International Journal of Scientific Research and Engineering Development-– Volume 6 Issue 2, Mar-Apr 2023

Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

Comparative Analysis of Three Different Popular Cross Sections for Low-Cost Simple Agricultural Tractor Chassis for Small Holding Farmers in Sudan

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Abstract:
Chassis is the basic component of any vehicle of vehicles on which the other components are placed. For small tractors, chassis can be made of different types of materials and cross sectional profiles. In this conceptual study, different cross-sectional profiles are studied and graphs showing variation of deflection and twist angle for C, Tubular, and hollow rectangular cross sections profiles are presented. Two types of load distributions were considered which are typical and uniform distributions. The graphs are readily usable to choose the cross-sectional profile that would give the maximum deflection and twist angle. The twist angle however showed little significance as basis for selection for all sections considered.

Introduction:

About 80%[1] of the citizens in Sudan depend for their livelihood on the production of food, cash grains, and livestock breeding. Small-scale farmers represent the vast majority of those engaged in traditional rain- fed agriculture and live in conditions of extreme poverty, which makes the community such communities vulnerable to climate change, and adversely affected by climate change. This led to delayed development, the emergence of violent protests and sustained weak indicators of social development such as education, health, and clean water. The situation has been exacerbated by the irrational exploitation of land by humansin agriculture and overgrazing. FAO Country Programming Framework[2] called for capacity developmentof agricultural research, technology and knowledge development and transfer for enhanced productivity, production and competitiveness institutions, systems and mechanisms in agriculture, fisheries, and forestry of Sudan. The program[2] called also for Natural resource management and livelihood, food security and nutrition response, protection, and recovery. The most noxious components in the transmission system weregearbox (34%), especially gear 2, bearings (21%) and cultch plate (15%), which indicates the poor maintenance and repair. The level of mechanization ranges between 0.2-0.58, which reflect the smaller number of tractors to the cultivated areas in the state [4].

Most tractor leasing projects in Sudan, have failed to make tangible impact on the lives of smallholder farmers. The technological gap in Sudan farming include lack of infrastructure, limited access to finance, lack of education and training, inadequate research and development, and poor extension services.

Objective of the study:

Among efforts to alleviate drudgery of manual work, and make farming more attractive, especially to the youth, is designing and development of a low-cost small tractor for use in Sudan. To reduce the cost of thetractor while still providing the necessary performance and functionality, and to be within the purchasing power of the average small farmer in Sudan, a minimalist approach in which standard components was adopted. To reduce the manufacturing cost, only locally sourced materials, such as steel and aluminum including scrap and reusable parts were considered. This paper is focused on providing a readily usable graphical data for choosing the appropriate section chassis frame for safe to operate chassis for small horsepower range (15-20) tractor. The chassis would be simple, modular architecture which will use small number of simple, well established and ascertained components that can be built locally or standard parts that can be purchased from the local market. Design of such low-cost small tractors will make it affordable and accessible for the small-scale farmers in Sudan. The chassis must be able to support the weight of the engine, transmission, driver, payload and any other components or implements that may be attached to the tractor. The tractor must be able to turn and move easily in tight spaces, such as in small fields or on narrowroads. The chassis is usually subjected to bending and torsion or both. Therefore, the tractor chassis must be stiff enough to resist deformation and deflection as well as angular twisting under load and insure the stability, durability, and performance of the tractor. A larger cross-sectional area provides greater stiffness,but also increases the weight of the chassis. The geometry of the chassis components, such as the shape, size, and orientation of the tubes and beams, affects the stiffness of the chassis. Therefore, selection of theproper chassis frame section is critical to the overall cost, and performance of the tractor.

Types of Tractor Chassis Frames

Basically, there are two types of chassis: namely, the chassisless (or no frame), and those with frames. For the conventional tractor, the engine itself constitutes part of the chassis, and the housing of the transmission forms the remaining part of the chassis. When the objective is to design a simple, and least cost tractors, other alternative frames are used. The tractor in the study is the later type; and the chassis is simple and made of only double rail ladder frame or a single rail frame. Both frames extend from the beginning to theend of the tractor including the rear and front overhangs. C, rectangular tubular, and circular tubular x- sections are mostly used in such small tractors, in the 10-20 hp size range used in Sudan for their strength,which the subject of this study. The weight distribution is extremely important. For the conventional 2-wheel drive tractors, the weight distribution should be approximately 30% on the front axle and 70% on the rear[7]. However, generally this distribution can be 30-50% on the front axle and 70- 50% on the rear axle. Four-wheel drive tractors generally carry approximately 60% on the front and 40% on the rear axle. Allowances for additional weight due to attachments should also be calculated and weight distribution may be adjusted accordingly. The weight of the chassis must also be considered in determination the total tractor wight. Any dead weights, including ballast and payloads must be considered when computing the total tractor weight. Previous studies showed that the Lateral Loading is less sensitivity to the differences in chassis stiffnessescompared to torsion case[8]. According to some studies, the rectangular box cross-section type of Ladder Chassis gave the least deflection, and maximum shear stress for Steel in all the of three different cross section type of ladder chassis[9]. Other studies found the optimum section based on consideration of bending and torsion models found that the C profile with thickness = 5.5 mm, height = 100 mm, andprofile width = 55 mm is the optimum one[10].

