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Diesel Locomotive Cockpit - Exploring Ergonomic Problems and Some Design Solutions

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***Abstract*—Diesel locomotive has always been considered as a prime mode of transport especially for the rail road industry. So, the ergonomic design of the cockpit is very much the necessity at this juncture. An ergonomic cockpit is required so that the locomotive pilot can sustain under extreme circumstances. In this paper, the prime focus has been on designing the driver's seat and control panel of the WDP_4 model, which is widely used in Eastern Railway, Howrah division. Existing model of the control panel with the chair was modeled after taking actual field measurements. Using RULA as the prime parameter for comfort of the locomotive pilot, a suggestive control panel with the chair was developed with a lower score. The analysis had been conducted using CATIA V5 R18 software. Designed for convenience, this approach mainly redefines the concept of design for human use. The goal of this paper is to design and suggest a safe and sound ergonomic control panel of WDP_4 diesel locomotive that would be helpful for a wide range of Indian drivers**

Keywords— Cockpit; Control panel; Diesel locomotive; Pilots.

I. INTRODUCTION

The Safety and Ergonomics of the cockpit of any transport vehicle is vital. The vehicle controls should always be strategically placed, i.e., the driver or the pilot should not face any kind of difficulty in operating the vehicle. In extreme scenarios, which can be noticed in India, if the controls are not easily accessed, the safety of the vehicle could be in jeopardy. In some cases, even though the controls are readily accessible, but after continuous operating of the vehicle, the driver complains of musculoskeletal disorder related issues. So, the design of any control panel is very challenging. The interface between man and machine is accomplished inside the cockpit, and especially for the rail road industry, it is very much essential to look after the human related factors while designing the control panel.

Now-a-days what is important is to design ergonomically or more appropriately we can say "Design for the Pilots". As improper work environment may cause not only physical problems to the pilots but also may induce several psycho-physical problems. Fatigue can also be induced due to poor working environment, other than due to irregular scheduling, which is further related to safety and harmony. Therefore a sound working environment coupled with comfort, is very much the necessity.

Most of the researches about locomotive are going on in the field of Fatigue related to safety like Dorrian, Roach, Fletcher, Dawson [1], Paterson, Dorrian, Clarkson, Darwent and Ferguson [2], Ku and Smith [3], Akerstedt and Landstrom [4]. All of them have described how fatigue could be a crucial factor for the safety of the railways. Another area which has also been a matter of importance is the Vibration Control as it has been described by Johanning, Fischer, Christ, Gores & Landsbergis [5] in which they have determined the whole-body vibration exposure of locomotive engineers in United States, Tiemessen, Hulshof and Frings-Dresen [6] have described about musculoskeletal disorders caused due to whole-body vibration exposure, Stein, Mucka, Gunston and Badura [7] have described the simulated vertical seat suspension system with a variable damper which can be effectively used in a real life situation so as to predict the vibration influence on locomotive driver under field conditions. Wilson and Norris [8] have described the different factors related to the safety of the Railways like driving, signaling and controlling, maintenance, reporting systems, passenger interest, planning and technical systems change. In fact Edkins and Pollock [9] described in their paper a method named as RAIT (Rail Accident Investigation Tool) to analyze the accidents and incidents occurred around 1990 to 1994 in the Australian Railroad industry. Similarly, Lamonde [10] have already proposed in his paper the importance of ergonomics and how its implementation in the workstation design is vital for human safety. What is quite similar in their research is that they have focused mainly on the safety issues concerned with Railways.

A. Man-Vehicle interaction

Damiani, Deregibus and Andreon [11] have described regarding the evolution of driver-vehicle interaction. Similarly, it is of prime interest for the railway manufacturers to look after the interaction between a man and a vehicle. It does not matter whether one is discussing about designing the upcoming diesel locomotive or thinking of improvising the existing one, one has to keep in mind all the ergonomic criteria, including the modification of the driver's cockpit.

II. DIESEL LOCOMOTIVE UNDER CONSIDERATION

Diesel locomotives are very complicated and heavy machinery, which requires tremendous amount of power in order to do the desired amount of work.

In general diesel locomotives are structurally divided into three main categories: i) Hood unit cab, ii) Single cab forward and iii) Dual cab forward. Out of those three, WDP_4 falls into the single cab forward category.

The model overcame their earlier diesel counterpart, when one considers in terms of power and control panel design. But, little was focused regarding the cockpit environment, especially, pilot's chair.

Actual model of WDP_4 has been shown in the Fig 1.

