Design of Whip Test System for S.S Brake Hose Fatigue Testing and Analysis of Critical Component Whip Test System

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Abstract: Brake hose is one of the components in breaking system which create a flexible connection between brake pipes and wheel brakes. They transmit the hydraulic pressure to the wheel cylinders and brake calipers. Brake hose made of sheathed in steel braiding (braided stainless steel brake hoses). These types of brake hose have long service life. As braided stainless steel brake hoses also expand less even at increased brake pressure, the pressure point at the brake pedal is also more exact and braking can be done more precisely. When the driver presses the brake pedal, hydraulic pressure is generated in the master brake cylinder. So that a braking force is produced from this, the hydraulic pressure is transmitted to the wheel brakes with the assistance of the brake fluid. In motor vehicles, this happens via the brake linings. High-pressure braking hose in the automobile power braking system undergoes the complicated large deformation cyclic motion during the driver's steering operation and the up and down motion of vehicle, so that the fatigue damage becomes accumulated in proportional to the cycle number. Since the occurrence of fatigue-induced micro crack in the braking hose may cause the oil leakage, the fatigue life assessment becomes the most important task in the design of high-durable braking hose. So the Whip test system designed to measure the fatigue life of the brake hose assembly.

***Keywords* – Base frame modal analysis; Connecting plate; Brake hose; Master cylinder.**

1. INTRODUCTION

Hydraulic S.S brake hose is flexible conduit manufactured for use in a brake system to transmit and to contain the fluid pressure medium used to apply force to the vehicle brakes. it has end fittings to mount it in the hydraulic line.

The whip test is designed to measure the fatigue life of the hose assembly. The flexible action imparted by the test system with help of rotating head and provides a highly accelerated method of measuring the resistance of a hose to dynamic fatigue. According to IS: 7079-1979 Clause 3.44, the minimum life of S.S brake hose when tested in accordance with free length of brake hose ranging from 200 to 600 mm. For 3.2 mm brake hose diameter, length ranging from 200 to 400 mm. Brake hoses run continuously on whip test system for 35 hr. with 800 rpm.

The main assembly can be divided into:

1. Rotating Head
2. Stationary Head

1. Rotating Head:

The rotating head is basically consists of a 250 mm. nominal diameter of disc, proved with an adaptor fitted in bearing at a distance of $200 \pm 1\ \text{mm}$ diameter. The adaptors are fitted in bearing from dead end for hose mounting. The hoses are able to oscillate in these bearings, thus rotating without any twist. The disc is driven by single V- groove pulleys with standard set of V belts. Drive motor is mounted beneath the in slots to provide belt tensioning.

2. Stationary Head:

The stationary head consists of junction block which is able to slide on the bed and can be fixed at measured distance the stationary ends of hoses are connected to 4 stations of junction block. The four ends of each station consists of

a. Inlet from master cylinder
b. Outlet to hose
c. Connection to pressure gauge and pressure cutouts
d. Air bleed cap

Pressurizing system comprising of with master cylinder and hand lever clamp to generate pressure. Hand pump (to pressurize the hoses up to18 Kg/cm) maximum working pressure is 50 bar.

2. DESIGN OF TEST SETUP

The whip test system is to be designed to carry out the fatigue test on S.S Brake hose. Key points to be met as per customers' need and system requirements are as follows:

- The Brake hose are rotated with 800 rpm
- Pressure in brake hose is 18 bar having 5 mm diameter attached to plate
- Test to be conducted on brake hose : Fatigue Test for 35 hrs (for 17 million cycles)

Design of components:

1. Connecting Plate

Rotating end of brake hose is attached on connecting plate so Load exerted by Brake hose = Pressure in the brake hose × Area of brake hose. Load exerted by two rotating brake hose is 72 KN including factor safety 2. Plate dimensions are decided by satisfying deflection, maximum von mises stress criteria.

2. Torque on Disc

Diameter of disc is 250 mm as per standard. Considering the thickness of disc is 1 cm as per bearing and deformation constraints. Torque acting on two rotating disc about 1.5 N-m. considering the 5 sec required for achieving 800 rpm, torque is calculated from below formula

$$T_d = I_d \alpha \qquad 1$$
$$= \frac{I_d (w_2 - w_1)}{t}$$

3. Diameter of Pin

Pin used to connect disc and plate. The pin is subjected to shear stress and bending stresses. Therefore, Strength is also criterion for material selection of pin. On strength basis, the material for pin is selected as plain carbon steel of grade 30C8 $S_{yt} = 400 \ N/mm^2$

Failure due to Bending:

$$\sigma_b = \frac{32M_b}{\pi d^3} = \frac{32F_R \times L_P}{\pi d_{pin}^3} \approx 15 \text{ mm}$$