Calculation of the deflection and twist angle for the different cross sections:

The chassis was considered as a simply supported bean. The maximum deflection δ due to a concentrated force P at distance a from one support and distance b from the other support may be determined by $\delta = \frac{Pa^2b^2}{3EIL}$. The deflection δ at any point at distance x from the support for uniformly distributed load along

Chassis longitudinal Dimension		
Front overhang	Rear overhang	Wheelbase
435	300	1500
Vehicle parameters and loads typical small tractor		

Load source	Position (mm)	Load (kg)	Load (N)
ballast	0.0	50	500
Radiator and steering	300.0	60	600
Engine and Springs	650.0	90	900
Driver + seat	1100.0	170	1700
transmission	1400.0	45	450
differential	1935.0	30	300
payload	2100.0	160	1600

Table (1): Estimated loads on tractor chassis frame

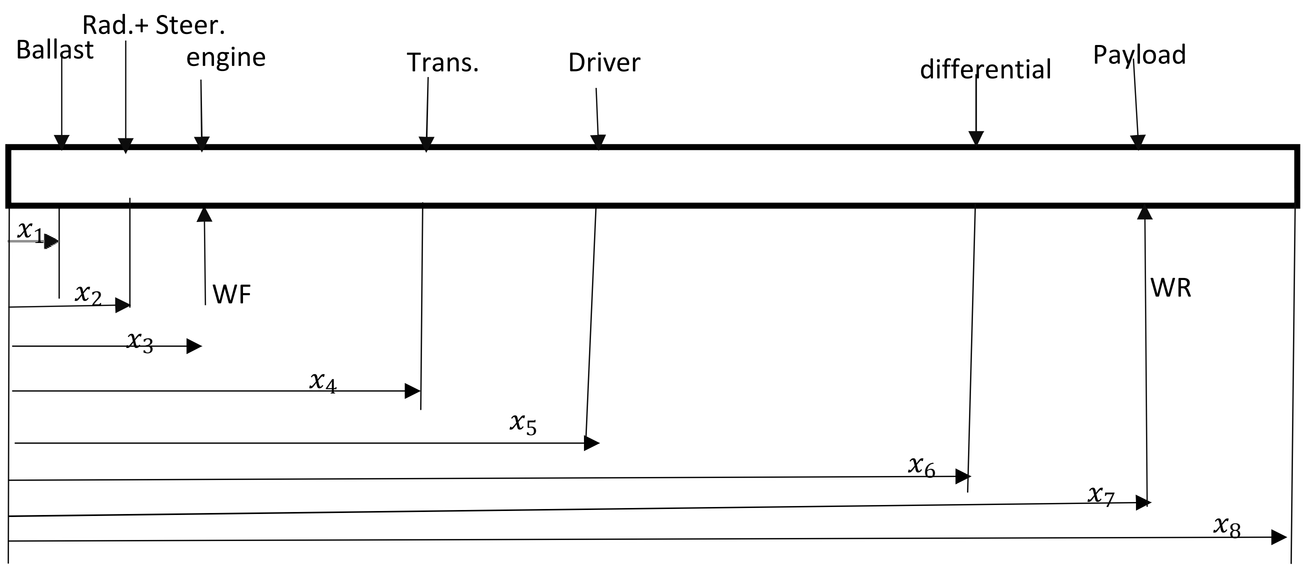

Fig. 1: Typical load distribution on small farm tractor chassis

the total span of the chassis is given by $\delta = \frac{Wx}{48EI}(3L^2 - 4x^2)$. The maximum deflection is at the midsection and given by the equation $\delta = \frac{WL^3}{48EI}$. The twist angle can be determined by taking the maximum torsional moment the chassis is subjected to. The method of superposition gives the total deflection at any point along the length of the beam is the sum of the individual deflections under different concentrated loads. Knowing the reaction at the supports (the wheels) the maximum torsional moment (M_t) is given the product of the smaller support reaction and the wheel space. i.e $M_t = R_{min} \times b$ where b is the wheel space. The twist angle θ is determined by the well ascertained equation $\theta = \frac{M_t \times L}{GJ}$ where G=modulus of rigidity of the beam material and J is the polar moment of inertia of the beam section. Deflection and angle of twist for two modes of loading, namely the typical load distribution and when load is assumed to be uniform across the total length of the chassis. Structural steel with modulus of elasticity of the material = 210x10^3 MPa, and density=7850 kg/m^3 was chosen.

Results:

Plots of deflection and angle of twist for the two chassis (single rail and double rail) and three chassis crosssection profiles were produced. The results were presented in a readily usable form as shown in Fig. 2 to Fig. 13. The distribution of loads throughout the chassis also affects its stiffness. Two modes of distribution (typical and uniform) were considered and the resultant effect on deflection and twist angles were also presented.

Conclusion:

Graphs showing variation of deflection and twist angle provides a basis for selection of the best profile fora small low-cost farm tractor chassis were produced. The study showed that the twist angle for the sections examined showed insignificant levels. Therefore, the focus always shall be on deflection. Excessive deflection can be avoided, and safe and stable frame can be selected for tractor weight below 10,000 N. The deflection remains to be decided by the designer, since the working conditions differ from. Under bumpy conditions and harsh working conditions, it is expected that the dynamic factors must be considered. It is estimated that the dynamic loads may reach levels up to 3 times the static loads. Therefore, the maximum load that may be seen can reach 18,000 N. However, the dominant small holding farm conditionis rather light, and the estimated loads may well represent the typical working conditions.

