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Design and Analysis of Axle Arm for ARJUN MBT Track Tensioner

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***Abstract*—This project focus on design and developing armored fighting vehicles such as ARJUN MBT, Mk-1, Mk-2, BLT-72 etc at CVRDE, Avadi. The ARJUN MBT Mk-2 is a state-of-art weapon system having superior fire power, invincible armor protection and excellent mobility. The ARJUN MBT Mk-2 is fitted with advanced Running Gears (RG) and suspension systems. Inline with the latest configurationally requirement of RG systems and to cater for higher loading conditions, a suitable track tensioner has been under development. The axle arm is one of the critical members in the actuator mechanism working under principle of slider crank mechanism, has been designed and developed as a forged integral piece. Being is a new development; a rigorous stress analysis has been taken up as scope of this particular project work. The design of integral axle arm will be evaluated both analytical and FEA methods, in addition to estimation of fatigue life.**

***Keywords*-- Tractive force; Resultant force; FEA; Fatigue life.**

I. INTRODUCTION

The **Arjun** MBT is a third generation main battle tank developed by India's Defense Research and Development Organization (DRDO), for the Indian Army. The pictorial representation of arjun MBT is shown in fig.1.

a. Specifications

The **Arjun** features a 120 mm main rifled gun with indigenously developed APFSDS ammunition, one 7.62 mm coaxial machine gun, and a 12.7 mm machine gun. It is powered by a single MTU multi-fuel diesel engine rated at 1,400 hp, and can achieve a maximum speed of 70 km/h (43 mph) and a cross-country speed of 40 km/h (25 mph). It has a four-man crew: commander, gunner, loader and driver. Automatic fire detection and suppression, and NBC protection systems are included. All-round anti-tank warhead protection by the newly developed Kanchan armour is claimed to be much higher than available in comparable third generation tanks. Weighing in at 58.5 tons.

b. Fire control and protection

Armed with a 120 mm rifled gun, the Arjun is believed to be capable of firing APFSDS (Kinetic Energy) rounds, HE, HEAT, High Explosive Squash Head (HESH) rounds at the rate of 6-8 rounds per minute and the Israeli developed semi-active laser guided LAHAT missile. The LAHAT is a gun-launched missile and is designed to defeat both enemy armour and enemy combat helicopters. In addition, the Arjun is armed with a 12.7 mm AA machine gun and a 7.62 mm coaxial machine gun. The Arjun can carry 39 rounds in special blast-proof canisters. The Arjun uses a manual loader and has a crewman to reload the gun. The turret and glacis are heavily armoured and use "Kanchan" (*"gold"*) modular composite armour. A new honeycomb design non-explosive and non-energetic reactive armour (NERA) armour is reportedly being tested on the Arjun. Nuclear, biological and chemical (NBC) protection equipment mine sweeps and an automatic fire fighting system. Electromagnetic-counter mine system can also be installed an electromagnetic pulse to disable magnetic mines and disrupt electronics before the tank reaches them signature reduction suite is also available for the is designed to reduce the probabilities of an object to be detected by Infrared, Thermal, Radar-Thermal, and Radar bands.[39]electro-optical/IR "dazzlers" Laser warning receivers, aerosol grenade discharging systems and a computerized control system. The tank has been 'painted' by a weapon-guidance laser and allows the crew to slew the turret to face the threat.

c. Mobility

The engine and transmission are provided by German companies MTU and RENK respectively. The water-cooled engine generates **1,400 hp** and is integrated with an Indian turbocharger and epicyclic train gearbox with **four forward and two reverse gears.**A local transmission is under trials and it is envisioned to ultimately replace the Renk-supplied unit.

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The tracks which were being supplied by German company Diehl are now being manufactured by L&T. The cooling pack has been designed for desert operations. The Arjun has a lower ground pressure than the lighter T-72, due to its design.

