


Fig.1: 3D view of 110t wagon tippler

The wagon tippler consists of two End Rings with reinforced shafts which are supported on trunion bearings and plummer blocks. It is capable of receiving, clamping and tippling BOXNHL25 wagons and other types of wagons used by Indian Railways. The tippler empties the wagons by rotating them through an angle of 160° (Max), though normally, evacuation is completed at 135° rotation.

The tippler is of robust construction and designed for continuous duty. The wagon is clamped in the cradle table during tippling with the help of hydraulic cylinders. The arrangement ensures that undue clamping pressure does not apply force beyond the allowable force of 1.5 tonnes per pad as per RDSO regulation and no damage is done to the sidewalls of the wagon. Hydraulic cylinders used for clamping also help to hold the wagon in inverted position. The tippler is gear driven, torque being available through hydraulic motors, combination of gear boxes & hydraulic motor or gear box and electric motor.

The important parts of a wagon tippler are:

(a) Cradle.

(b) End rings.

(c) Side Beam (Side Bolster Beam).

(d) Top Clamp Assembly.

(e) Drive System.

ANALYSIS PROCEDURE

Strain Gauge Rosette (three axis) arrangement were positioned at 4(four) locations and Strain Gauge single axis arrangements were positioned at 5(five) locations. The strain measurement was done for these locations. The stress results calculated from the strain values through this measurement were compared with the stress results obtained from the finite element analysis. Thus two types of measurements were conducted at site:

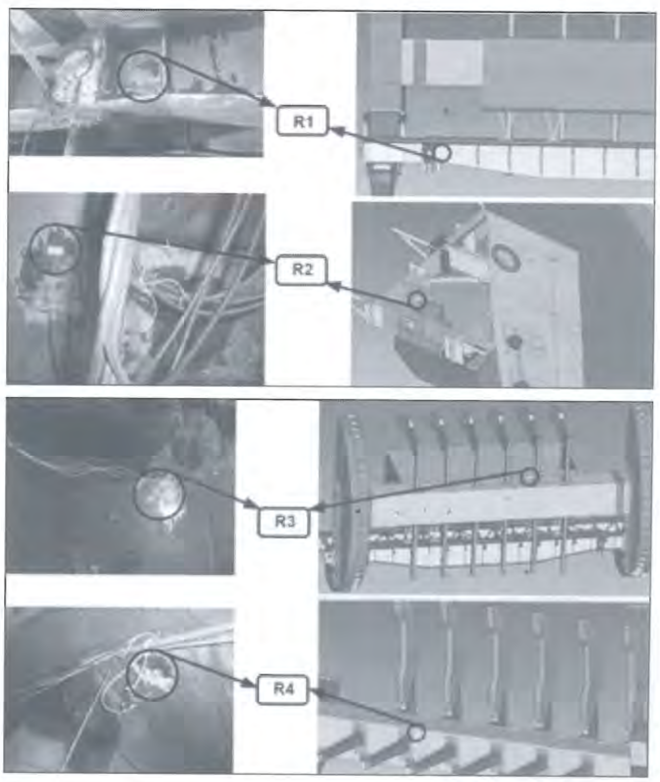
Experimental Measurement which includes:

i) Structural strain measurement

ii) Pressure measurement

Correlation activities include

i) FEA with updated boundary conditions and loads for stresses



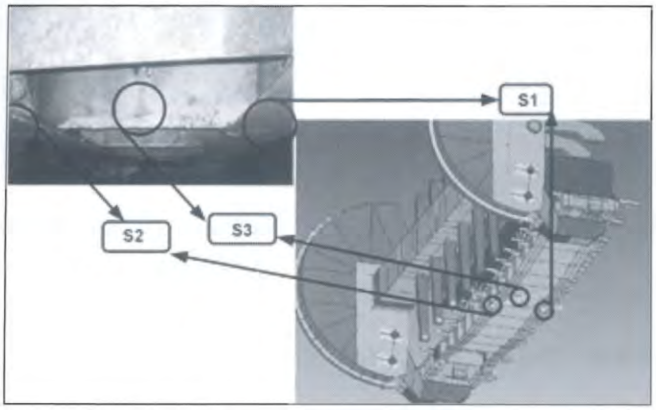


Fig. 2: Location of strain gauge on 110t wagon tippler

ii) Multi-body simulation with updated wagon loads for torque/pressure

Structural Strain Measurement

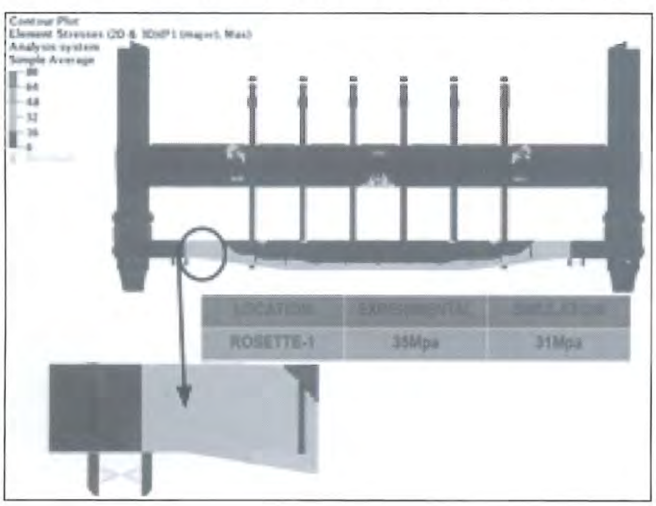
Experimental measurement of strains at corresponding locations on the tippler was conducted at Aravali Power Company's, Jhajjar site. The position for fixing strain gauges were selected based on the expected stress patterns in the structure in FE Analysis. The selected positions are shown in Fig. 2. The direction of strain measurement was also kept in mind. For measurement, half-bridge strain gauge arrangement was used. This arrangement is essential to compensate the effect of temperature variation on strain gauge reading which is bound to occur due to water spray for dust suppression.

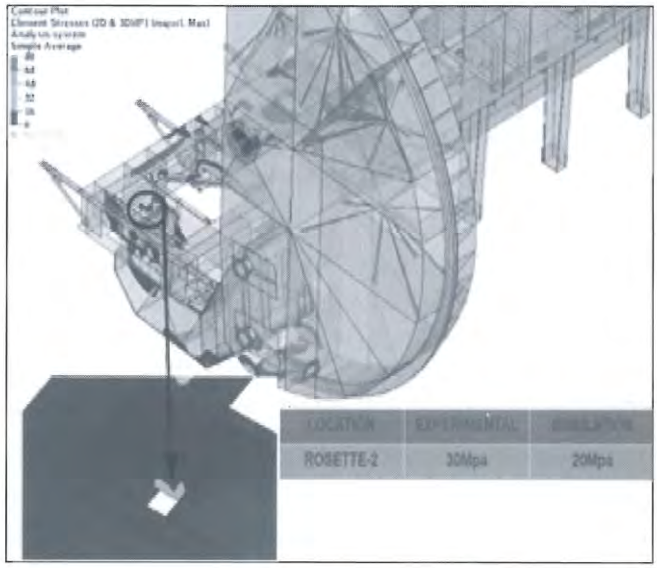
The instruments used were:

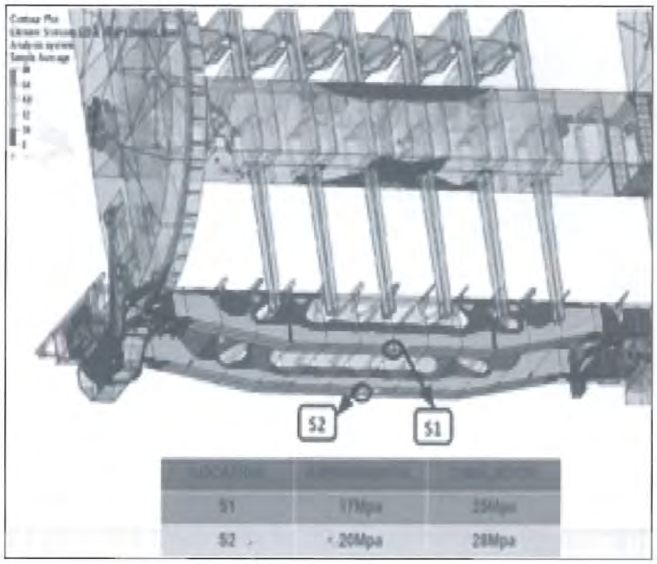
i) Data Logger.

ii) Strain Gauges & Rosettes.