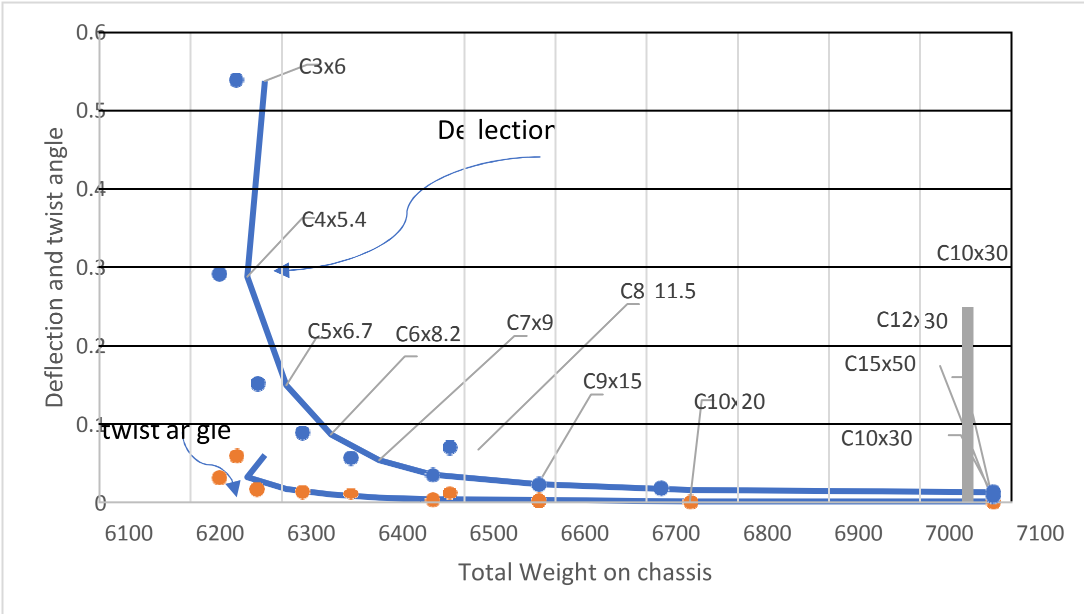

Fig.2: Graph of variation of deflection and twist angle with total weight of tractor for the C-section andone rail chassis frame under typical tractor total load distribution

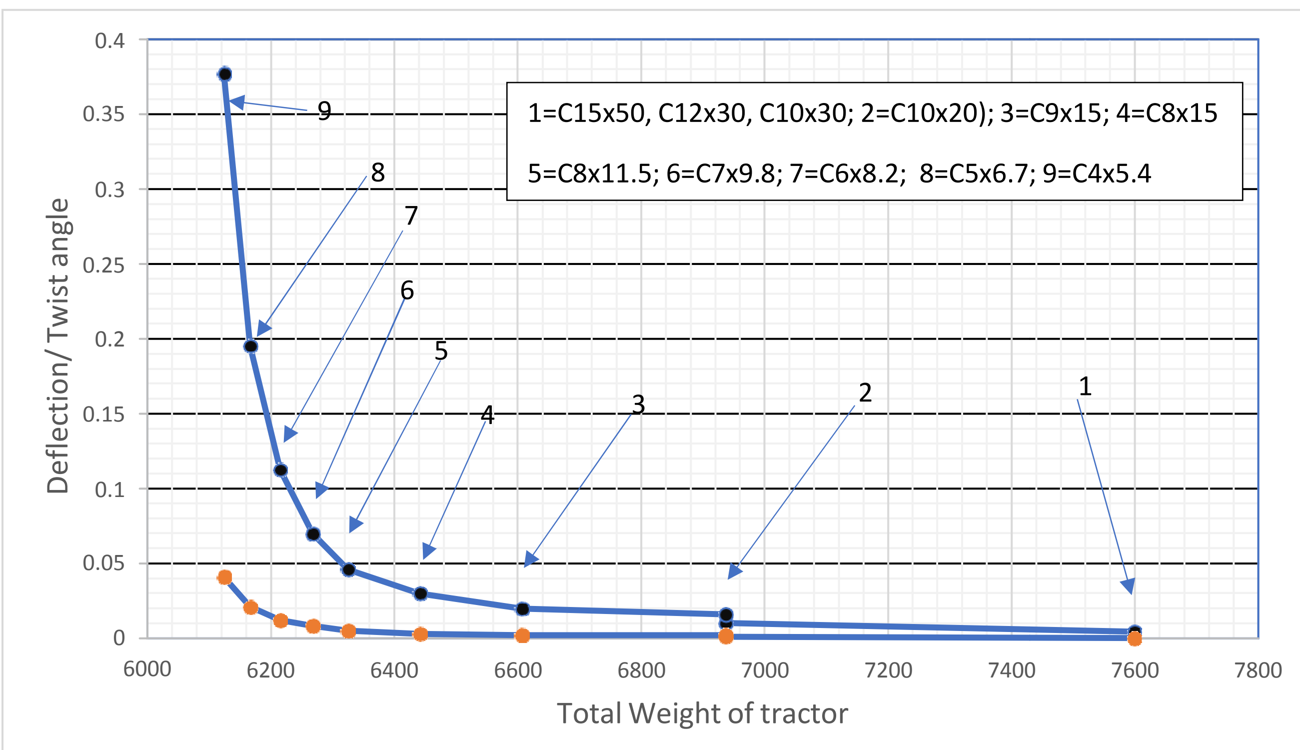

Fig.3: Graph of variation of deflection and twist angle with total weight of tractor for the C-section andone rail chassis frame under uniform tractor total load distribution