Fig. 1 WDP_4 model

A. Problems under consideration of WDP_4 model

The following are the key improvisation area which could be noticed if one observes carefully:

I. Chairs should be ergonomically designed, and improvement should be based upon that.

II. Control panels are always under dynamic change.

III. Toilets should be incorporated in the upcoming diesel locos.

IV. Turntables should be incorporated so that driving in the long hood forward mode can be reduced or eliminated.

V. There is an urgent need to reduce the heat and sound insulation.

The above are a few improvement areas, to name a few. This paper highlights and attempts to improvise the design aspect of the two main objects in the cockpit i.e., the pilot chair and the control panel of the WDP_4 model.

B. Importance of proper work environment

As far as the statement of Accidents, Failures of Railway Equipment and Unusual Occurrences on Government Railways for the year 2011-2012 [12] is concerned, one can notice that the number of accidents that took place due to the failure of the drivers is more than due to any other reason. The statistics is shown in Table 1.

Table 1

STATEMENT 41(A) - AT A GLANCE
ACCIDENTS (TRAIN ACCIDENTS AND MISCELLANEOUS ACCIDENTS
(INCLUDING YARD ACCIDENTS)) AND FAILURES OF RAILWAY EQUIPMENT

Sl. No.	Head	Grand Total (All Gauges)					
		1990-91	1995-96	2000-01	2005-06	2010-11	2011-12
A	Train Accidents						
1.	Collisions						
I	Failure of Railway Staff						
i)	Failure of Station Staff						
	a) Passenger trains	7	7	4	2	-	1
	b) Other trains	1	2	1	-	-	-
ii)	Failure of Drivers						
	a) Passenger trains	12	6	2	4	2	4
	b) Other trains	15	12	4	2	2	3
iii)	Failure of Other Staff						
	a) Passenger trains	2	-	2	-	-	-
	b) Other trains	1	1	1	-	-	-
II	Failure of Railway Equipment						
	a) Passenger trains	-	-	-	-	-	-
	b) Other trains	1	-	-	-	-	-
III	Other Causes						
	a) Passenger trains	2	1	6	1	1	1
	b) Other trains	-	-	-	-	-	-
IV	Total						
i)	Number						
	a) Passenger trains	23	14	14	7	3	6
	b) Other trains	18	15	6	2	2	3
	c) Total trains	41	29	20	9	5	9
ii)	Per million train kilometres	0.07	0.04	0.03	0.01	-	0.01

The above statistics throws some light of the accidents that took place over the last two decades, which excludes accidents such as derailment due to failure of railway staff and other members, accidents such as train wreckage, fire in trains, etc. The numbers of accidents caused by the failure of the drivers are also not a thing which can be overlooked.

So what is more important is to highlight the reason behind such failures by the pilots. One reason is probably, due to irregular scheduling, which is once again related to fatigue and safety, and the other reason is, improper work environment, whose improvement is the main objective of this paper.

Railway accidents caused by train divers' human errors continuously occur and major parts of human factors related accidents are associated with drivers. Thus, intensive care should be taken while designing any cockpit. The more intriguing fact is when the locomotive pilot has to work for long hours inside the cockpit; it should not lead to any kind of fatigue, musculoskeletal disorder of the driver.

Henceforth, there is an urgent need to review each and every aspect of the cockpit.

III. FACTORS INVOLVED IN THE ERGONOMIC DESIGN OF THE COCKPIT

In any transport vehicle cockpit the driver or the pilot is mostly affected by the following factors such as the following:

i. Noise- It is the unpleasant sound caused by the diesel combustion area, generator, horn , sound of wheels and external agents, such as passing trains, etc.

ii. Visibility- It is mainly related when the viewing glass is not properly maintained, and also upon the mode in which it is being driven. As for example, in the diesel locomotive under consideration, WDP4, driving in the long hood forward (LHF) mode is very much difficult. The fig. 2 shows the visibility of the driver from the LHF mode. It is supposed to be used with turntables, but the absence of turntables leaves no other choice but to drive in the LHF mode.

Fig. 2 Locomotive Pilot's view of WDP_4 in the LHF mode

iii. Occupational Stress- It is mainly related to irregular scheduling of drivers and improper rest, which results in the development of fatigue, sometimes the aesthetic values of the cockpit also involves in building up the stress level.

iv. Heat- It gets generated due to air friction, when the locomotive is running at a very high speed, coupled up with the heat generated by the engine, the temperature shots up to 43 degrees when the outside temperature is around 33 to 35 degrees.

So for developing a sound cockpit, the above factors should be kept in mind before making any kind of modifications inside the cockpit. The block diagram showing different factors interlinked are shown in Fig.3.