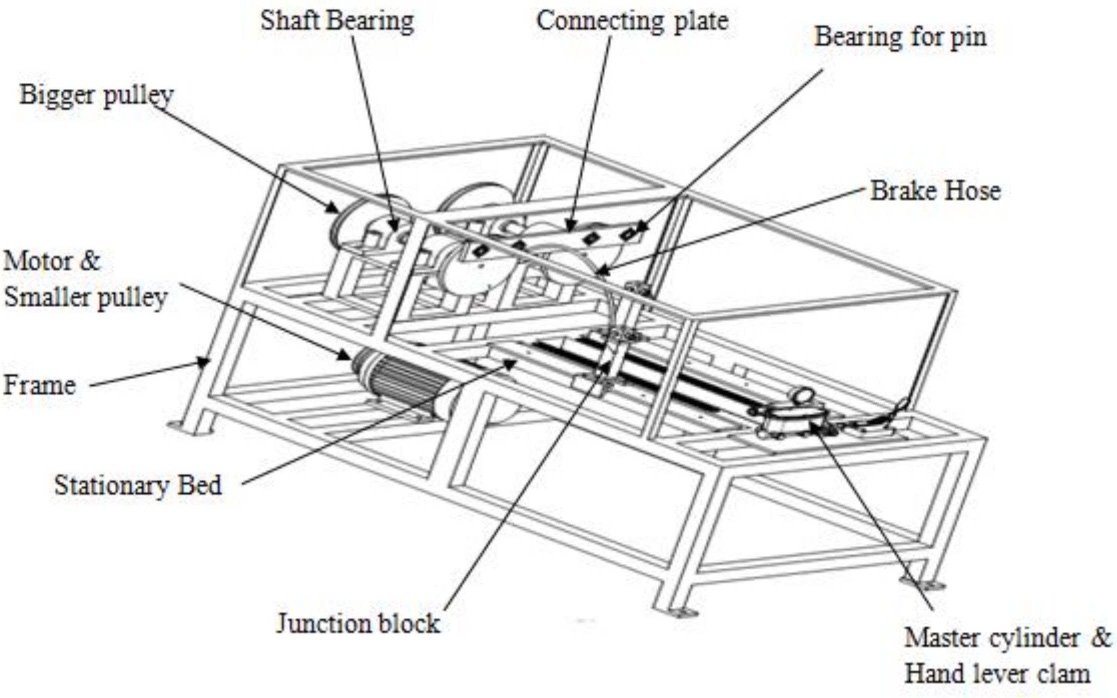


Figure 2.1 Schematic diagram of Test Setup

4. Design of Shaft

On strength basis, the material for shaft is selected as plain carbon steel of grade 30C8 $(S_{yt} = 400 \ N/mm^2)$

Length of shaft considered as 38 cm. assuming it is cantilever beam, disc weight, half plate weight, balancing weight are acted on other end of cantilever beam. Maximum moment of inertia of cantilever $M_1 = F \times L_r$ and moment due pin reaction $M_2 = F_r \times r_e$.

$$t_{\max} = \frac{16}{\pi d_{rod}^3}\left[\sqrt{M_e^2 + T_e^2}\right] \approx 10 \text{ mm}$$

Considering factor of safety 3.5, So diameter of rod becomes $d_{rod} = 1 \times 3.5 = 3.5$ cm.

Key on shaft is design as per standard calculations.

5. Motor Power

Considering factor of safety 2, Torque= 3 N-m, Power is calculated $P = \frac{2\pi N T_d}{60} \approx .24$ kW

Power in HP with 80% efficiency = 0.4 HP

Pulleys are designed as per standard calculations and V belt selected as per standard chart.

6. Selection of Bearing

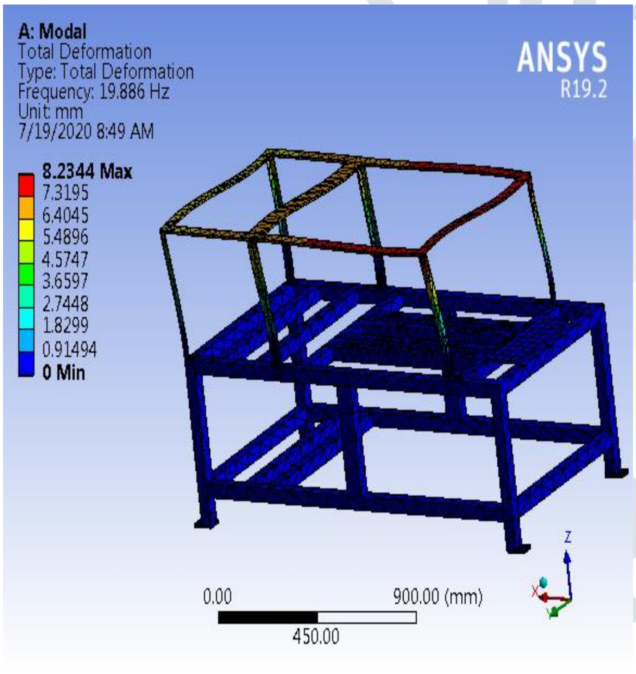
Bearings are selected as per standard calculations.