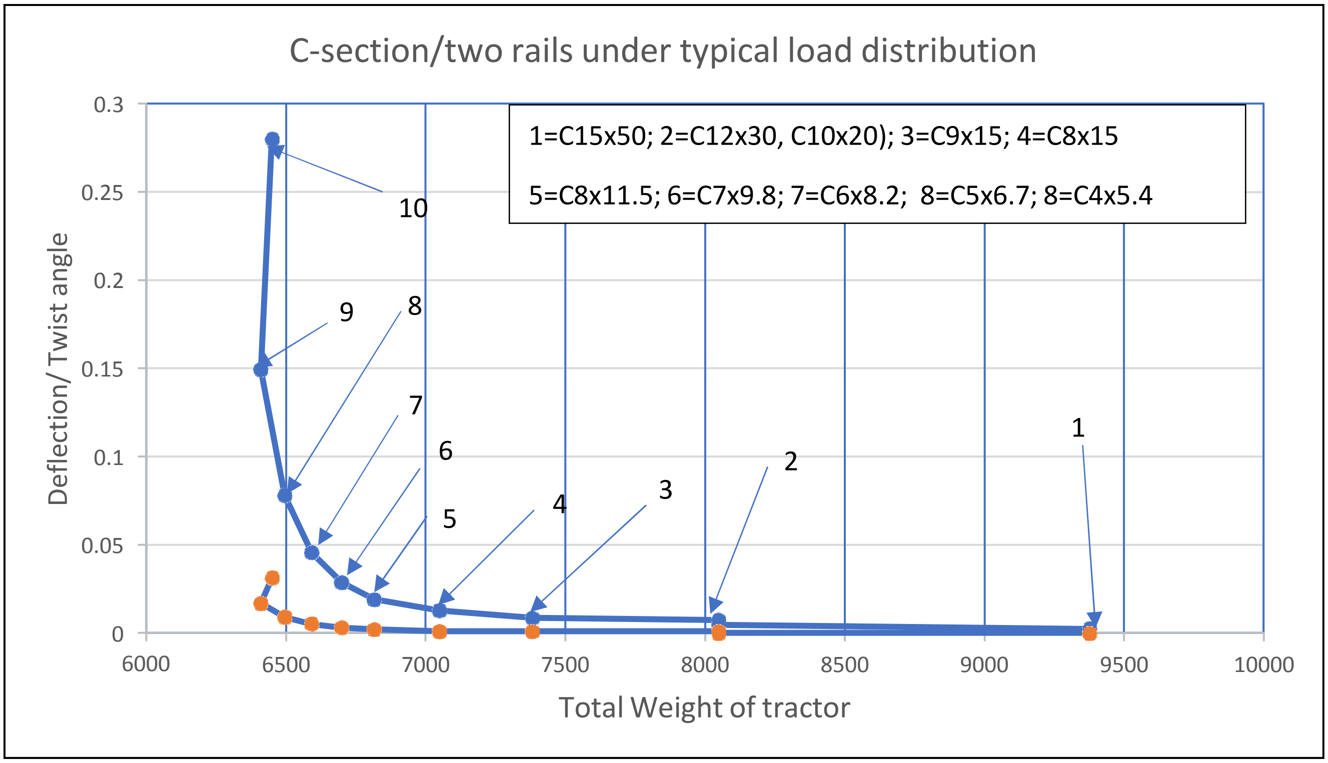

Fig.4: Graph of variation of deflection and twist angle with total weight of tractor for the C-section andtwo rail chassis frame under typical tractor total load distribution

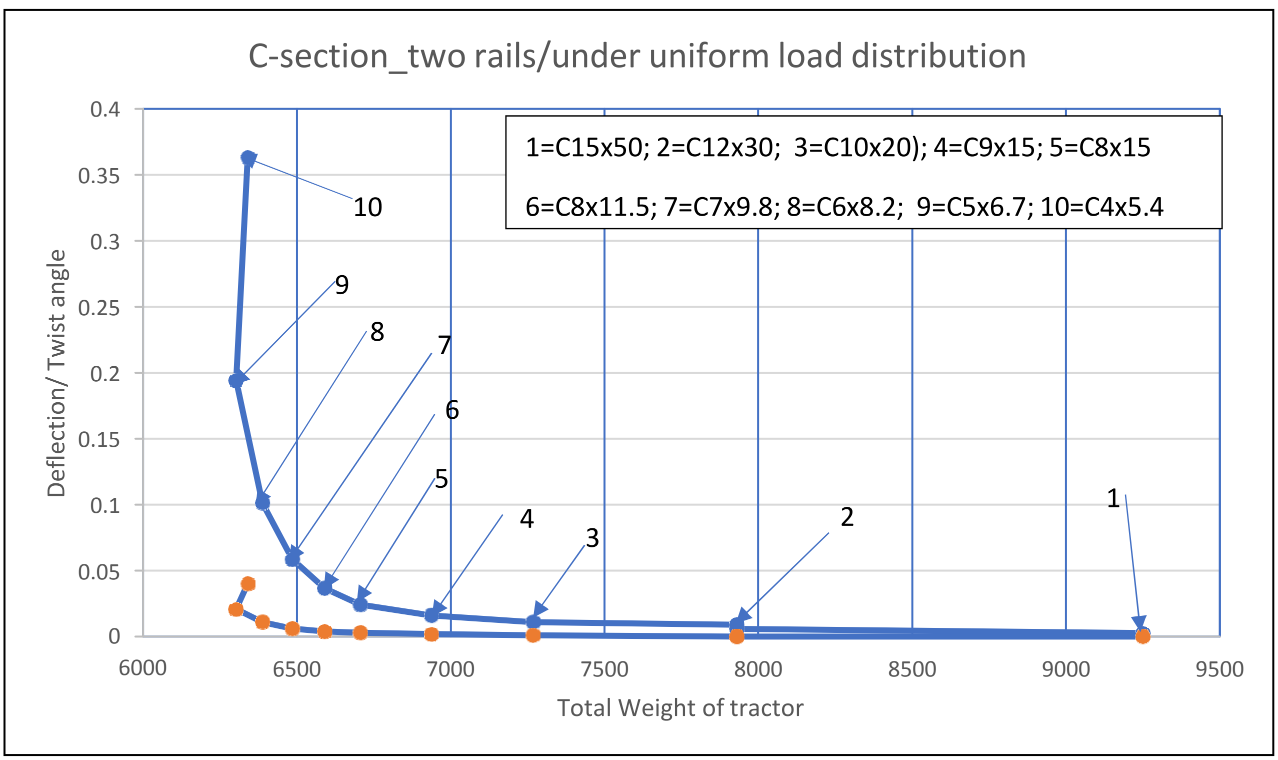

Fig.5: Graph of variation of deflection and twist angle with total weight of tractor for the C-section andtwo rail chassis frame under uniform tractor total load distribution