The Arjun features a hydro-pneumatic suspension. This coupled with the Arjun's stabilisation and fire control system allows the tank excellent first-hit probability against moving targets while on the move. Its ride comfort is highly praised. Though on the negative side, it is a more maintenance-intensive and expensive system, even if more capable than the simpler and cheaper torsion bar system utilised on many older tanks worldwide. During trials, the Arjun showcased its fording capability, by driving under six feet of water for 20 minutes.

d. Arjun Mk-II

The Arjun Mark II will have a total of 93 upgrades, including 13 major improvements. The major upgrades would be missile-firing capability against long-range targets, panoramic sight with night vision to engage targets effectively at night, containerization of the ammunition, enhanced main weapon penetration; additional ammunition types, explosive reactive armor, an advanced air-defense gun to engage helicopters; a mine plough, an advanced land navigation system and a warning system which can fire smoke grenades to confuse laser guidance. Other upgrades are an enhanced Auxiliary power unit providing 8.5 kW (from 4.5 kW) and an improved gun barrel, changes in the commander's panoramic sight with eye safe LRF, night vision capability including for driver, digital control harness, new final drive, track and sprocket.

e. Running gear

The term **running gear** is used to describe the wheels, suspension, steering, power train & chassis/body shell of a motor-car or automobile, or the tracks and road wheels of a tank or similar tracked vehicle.

The running gear system of a tank comprises of the following assemblies:

(a) Track
(b) Sprocket
(c) Road wheels
(d) Idler wheel
(e) Twin top roller
(f) Track adjuster
(g) Suspension

f. Track

The track has 85 track blocks/links on each side. The track is wrapped over the sprocket at the rear end, supported by twin top rollers in the middle and by the track adjuster in the front. The track shoes provide the necessary attractive effort to keep the tank moving. The road wheels mounted on the Hydro-Pneumatic Suspension Unit (HSU) keep the track in contact with the ground. The track block assembly is a steel cast block, having a central and integral guide horn. It has two holes into which rubberized track pins are inserted. Two rubber pads are inserted into the bottom groove of the track block and secured by the grooves.

g. Sprocket

The sprocket is a multi toothed steel ring. It transmits the torque from the power train to the track. Two sprockets are mounted on drums using high tensile hexagonal bolts and corrugated washers. The bolts are tightened to a torque value of 75 kg-m. The drums fitted with the sprockets are mounted on either side of the final drive assembly which is in turn mounted on either side of the hull.

h. Road wheels

The road wheels support the vehicle and transmit the ground reaction load on the tank to the suspension system. This ensures a smooth ride with less noise. The road wheels have a rubberised layer over a light aluminium alloy rim. There are a total of 28 wheels mounted on the MBT. Two wheels are mounted on each HSU and they are driven by the track. Four more wheels are mounted, two wheels on each side of the track adjuster units to support the track at the front of the vehicle.

i. Idler wheel

The idler wheel is a machined aluminum road wheel which has a layer of rubber on its outer surface. An anti-wear ring is press-fitted on the face of the wheel to prevent abrasive wear against the track guide horn. The idler wheels mounted on the track adjuster units have 24 holes for mounting (as compared to wheels fitted on HSUs which have 18 holes).

j. Fire control and protection

Armed with a 120 mm rifled gun, the Arjun is believed to be capable of firing APFSDS (Kinetic Energy) rounds, HE, HEAT, High Explosive Squash Head (HESH) rounds at the rate of 6-8 rounds per minute and the Israeli developed semi-active laser guided LAHAT missile. The LAHAT is a gun-launched missile and is designed to defeat both enemy armour and enemy combat helicopters.

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The position of Track Adjuster and the AHSU Ist station when the vehicle is on a bumpThe axle-arm is to be examined for its strength at the resisting area for the given loading conditions when the vehicle crossing a bump (fig. 3) and at the time of sudden breaking condition

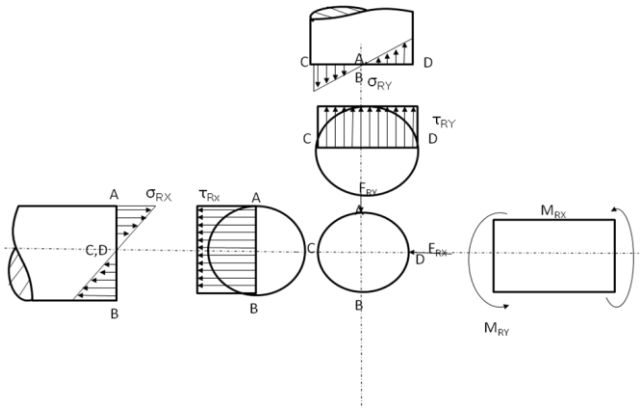

Table 1
Stress at identified locations

		Locations			
	Stress in (MPa)	A	B	C	D
Normal stress	σ_{RY}	121.304 (Z)	-121.304 (Z)	0	0
	σ_{RX}	0	0	409.924 (X)	-409.9924 (X)
	σ_{Res}	121.304	121.304	409.9924	409.9924
Tangential stress	τ_{RX}	28.5847 (X)	28.5847 (X)	28.5847 (X)	28.5847 (X)
	τ_{RY}	8.467 (Y)	8.467 (Y)	8.467 (Y)	8.467 (Y)
	τ_{Res}	29.812	29.812	29.812	29.812
Principal stress	σ_1 max	128.22	128.22	412.146	412.146
	σ_2 min	6.918	-6.918	-2.154	-2.154