Load on Bearing in N	Bearing Number	Application at	Dynamic load capacity, C (N)	d × D × B (mm)	Million Rev.
112.5	61806	Shaft	5590	15 × 32 × 9	480
630	6002	Pin	4933	45 × 100 × 25	480

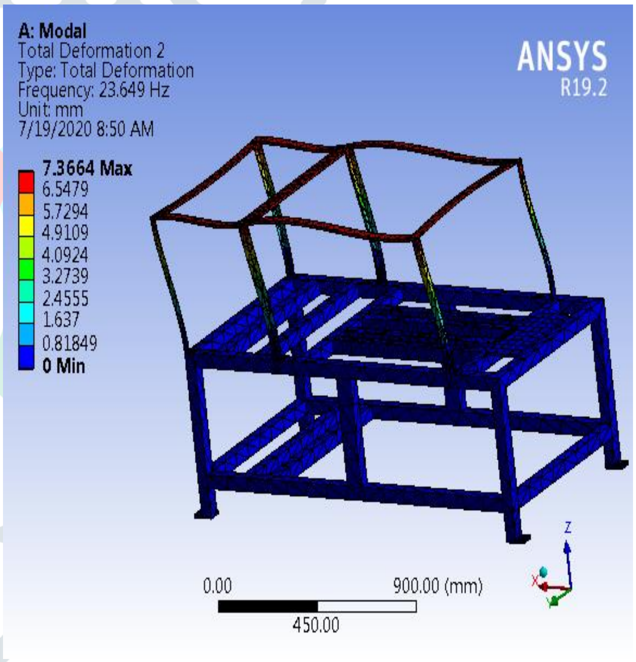
Table 2.1 Specifications of bearings

3. MODAL ANALYSIS OF BASE FRAME OF WHIP TEST SYSTEM

The entire assembly of test setup is going to mount on the base frame. Thus, modal analysis of base frame is necessary. The modal analysis of the base frame is done using ABAQUS 6.14.1. The tetrahedral quadratic elements C3D10M element is used. It was found that the solution gets converged for mesh size of 8mm.



(a) Mode 1



(b) Mode 2

Fig. 4.5 Modal analysis of Whip test base frame.

The first natural frequency (Mode1) obtained in this simulation 19.886 Hz i.e. 1193.16 rpm which is well above the operating frequency of the frame which is 800 rpm. Thus, the frame design safe for use.

4. ANALYSIS OF CRITICAL PARTS

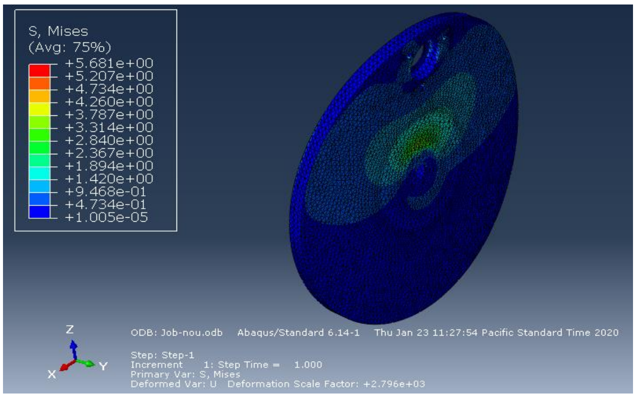


Figure 4.1 Analysis of disc

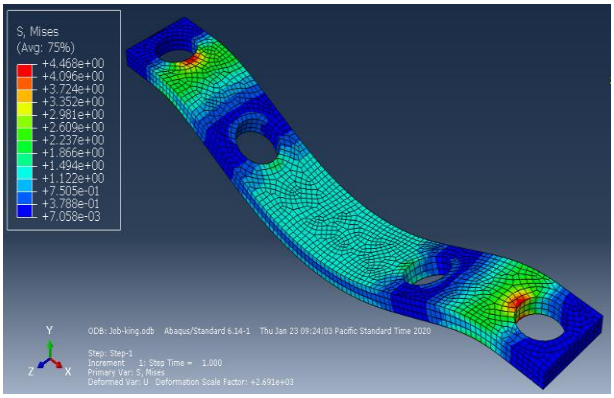


Figure 4.2 Analysis of connecting plate

5. ANALYSIS RESULTS OF CRITICAL PARTS

COMPONENT TYPE	MAXIMUM VON MISES STRESS	MAXIMUM DEFLECTION
Disc	6 MPa	10 micron
Connecting plate	5 MPa	15 micron

Table 5.1 Analysis result of critical parts

6. CONCLUSION

As per the requirement of firm that is as per design inputs given by firm, the whip test system is designed to test fatigue life of S.S brake hose for 800 rpm for 35 hr. Designed components whip test system are connecting plate, connecting pin, disc, shaft, pulley, bearing etc, as per standard calculations.

These designed components are modeled in cad software and analysis of main components like connecting plate and disc are done. It is observed, the maximum von mises stresses and deformation for designed component are significantly less but due to deflection constraints and other design constraints we have design the components according to design calculations. Modal analysis of base frame of whip test system shows The first natural frequency (Mode1) obtained in this simulation is well above the operating frequency of the frame. Thus, these frame design safe for use.

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