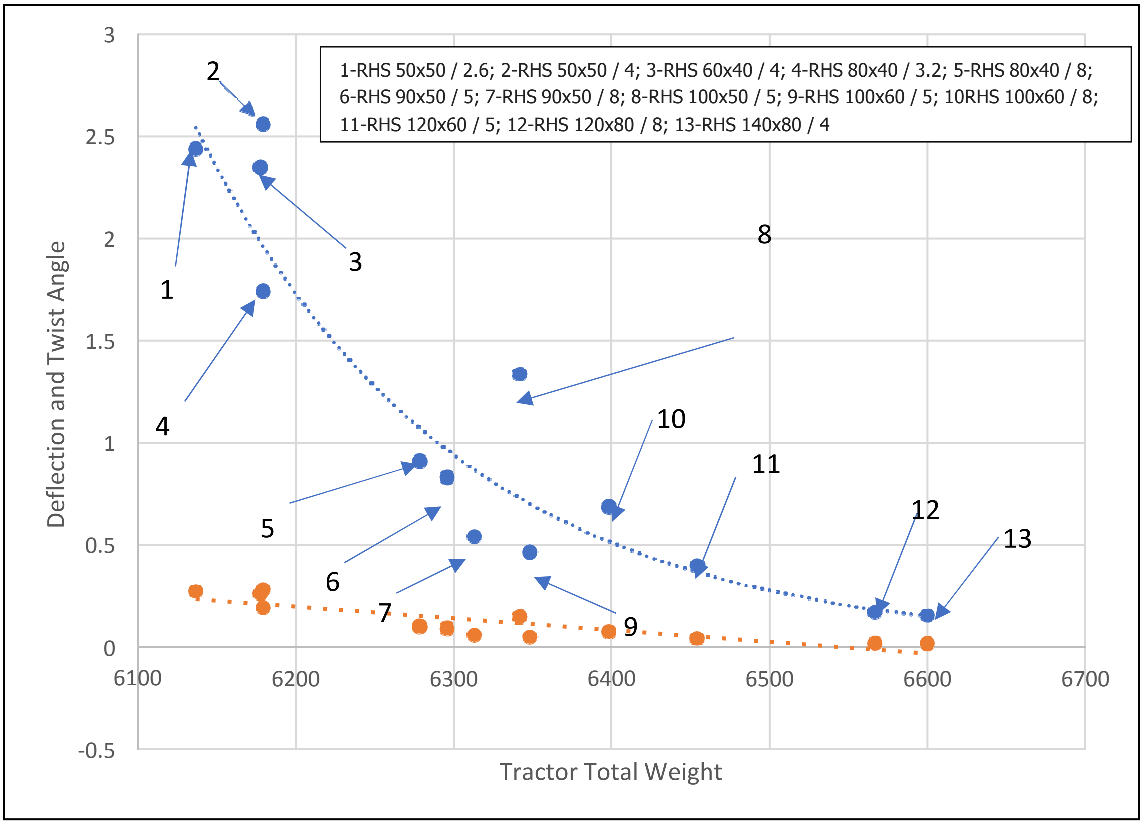

Fig.6: Graph of variation of deflection and twist angle with total weight of tractor for the rectangular tubesection and one rail chassis frame under typical tractor total load distribution

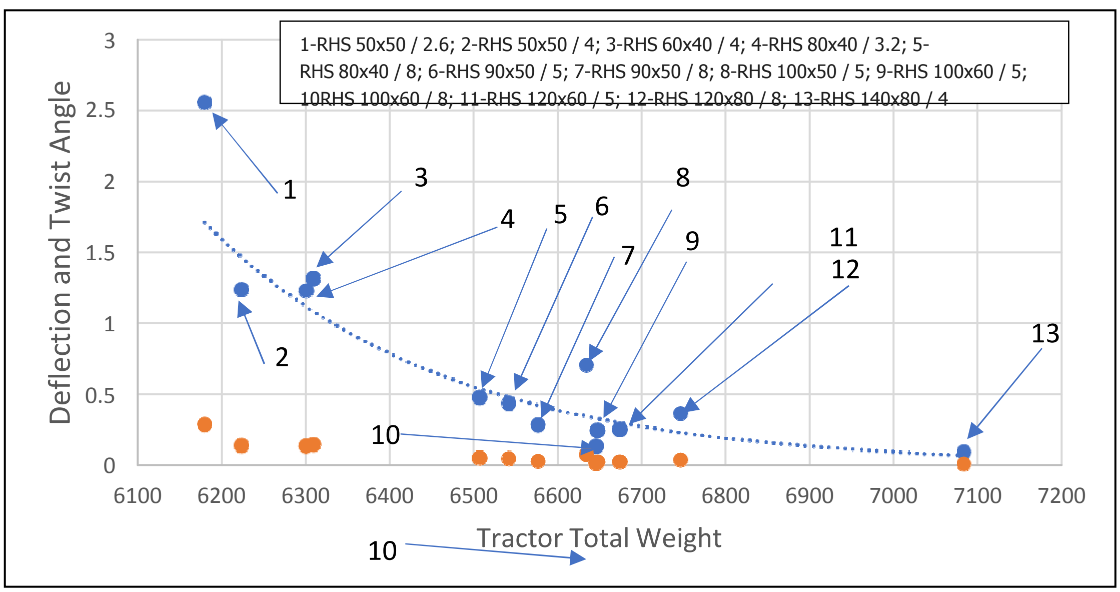

Fig.7: Graph of variation of deflection and twist angle with total weight of tractor for the C-section and two rail chassis frame under typical tractor total load distribution