From the measured strain gauging data, the stress (maximum & minimum principle) was calculated. The stress can be seen in different conditions as given in Fig. 3







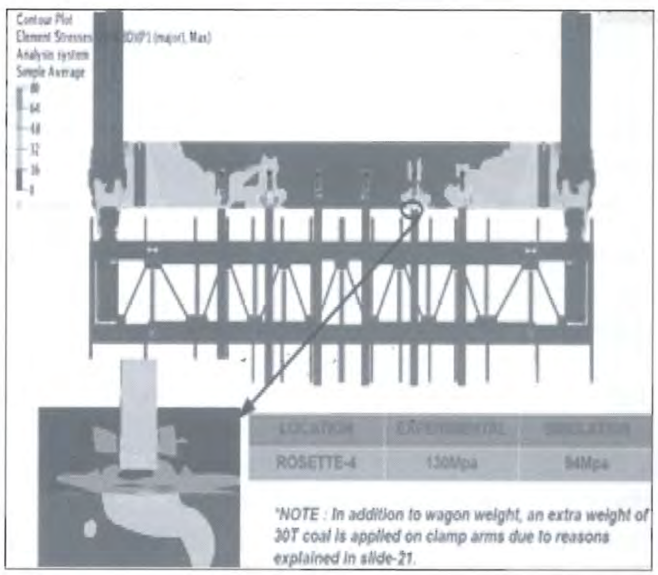


Fig. 3: FE results of stress of some components of 110t wagon tippler

Summary of Result

Location	Validation Case					
	Static Zero Deg			Loaded 5° in Tippler		
	Exp	SIM	ABS ERR	EXP	SIM	ABS ERR
R1	35	31	4	–	–	–
R2	30	20	10	35	37	2
R3	1.5	2	0.5	19	10	9
R4	6	11	5	130	94	36
S1	17	25	8	16	27	11
S2	20	28	8	17	17	0
S3	1.8	0.14	1.6	7	2	5
S4	0.7	0.3	0.5	76	78	2
S5	1.8	0	1.8	13.4	4	9.4

*Exp: Experimental, SIM: Simulation, ABS ERR: Absolute Error,
** All values are in Mpa Units

Inference

- The correlation levels are quite high under load or an absolute error below 15 Mpa, which is considered a fine level of accuracy in a structure with payload over 100 tonnes
- One location at bottom of side beam shows correlation difference of 36 Mpa (25% error). This is clearly because only two clamps were in working condition during operation instead of all clamps and substantial amount of coal was stuck in the transfer beam gaps.

