7.0 SUMMARY

Jharia coalfield, in Dhanbad district of Jharkhand state is the biggest coal mining area, where 300 collieries and 1121 inhabited villages (Census of India, 2001) are present. Dhanbad district is famous for coal mining. Famous companies established in Jharia coalfield are engaged mainly in Coal mining, Coal washing, and Coke making. The initial loading and unloading of coal and coal products in mines are mostly done manually. Cane or fibre cane baskets are generally used as hand tool by these loaders for the purpose. Ear;ier studies conducted on basket loading in mines have shown that this task exposes the loaders to unique physical and environmental demands. As a result, the physiological demands due to manual work are very high involving high risk of suffering from occupational health disorders. In such exploration work, employees are forced to work which includes usage of potentially ill-designed dangerous equipments, extreme climate and altitude changes. Though manual material handling is being replaced by mechanical equipments, there are several areas where MMH is still just unavoidable. Manual basket loading in coal mines is one such area in India.

An attempt to explore the task performed by loaders and the occupational stress imposed on them along with detailed analysis of the hand tool (cane basket) used by them, and subsequently to suggest some improvement of the basket design has been made in the current study.

The aims of this research work were -

1] Identification of the potential hazards and risks to the workers engaged in basket loading in coal mines, and to evaluate work related stress.

2] Determination of strategies for elimination of occupational hazards among coal mine basket loaders using Ergonomic Engineering Control Technique to modify the design of the basket to increase efficiency, improve safety, and reduce possibilities of their occupational health disorders.

Demands of the job and limitations of the loaders were documented. Ans adequate nutrition is essential for maintaining good health and normal physical efficiency

among the workers, nutritional status of these workers were examined. Main hand tool of these loaders for carrying broken coal, waste rocks and slurry is conventional baskets, mmade of cane and synthetic fibre. Occupational risk factors associated with the use of these baskets were identified and accordingly the design of the tool was modified.

Evaluation of Occupational Stress

The analysis of the general health revealed that the general health of the basket loaders are not sufficient to combat with the stress/demands of the job they are performing. During the evaluation of occupational stress, percentage of loaders suffering from MSDs and discomfort level was assessed to bring out the most adversely affected body parts during operation. The results revealed that both male and female loaders were found to suffer from pain/injury in the lower arm region i.e. the wrist/hands; followed by lower back, ankle/feet and neck. All the MSD's and discomfort present among the surface and underground loaders may be due to the por design of the handtool used.

Qualitative assessment was then conducted which included the estimation of postural and biomechanical stress, cardiovascular stress assessment of pulmonary function status. The assessment of biomechanical stress included CG analysis, OWAS, postural stress, RULA, Computation of RWL and LI, BCF and shoulder moment.

Compared to that during lifting (55.02%) and throwing (59.9%), the percentage of Whole Body Center of Gravity (WBCG) location was higher during carrying task (77.03%). This vertical shift of WBCG noted during carrying of the load on head is responsible for imposing great stress on the musculoskeletal system of the loaders. Stability is essential in avoiding falls and over exertion injuries. This shift of the WBCG also causes imbalance of the body which is corrected by the muscular contracture of the opposite side which may lead to high degree of physiological stress. This may be the reason behind the occurrence of the large number of MSD complains recorded in this study. Moreover in OWAS study, it was observed that the most the number of observed postures for lifting the slurry/coal

loaded basket and carrying the basket on head fell into OWAS action categories 3 and 4 respectively. OWAS method of posture analysis classifies that the postures adopted by coal mine loaders during lifting and carrying the loaded basket are very awkward. The frequency of the lifting and carrying is very high which puts the loaders into more stressed circumstances of work. Thus OWAS study specifies that lifting task, carrying task and throwing task have a very harmful effect on the musculoskeletal system and requires immediate attention.