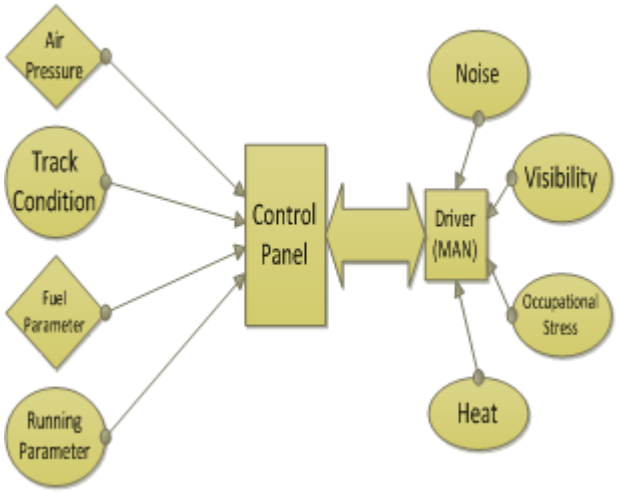

Fig. 3 Block diagram of the factors involved in the cockpit

The above block diagram clearly depicts the inter-relationship between a man and a machine, i.e. the control panel in this case. These are just minimum criteria that need to be fulfilled so that modification can be done in the control panel. Even though there can be other factors also, depending upon the situation, place, time, etc. But the aim should be such that the above block diagram should be kept in mind while designing.

Sometimes it can be seen that changes inside the cockpit, may lead to some changes as far as the complete model of the locomotive is concerned. Consider the visibility factor, research and development is going on in this field, on how to improve the visibility. So, a dual cab locomotive in the name of WDP_{4D} has come into play. Initial cost of that locomotive remains an issue. For the single cab locomotives, if one wishes to work on the visibility issue, one need to have knowledge of the whole locomotive so that design modifications can be done and implement successfully.

The fuel condition or the running parameters or the pressure gauge, all forms a crucial index as far as the locomotive is concerned, and they can be controlled with the help of the control panel.

IV. DESIGN OF THE LOCOMOTIVE PILOT CHAIR

The desired aspects for any seat design includes factors such as comfortablity, mobility, durability, ability to absorb sweat, etc, to name a few. Fail, Delbressinel and Rauterberg [13] provided the aspects required for any transport vehicle seat as shown in Table 2 and the actual pilot seat is shown in Fig. 4

Fig. 4 Locomotive pilot's chair

Table 2

Aspects	Percentage of importance
Comfort	32.8 %
Good adjustments	21.2%
Roomy	14.6%
Good back support	10.2%
Hygiene	5.5%
Antiperspirant	3.5%
Durability	3.2%
Good mobility	1.2%
Aesthetically pleasant	1.2%
Without opinion	6.6%
Total	100%

But if the current existing seat of any diesel locomotive is observed, majority of the locomotive pilot complains of having back problems after working for prolonged duration in a day. The CATIA model of the existing pilot seat is shown in Fig. 5.

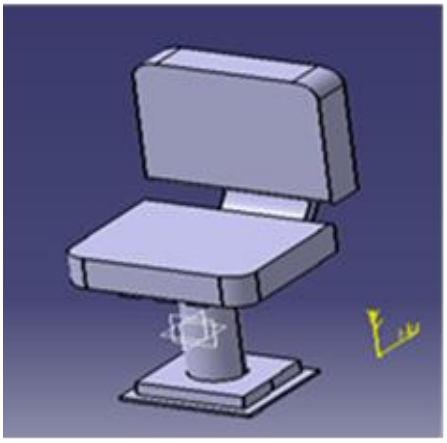

Fig. 5 CATIA model of the existing pilot's seat

The desired aspects highlighted in table 2 may vary in percentage from person to person, but the majority of population of drivers considered that incorporation of arm rest would certainly be helpful for them. The back rest also needs to be reviewed in the upcoming locomotives. As a result a suggestive model has been shown in the Fig. 6.