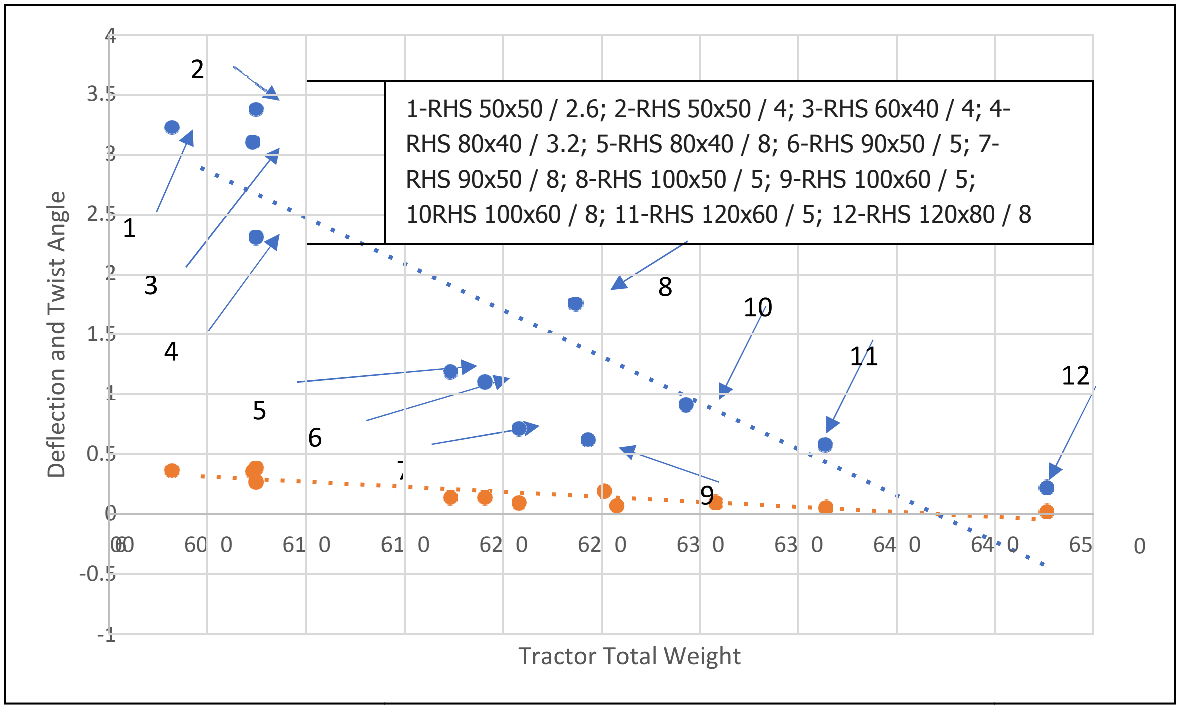

Fig. 8: Graph of variation of deflection and twist angle with total weight of tractor for the rectangularsection profile and one rail chassis frame under uniform tractor total load distribution

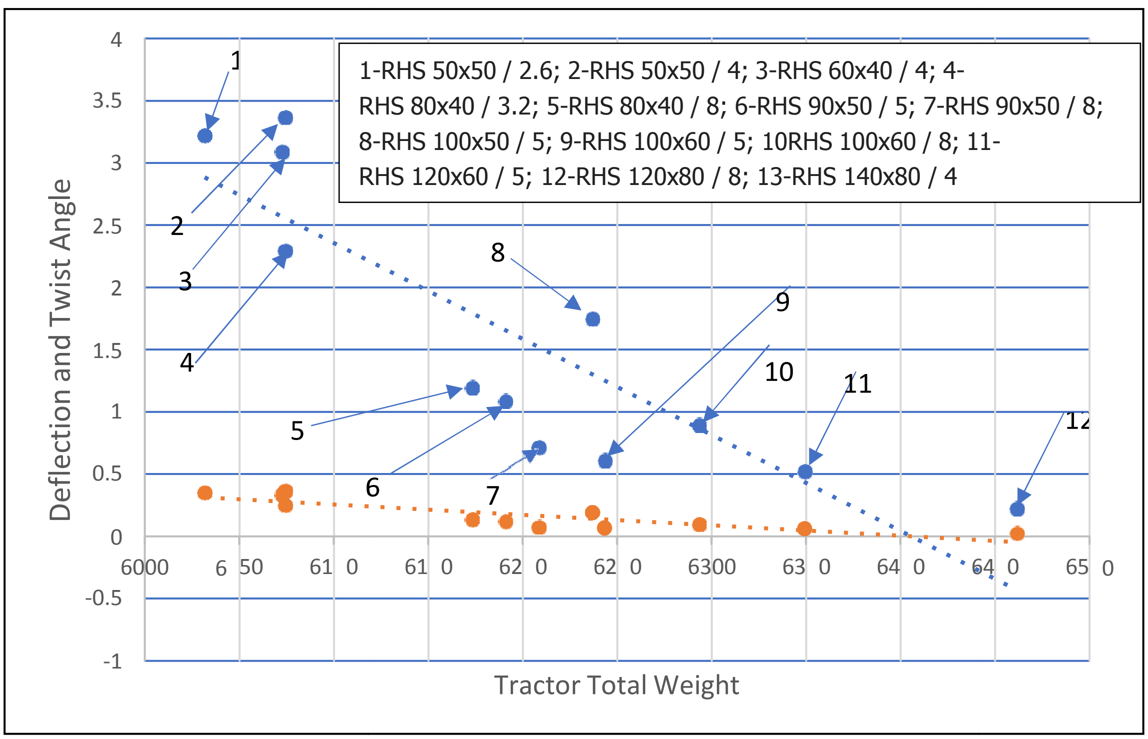

Fig. 9: Graph of variation of deflection and twist angle with total weight of tractor for the rectangularsection profile and two rail chassis frame under uniform tractor total load distribution