In time study analysis, bending, walking with the load overhead and walking without the load are the four postures that were studied. The total duration of the bending posture among slurry loaders was about 8% of the loading cycle time and that of underground loaders was 18% of the loading cycle time. So as the underground loaders in the current study were found to spend more percentage of time in bend posture, they are more susceptible to redundant pressures in inter-vertebral disc leading to spine/low back disorders. This unwanted excessive bending can be reduced by proper redesign of the task performed using ergonomic principles. *Throughout the filling of the basket at surface as well as underground, the dominating posture noted was the bend posture.* This bending posture took about 60.65% of the total work time for cutting slurry accumulated in the slurry pond during slurry loading and 71.3% for digging and cutting the coal during underground coal loading. Less space in the underground phase allows only 1-2 loaders to dig and accumulate the coal and coal dusts that are settled on the ground after blasting; whereas in slurry loading digging and arranging of slurry is done by more than two loaders so the time spend by each loader for cutting slurry is less when compared with the time taken by the underground loader to cut and arrange coal. This increases the physiological cost, due to postural stress, of the underground workers when compared to that of surface workers. The *underground mine workers had more postural stress than that of surface workers.* These results obtained are in line with earlier studies conducted among the coalmine workers where similar inference was drawn that miner's especially *underground workers experienced more postural stress*.

In Rapid Upper Limb Assessment (RULA), it was observed that all the three activities (lifting, carrying and disposing) obtained the maximum score of 7. *A score of 7 or more indicates for the selection of action level 4. This means that an immediate investigation should be done on the work process and appropriate changes should be incorporated*

immediately. The neck, trunk and leg group were found to have maximum score during lifting, followed by that during disposing and carrying of the load respectively. For carrying the load over head, arm-wrist segment obtained the greater score than the neck, trunk and leg segment.

Results indicate that *the load handled by the loaders should be modified immediately*. The load is the weight of the slurry or coal loaded basket. So this assessment indicates that the weight of the loaded basket should be reduced. Usually the weight of a coal laded basket is around 30 kg, whereas that of the slurry filled basket is about 28 kg, and an empty basket weighs nearly 2 kg. However, much load cannot be reduced by changing the weight of the basket. The weight of the coal /slurry may be reduced by reducing the size of the basket. *Before doing that optimization of load for Indian coalmine workers is very much necessary. Further study is needed in this direction.* Changes in the designs of the head pack and the basket may be done so that the strain in the neck, trunk and arm segment of the body can be reduced.

Joint angle analysis aimed to locate the exact subtask of the job creating unwanted joint mobility that act as stress on the worker to locate the strenuous part of the task performed; thereby, utilizing the information for further job/hand tool design. The body joint angles (wrist, elbow, shoulder, hip, knee and ankle) during operation of loading basket were found to be deviated from that of normal standing posture. Therefore, the results indicated that postural discomfort was prevalent during operating with the conventional basket.

Wrist was found Ventriflexed during lifting, dorsiflexed during carrying of the load overhead and dorsiflexed and adducted during throwing of the load. The wrist is under considerable stress during all the three activities as it is deviated more than the normal unforced range of mobility. During lifting and throwing task, the elbow was not relaxed instead it was holding the load away from the body in a strained position. The total weight of the load rests on the arm at this moment. During carrying the elbow was more flexed but not in stressful position. Owing to the nature of work, the shoulder angle was found to be more flexed while carrying and throwing of the load. Moreover, during these postures the load is held above shoulder level which results in shoulder stress.

Extreme bending (flexion) at the hip was noted during lifting and throwing of the load. Vast literature reveals that extreme forward bending during lifting may be stressful. During throwing task, the strain imposed on the back muscles is comparatively less than that imposed during lifting task. Knee was found flexed more during lifting of the load and during throwing/ disposing the load. The loading job requires walking with the load and without the load and this includes extension and flexion of the ankle. Treading along extremely uneven ground leads to the mild extension at the ankle joints.

The relative estimate of the level of physical stress associated with the manual lifting task in coal and slurry loading was studied by computing recommended weight lift (RWL) and Lifting Index (LI) for the current task as recommended by NIOSH. According to the results obtained, the weight to be lifted (RWL) at the origin (15.19kg) and at the destination (30.38kg) is greater than the RWL at the origin (14.56kg) and at the destination (17.01kg). The LI at the origin is 1.03 and LI at the destination is 1.79. When the multipliers were compared to table 8 of NIOSH Lifting Guide, it was observed that only HM and AM had a value of 1 and the remaining multipliers were having a value less than 1.0. NIOSH considers lifts with a lifting index greater than 1.0 to "pose an increased risk for lifting related low back pain for some fraction of the workforce".

LI being the relative estimate of the level of physical stress associated with a particular manual lifting task, revealed that the lifting task studied in the current study can be hazardous for a majority of healthy coal miners. In the present study the weight of the load handled is shared by two loaders whereas at the destination this shared weight is handled by one loader only. So the LI computed at the origin was less compared to that at the destination. As LI is more than 1, it is recommended, according to NIOSH guidelines, to lower the load. But lowering the weight of the load is not feasible as it would affect the production; so it is suggested to incorporate various redesigns that can reduce the adverse affect of lifting of heavy weights. This may include redesigning of the hand tool.