Bending stress due to F_{RY}

$$\sigma_{FRy} = \frac{M}{Z}$$

M = bending moment due to F_{RY}

$$M = F_{RY} \times L_1$$

$$L_1 = 0.227\text{m}$$

$$= 104.9931 \times 10^3 \times 0.227$$

$$M = 23.8334 \times 10^3 \text{ Nm}$$

$$Z = \frac{\pi}{32} \times d1^3$$

$$D = 0.126\text{m}$$

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$$Z = \frac{3.14}{32} \times (0.126)^3$$

$$= 1.9628 \times 10^{-4} m^3$$

$$= \frac{23.8334 \times 10^3}{1.9628 \times 10^{-4}}$$

$$= 121425.514 \times 10^3 N/m^2$$

$$\sigma_{FRy} = 121.304 MPa$$

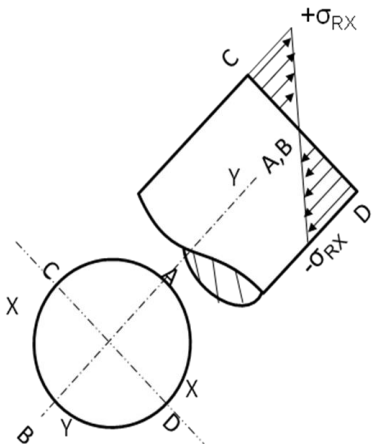

Fig 1. Schematic representation of bending

Direct Shear Stress Due To F_{ry}

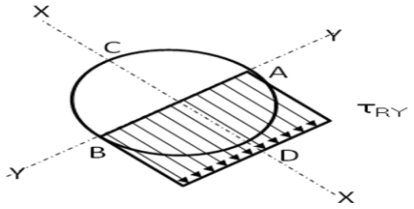

Fig 2 Schematic representation of direct shear stress

$$\tau_{FRy} = \frac{FRY}{A}$$

$$F_{RY} = 104.9931 \times 10^3$$

$$A = \frac{\pi}{4} \times d_1^2 = \frac{\pi}{4} \times (0.126)^2$$

$$A = 0.124\, mm^2$$

$$= \frac{104.9931 \times 10^3}{0.0124}$$

$$\tau_{FRy} = 8.467 MPa$$

Bending stress due to FRx

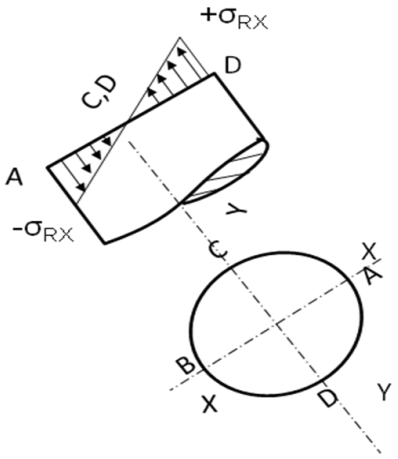

Fig 3 Cross section of bending stress acting on stub axle

$$\sigma_{FRx} = \frac{M_{FRx}}{Z_1}$$

M_{FRX} = bending moment due to F_{Rx}

$$M_{FRx} = 354.4508 \times 10^3 \times 0.227$$

$$= 80.460 \times 10^3 \text{ Nm}$$

$$Z = \frac{3.14}{32} \times d^3$$

$$Z = 1.9628 \times 10^{-4}$$

$$\sigma_{FRx} = \frac{80.460 \times 10^3}{1.9628 \times 10^{-4}}$$

$$\sigma_{FRx} = 409.9924 MPa$$

Direct Shear stress due to FRX

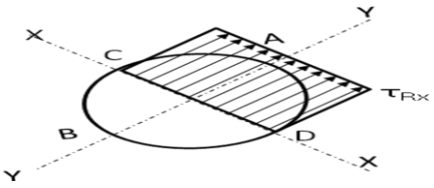

Fig 4 Cross section of the shear stress acting on the stub axle.

$$\tau_{FRx} = \frac{FRX}{A}$$

$$F_{RX} = 354.4508 \times 10^3 N$$

$$A = \frac{3.14}{4} \times (0.126)^2$$

$$A = 0.0124\, m^2$$

$$\tau_{FRx} = 28.5847 MPa$$

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II. Results And Discussion

a. Existing configuration:-

In Arjun MBT MK-I the running gear consists of suspension system in this system one of the critical patrt AXLE ARM which was made by two piece configuration i.e one part is crank pin and another part is arm with stub axle .that two piece is made into single piece by joining with following methods.