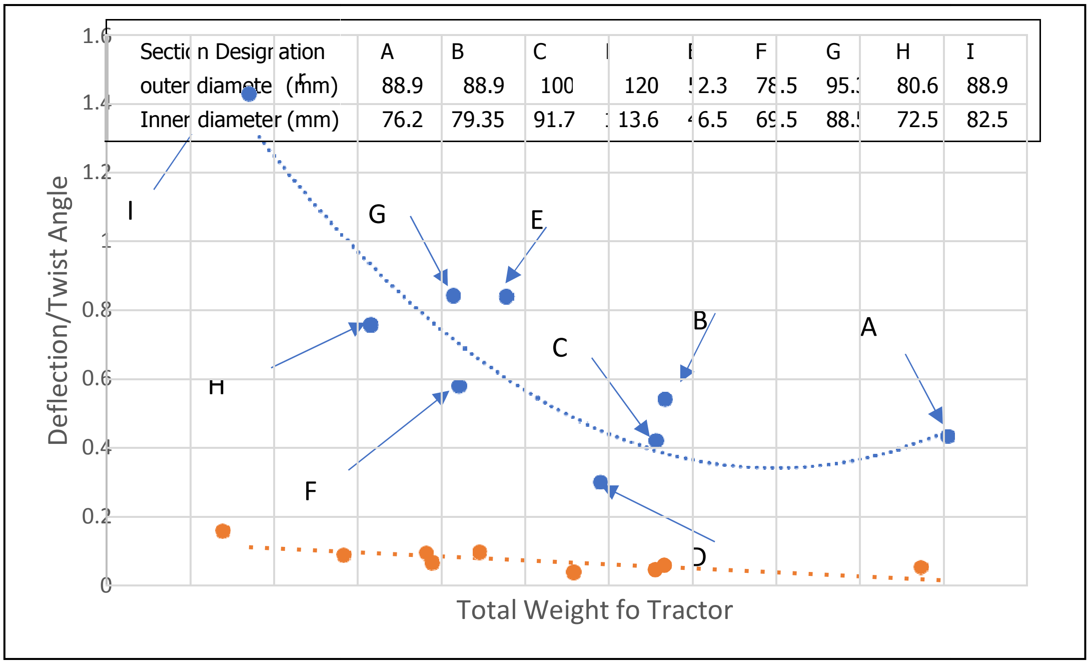

Fig. 10: Graph of variation of deflection and twist angle with total weight of tractor for the tubularsection profile and two rail chassis frame under uniform tractor total load distribution

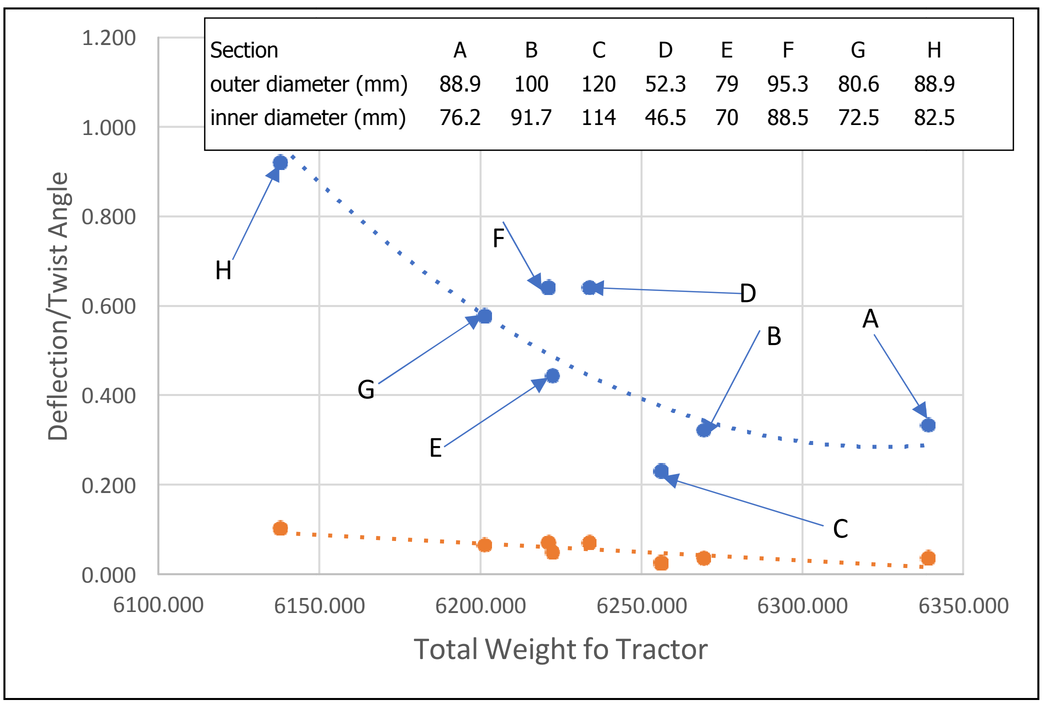

Fig. 11: Graph of variation of deflection and twist angle with total weight of tractor for the tubularsection profile and one rail chassis frame under typical tractor total load distribution