Literature reveals that an important part of quantifying spinal loading is accurate estimation of back compressive force (BCF) to identify potentially hazardous jobs which in turn help reduce the number of low back disorders in the workplace. In the present study, F_c *during disposing task (photo5) was highest (659.67 lbs) compared to lifting task (615.67 lbs) and carrying task (418.51 lbs) respectively*. It was observed that *Term B (i.e.* back muscle force

reacting to the load moment) *contributes more to the low back stress during disposing task.* The value of F_c during throwing task can be reduced if the magnitude of the *load is reduced* along with the reduction in horizontal distance between the low back and hands. Both reduction in load and horizontal distance between the load and the low back can be reduced by changing their work pattern or changing the design of the cane basket. If handles are introduced, this distance can be reduced to some extend. The second highest value of F_c (569.73 lbs) was obtained during assessing lifting task and term A (back muscle force reacting to the upper body weight) was found to be more during lifting task. Moreover during lifting the computed lumbar spinal compression is 44.42% of the ultimate compression strength of adult male, which is within the margin of safety but very near to the higher range of margin of risk of 45%. The back angle can be reduced by job redesign or modification in the design of the hand tool which can reduce the angle. The probability of fatigue fracture in case of lifting, carrying and throwing operations of a basket loader in the present study was computed as 22.26%, 16.315% and 25.715%.

This was followed by a semi quantitative method of computing stress at the shoulder. For the three tasks (lifting, carrying and disposing) the mean M_{task}/ M_{cap} ratio was about 0.3. This result indicates that the task performed is *not hazardous for most of the workers unless the frequency is quite high as the ratio is less than 0.5*. No severe injuries at the upper extremity, especially the shoulder region were reported in MSD survey. This may be because no severe joint forces and moments were produced during the task performance.

The physiological stress included the analysis of resting pulse rate and working pulse rate along with computation of cardiovascular stress index (CSI). Mean working pulse rate recorded among underground male loaders were117.79 beats/minute while those of male and female slurry loaders were recorded as 113.94 beats/minute and 116.9 beats/ minute respectively. The difference in the pulse rate noted among the underground and surface loaders was attributed to the difference in amount of load they handle during loading, the distance traveled with the load, exposure to more coal dust (as they work in a confined space) and environmental stress. The increase in pulse rate was also attributed to upper body strained postures attained throughout the performance. The mean values of age, resting pulse rate, maximum working pulse rate and workload assessment of underground loaders were compared among different studies in different eastern coalfields in the year 2003, 2007 and

2009. The difference noted among the mean values can be attributed to the age difference and activity level of the workers.

Maximum CSI was observed in underground loaders male (34.32). This can be attributed to the nature of work performed by these loaders as well as the underground environment. CSI of the coalmine workers in the current study was compared with CSI recorded from workers engaged in different occupation. It was observed that CSI computed from different workers were different and this may be due to the different nature and heaviness of work, work conducted in different environmental conditions and duration of work.

The miners exposed to workplace circumstances in underground and opencast mining throughout the work shift were found to have an elevated risk of developing occupational health risks which includes development of occupational respiratory diseases. So in mining occupation, the amount of respirable dust contained in the ambient air, the workers physical work load and hence the magnitude of his pulmonary ventilation are of great concern. In the present study it was noted that an appreciable number of the affected loaders had restrictive disease (28.61%), about 12% of the affected loaders were suffering from obstructive diseases; and about 5% of the affected loaders were suffering from mixed blockage. There were no case of severe obstruction and restriction noted in the current study. 65% of the loaders were unaffected from any kind of lung function abnormalities. Affected and unaffected loaders were compared in comparison to the smokers. It was observed that maximum percentage of smokers was suffering from obstructive disease than nonsmokers. Moreover none of the smokers was found to suffer from mixed blockage, but 4.65% of the nonsmokers had mixed blockage. The results obtained reflect the fact that smoking may exacerbate lung function abnormalities. Maximum percent of the nonsmokers were found to suffer from restrictive disease.