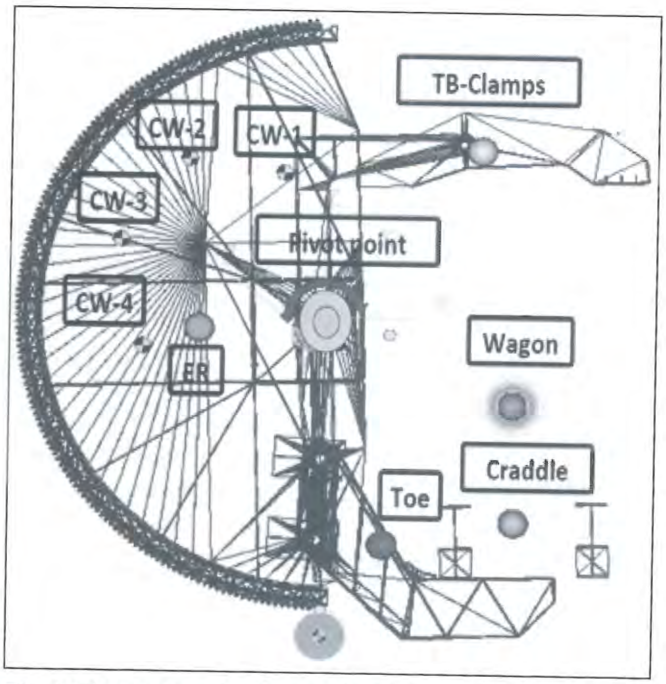
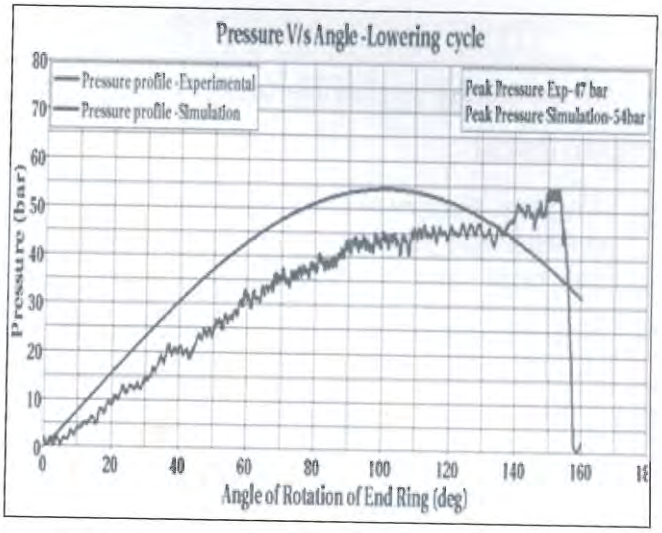
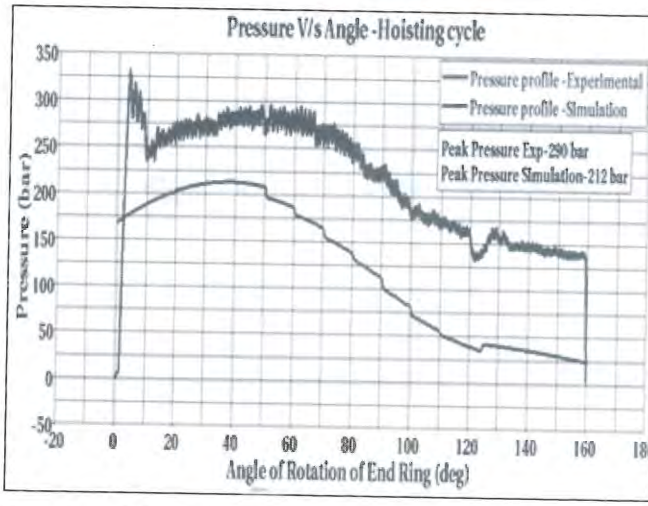


Fig. 4: The various bodies and their positions with global considered in the MBD model





Pressure Measurement

One pressure Transducer was used to measure the hydraulic pressure during tippling. Multi-body Simulation of Wagon Tippler was used for torque (pressure) correlation.

Inference

The comparison plots convey that there is a qualitative match of the trends of pressure variation. However, the quantitative correlation is not very accurate. The primary considerations are:

- Designed Tippler and Counter Weights may be different than field Tippler and Counter Weights. There is no way to correlate this critical piece of information in the field since the tippler is in operation at the plant.
- DESIGN hydraulic circuit and site hydraulic circuit may be different. There is clear gap in this since the relief valve is set to be at 240 bar as per design while the measured data crosses 290 bar

- The simulation is only mechanics based and a full co-simulation with hydraulics and mechanics needs to be executed with Counter Weight sensitivities.

CONCLUSION

- The Finite Element Analysis predictions of structural stresses was successfully validated as observed from close match with field measurements
- This indicates that the structural strength predictions via FEA can accurately predict the field performance as long as:
  - Field equipment and Design release equipment are same/similar
  - The events studied in FEA replicate boundary conditions of actual field conditions.
- It can be safely concluded that FEA results can be leveraged for Structural Design Optimization with a factor of maximum 15% variation expected
- From the pressure comparison it is also clear that multi-body Simulations can predict the system level mechanics very well.
- Also, the experimental study highlights that there are significant differences in the FIELD PRODUCT and DESIGN data. – e.g. two transfer beams in operation, pressure relief settings differences, counter weight differences. These aspects need to be controlled during installation and commissioning.

Useful Application of Validation

As per RDSO (Research Design & Standards Organization), G33 Rev.1, we developed Wagon Tippler to handle 140 T DFC- 25 Wagon was developed and design validated based on the FEA done in a similar fashion.