Fig. 6 Proposed model of the pilot's chair

V. DESIGN OF THE CONTROL PANEL

The control panel which the WDP_4 model house, possess four main levers, each serving a specific purpose. One lever is used for reversing the direction; two are used for braking purpose and the last one for throttling. The control panel has two brakes, one for the locomotive itself and the other for the whole train. The indicators present in the panel also have several specific functions, which includes from displaying speed, to different air pressure condition of the locomotive. The actual control panel is shown in Fig. 7

Fig. 7 Existing control panel of the WDP_4 model of the locomotive

The existing control panel after being developed in CATIA is shown in Fig.8

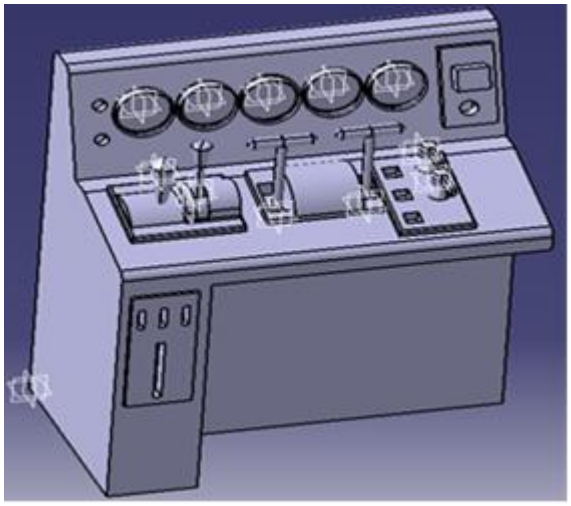

Fig. 8 CATIA model of the WDP_4 locomotive control panel

The proposed model of the control panel ensured that the glass panel comes in no way in front of the pilot, if we consider from the view point of the locomotive pilot. The levers are also designed and placed in such a way, so that the pilot does not need to lift their hand much, which is the case with the existing panel. Most importantly any design and development of a control panel is always under dynamic environment, i.e., some changes or the other always remains even after development. The writing area has also been focused in the proposed model, as left handed people find it difficult to write while the locomotive is in motion, while the proposed one makes sure that the writing area is centered. This would certainly help both the left handed as well as the right handed pilots. An isometric view of the proposed CATIA model of the control panel has been shown in Fig. 9.

The proposed model was also designed in such a way, so that the panel seems to be surrounding the pilot. Another important modification which if implemented would be helpful for the locomotive pilot is that all levers should function within 0 to 90 degrees, which would result in less stretching of the hand of the pilot. Therefore, the above facts were kept in mind while developing the proposed model in CATIA.

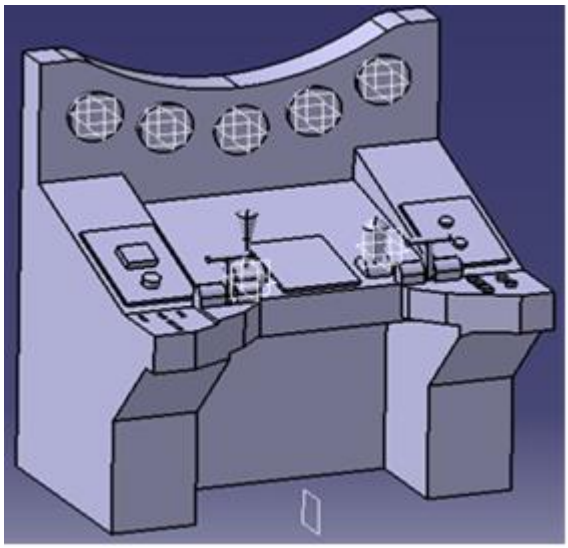

Fig. 9 Proposed model after being developed in CATIA

VI. MANIKIN INVOLVED IN THE ANALYSIS

The manikin who was used in the analysis was of Korean type, with the 70^{th} percentile of the population. The Korean type resembles to some extent of the Indian drivers, so it was used for the analysis of the study. A manikin of that type with reach envelope is shown in Fig. 10.

Fig. 10 Manikin with the reach envelope

VII. PILOT CABIN ASSEMBLY

After the design stage it was then required to assemble the chair, control panel, cabin and the manikin. The resulting assembly of the existing cabin of the existing assembly has been shown in Fig. 11. Similarly, the assembled view of the modified pilot chair, cabin, and the proposed control panel with the manikin has been shown in Fig. 12.