- Liquid nitrogen Shrink fit
- Welding
- dowel pin

Problems faced (disadvantages):-

- *Shrink fitting*

With liquid nitrogen shrink fitting the necessary clearance is obtained by shrinking the inner component (instead of expanding the outer one).this is achieved by immersing the inner component warms up ,expanding to form a tight distortion free interference fit.

Due to this a lot time is needed and failure may be occur.

- *Welding*

Welding failures occur because of overstress, corrosive environments, misuse, abuse, and from defective welds and/or welding.

- *dowel pin*

In dowel pin the failure may be occur due to the load acts on the axle arm the pin get broken and failure of design takes place.

b. Approach

Suggested method:-

We interested to do project in this area in order to avoid the above problem after the various study we suggested to make two piece component into single piece component by using one of the best manufacturing methods forging and made the integral axle arm. It's the single configuration method.

c. Problem solved :-

- There is no requirement of of welding .
- There is no requirement of shrink fit.
- Crank pin is not required.

We approach the strength adequacy of the newly designed component both analytically and by FEA method.

We found that the maximum von misses stress **413.272 MPa receiving** at the stub axle/axle arm/crank pin of integral axel arm.

The factor of safety found to be **1.9372**

In the FEA though a higher stress value is found in a certain area it may be ignored owing to the sharp corner feature present in those location .however the stresses on the critical locations are within the safe limit.

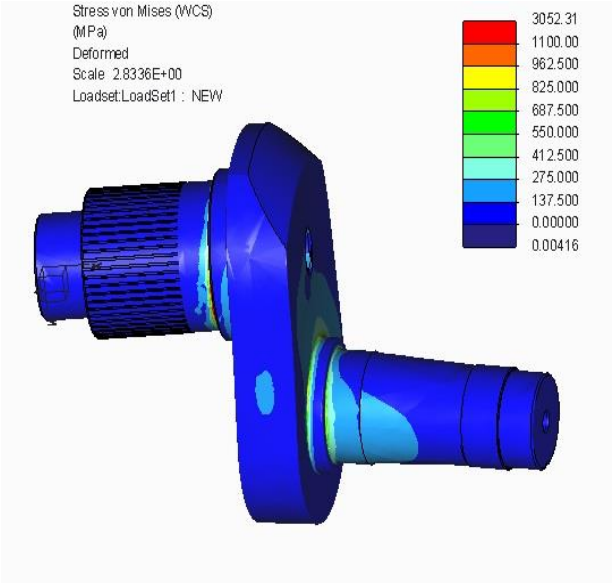

Fig 5 Integral Axle Arm Model

Table 2
Stress for identified locations

		Locations			
	Stress in (MPa)	A	B	C	D
Normal stress	σ_{FRX}	209.2389 (X)	209.2389 (X)	209.2389 (X)	209.2389 (X)
	σ_{FRX}	127.73454(Z)	-127.7345 (Z)	0	0
	σ_{FRY}	0	0	25.004 (Z)	-25.004 (Z)
	σ_{Res}	245.146	245.146	210.72	210.72
	σ_{Res}	210.72	210.72	210.72	210.72
Tangential stress	τ_{RY}	61.9793 (Y)	61.9793 (Y)	61.9793 (Y)	61.9793 (Y)
	τ_{RY1}	115.5322 (C.W)	115.5322 (C.W)	115.5322 (C.W)	115.5322 (C.W)
Principal stresses	τ_{RY}	131.107	131.107	131.107	131.107
	σ_1 max	302.04	302.04	273.55	273.55
	σ_2 min	-56.9	-56.9	-62.83	-62.83

III. CONCLUSION

In this Mk-ll integral axle arm, has been manufactured as a single component, will withstand heavy loads in off-road running condition. We analyzed integral axle arm using ansys, and find out maximum principle stress, factor of safety and frequency cycles are within safe values of the material. Hence the design is safe.

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