Thus the qualitative and quantitative analysis of occupational stress revealed that the coalmine loaders were exposed to various physiological and biomechanical stress which require immediate ergonomic interventions to reduce the affects of the existing occupational stress and help loaders to increase their productivity and their general health. For this the existing cane and fiber basket was evaluated and drawbacks of the conventional design were identified using direct observation method and subjective evaluation. These drawbacks may be the reason behind the onset of various physiological and biomechanical strains. The

anthropometric and physiological design deficit includes lack of proper grasping area, gaps between the winded sticks, excessive volume of the basket, and increase in weight of the empty basket as it gets wet during the activity. This was followed by its productivity study. Lifting Frequency was computed as recommended by NIOSH (1991) and it was 0.67 lifts per minute.

MODIFICATION IN THE DESIGN OF THE BASKET:

To overcome the recorded drawbacks of the prevalent basket design, four design concepts were developed by incorporating different kinds of grasping devices (handles) in different positions. Concept I was one handle concept; where the basket was provided with a total of two handle. Thus each worker was provided with one handle for one hand and the other hand was devoid of an handle and was insert into the gaps of the cane sticks entwined during loading and unloading.

In Concept II, four handles were provided to the basket. For this two stiff bamboo rods were inserted, the two ends of which were used as handles. In concept III four angled handle was provided to the basket. This handle was used to keep the hand arm system in non-strained posture throughout the task performance. The handles were fitted 30 degree angled to the horizontal. These handles were made of the same material that was used to make the body of the basket. In concept IV, the material of the basket/ handle was suggested to be changed.

After development of the concepts, different dimensions of the basket were determined using the anthropometric dimensions of the users and the psychophysical response of the workers. The pair comparison test was employed to the psychophysical response of the users and different dimensions were determined from the computed scores of the test. The results revealed that the model *SF3 was the most wanted model having an upper diameter of 45cm, inner depth of 16 cm, lower diameter of 17cm and had 4 cane handles angled in 30 degree to the horizontal.* To avoid strain at the shoulder joint, the placement of the handle at the middle of the basket was comfortable for the users during holding the same. Some clearance was given for free movement of the hand during operating the same. It was noted that there was significant improvements in the joint angles recorded while using the newly designed basket. The productivity study also revealed a significant increase in productivity in terms of lifting time. It has been noted that the redesigned basket was suitable for the loader and it fulfilled most of the required criteria for the users.

The final design was made with both bamboo and cane sticks. It was noted that *the alignment of the handle with the suggested angle became problematic especially with the bamboo stick.* As the handles were tied to the basket, after few lifts these handles got loosened. Further it was very difficult to maintain the desired angle of the handle with the basket wall.

The problem was solved by *making an iron frame* in accordance with the shape of the basket. The handles were fixed in the proper alignment. The bamboo made basket was fitted within the frame by some small nuts and bolts. It was observed that none of the materials used to make the conventional baskets i.e. natural cane, fibre cane or bamboo, was suitable for making the handles with proper stiffness so that they do not bend to change their positions or angles during loading, lifting or unloading. Thus such handles were not effective to serve the purpose for long term use.

But the iron frame too had some disadvantages. The frame increased the weight of the basket by 1.2 kg approximately which may slightly increase the physiological cost of the workers. Secondly, the iron frame may get rusted and worn out in the course of time. To solve this problem *hard plastic frame may be used* instead of iron frame or the whole of the basket can be made of hard plastic. The use of tough graded materials like High Density Poly Ethylene (HDPE) etc having high Environmental Stress Cracking Resistance (ESCR) value would solve both the said problems. While carrying the loaded bamboo/cane baskets loss of material was noted that can be avoided if *the material of the basket is changed to light weight, unbreakable material having no gaps* i.e. one piece moulded without any joints, welding etc. in its body. The *hard stiff handles* should be moulded along with the basket and thus would have no joints etc. making it more durable and can *reduce the cost and time for maintenance of the basket thus would be economical*

A new **head pad** was also designed in this study. Thus the newly designed head pad was found to be more comfortable as the basket fits on it well and as it was tied on the helmet the fear of its falling while lifting was eliminated and this in turn would decrease the necessary of strained neck posture attained during lifting.

CONCLUSION:

There were various direct benefits identified that can be accrued from the research work done. These were discussed in terms of the following topics:

- Productivity:
- Comfort, Health & Safety:
- Medical Care Cost:
- New Product - New Market :
- Creating Ergonomic Consciousness and Safety and Health Awareness among Workers:
- Database Utility:

This was followed by identification for various scopes for future study and by products of the current study that can be used by the mine management.