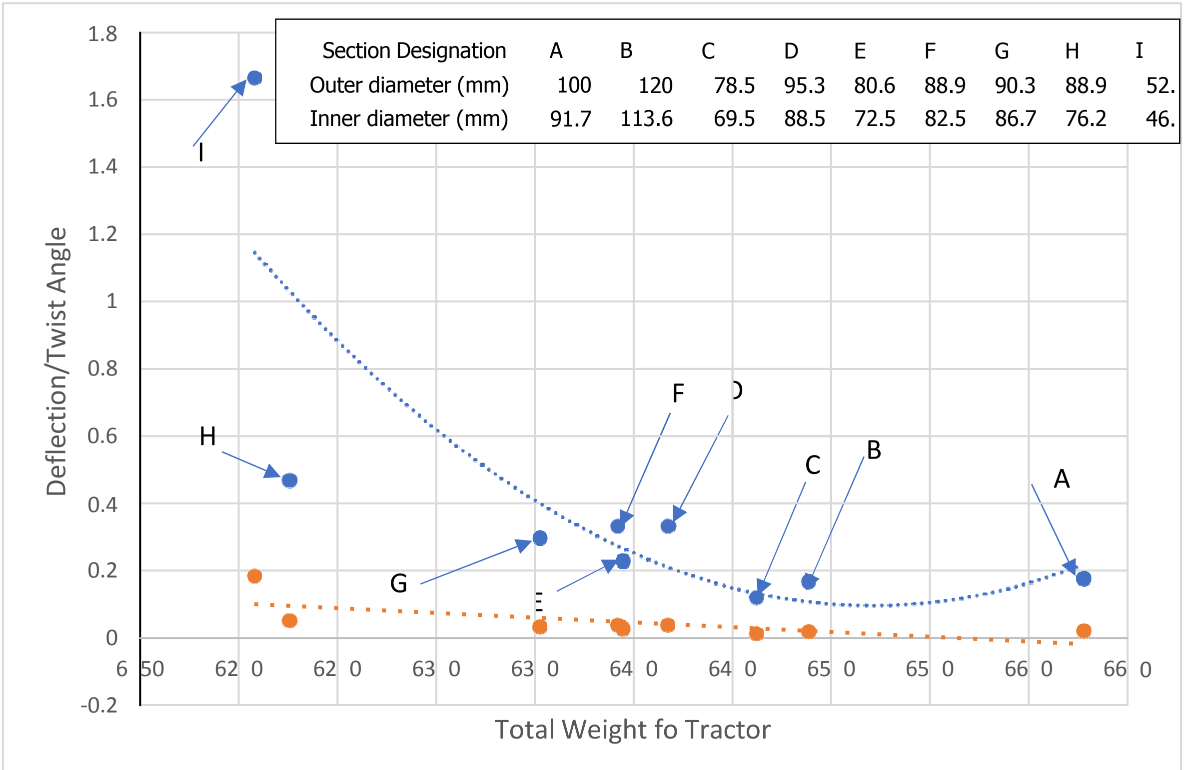

Fig. 12: Graph of variation of deflection and twist angle with total weight of tractor for the tubularsection profile and one rail chassis frame under typical tractor total load distribution

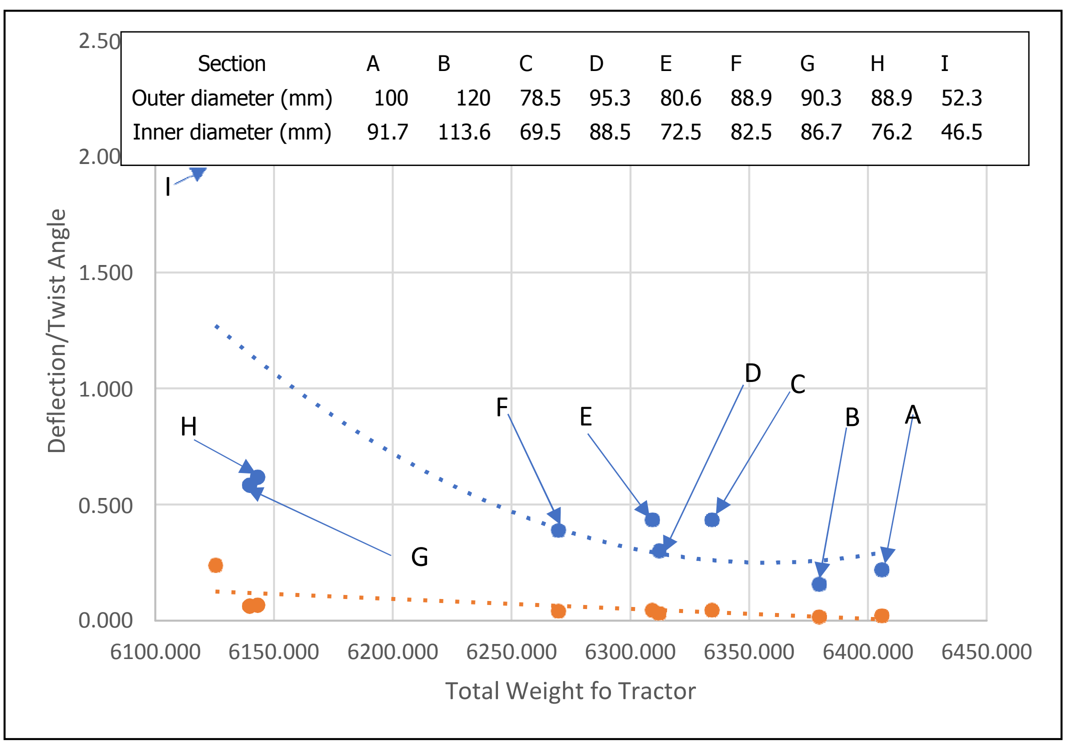

Fig. 13: Graph of variation of deflection and twist angle with total weight of tractor for the tubularsection profile and two rail chassis frame under uniform tractor total load distribution

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