Fig. 11 Existing Pilot Cabin Assembly

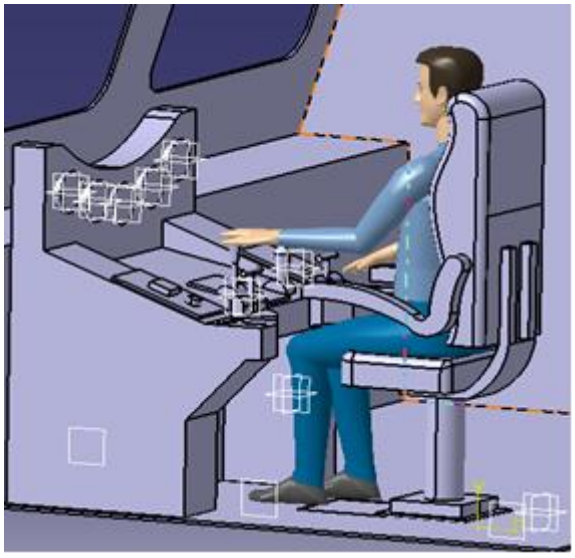

Fig. 12 Proposed Pilot Cabin Assembly

The assembled view can be noticed that the arm rest are placed in such a way so that the two brakes are almost in the same line as that of the arm rest. Most importantly all levers should operate between 0 and 90 degrees, which would ensure less stretching of the pilot's arm. The panel of WDP_4 has been designed keeping in mind a variety of Indian drivers, so that they would face little or no difficulty while driving for long duration.

VIII. ERGONOMIC ANALYSIS

An ergonomic analysis is carried out using CATIA V5. The 70^{th} percentile manikin model has been used to draw the comparison between the existing and the proposed model.

The result of the analysis of the existing assembly with the extreme position of the lever has being shown in Fig. 13.

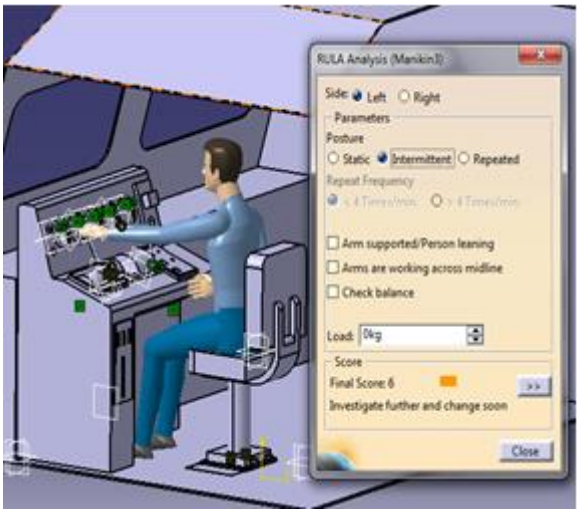

Fig. 13 RULA result of the existing assembly

Similarly the result of the analysis of the proposed model with the result of RULA has being shown in Fig. 14.

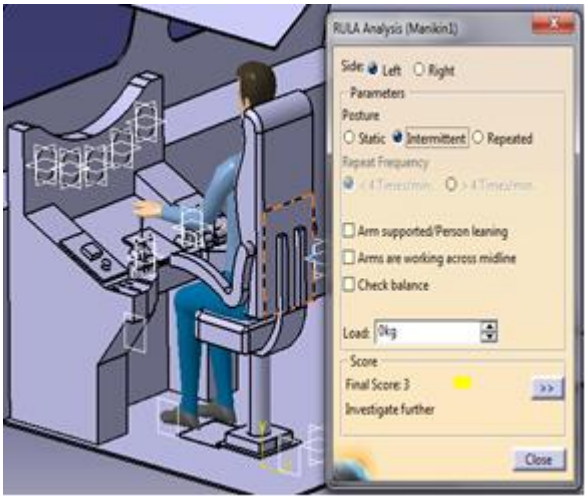

Fig. 14 RULA result of the proposed assembly

The above results of the RULA analysis depict the score when the manikin is operating with his left hand. The lever is also in the extreme position in both the two cases. Therefore, the comfort level is much better in the proposed model, having a RULA score of 3, unlike the existing case, where the RULA score is 6. So, it is highly evident from the analysis that there is a need to investigate the working environment of the WDP_4 model, with the proposed model providing better results.

IX. CONCLUSION

An inference which can be drawn based upon the ergonomic RULA analysis, that there is postural discomfort present in the existing model, which makes the RULA score to be around 6. Such problems are minimized in the proposed model, as far as the RULA score is portraying.

So this has been a new approach in the rail road industry to try and improvise an existing model, so that a large number of drivers can be benefitted by this proposed model, if implemented in future. It has mainly focused upon the pilot

chair and the control panel. This approach can not only be applied for the rail road industry, but also for any transport vehicle, varying from bus, ship, aero plane, automobile, and many. In fact, research and testing are still going on in the field of transport, on how to improvise the driver's cockpit, but little was done for the cockpit of Diesel locomotive till date. Henceforth, the cockpit environment, as already highlighted, plays a pivotal role, when it comes to safety and harmony.

The research presented in this paper is just suggestive recommendation, which requires practical implementation. Most importantly, in a cockpit there are other factors excluding the control panel and the pilot chair, where the future researchers can expand their research and development upon those aspects. The future work on diesel locomotive can also be expanded over the whole design structure and not only limited to just cockpit.

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