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Research Article

Motion and Time Study for A Lathe Machine Under Varying Light Intensities

Dr. Amit Kumar[a]

[a] Department of Mechanical Engineering, National Institute of Technology Patna, India

Abstract: For creating a conducive working condition in an industrial production center, sufficient and well-balanced illumination levels are essentially required. A variety of visual tasks may be needed at various points involving different activities. One of the important factors for the higher productivity and comfort levels of the workers is the quality and intensity of the illumination provided at the workplace. Safety and morale of the workers are improved, especially near rotating machines. To create a safe environment and security at the industrial workplaces balanced brightness ratios, glare control or strobe effect should be considered. With the provision of sufficient lightning, an industrial unit can increase productivity by 10% to 50% and reduce errors by 30% to 60%.

A motion and time study was conducted for a lathe machine, in a busy workshop engaged in producing a standard job on a mass scale. Several sets of observations were taken under varying illumination levels (natural and artificial lighting combined). It has been observed that a certain range of light intensity is required for optimum output if other conditions remain the same. There is a considerable reduction in productivity if the light intensity is less or more than this standard range. The reduction is higher at lower ranges than the reduction in higher ranges of illumination.

Keywords: Illumination, lathe machine, productivity, task-lighting, motion, and study

1. Introduction

Lightning is the specific use of natural or artificial light to create a practical or aesthetic environment at a place. Sunlight is used through windows, skylights, or other openings for providing light at workplaces. Sometimes, day lightning is not able to provide sufficient illumination at the workplace. This forces us to use artificial lights wherever required. This requires energy which costs and not available freely as sunlight. Too much light intensity creates glare and troubles the workers whereas poor lighting results in eye strain, stress, headaches, fatigue, and accidents. [1]

1.1 Lighting and Productivity

Productivity measurement was simple to measure in the recent past industrial period. It was the number or weight of the product per unit time or cost. This system was quite efficient in a well-defined production unit. Nowadays, the unit of output has become more complex and governed by service and information-based produce. Hence, it has become cumbersome to measure productivity. In the modern economical society, consumers give importance to the quality of the product, their variety, and the after-sale services. In the present era, productivity is not an input/output model but a changed model of value addition. This has achieved saving in the cost of production.

The lighting sector has been greatly affected by this value of addition concept in many ways. The more adaptable lighting system at a workplace improves the quality of work, and comfort of the workers, resulting in a better quality of the products and services. Thus, working efficiency, in general, is increased. The cost of lighting can also be reduced by using an energy-efficient lighting system and equipment. Thus, health hazards from poor lighting are also eliminated. For providing an appropriate level of lighting in an industrial unit lighting survey needs to be conducted which should include the following. [2]

- The nature of the job
- The working environment
- Availability of natural light
- The requirements of artificial lighting, its kind, and the amount

1.2 Assessment of Light Needs

An industrial unit consists of an office area, stores, movement ways, and operational areas including very hazardous areas. The need for the lightning of each area is to be decided based on broader guidelines provided by various standards. General factors to be considered may be as follows: [3].

- Quantity of light and light intensity as per current standards.
- Amount of glare, diffusion, and distribution.
- The vision contrasts and effects of short shadows if any
- The presence of natural light sources.

1.3 Sight Affecting Factors

- Shape and extent of the object.
- The contrast of the Object
- Light intensity.
- Vision ability.

1.4 Factors influencing effective lighting

- Brightness
- Uniformity of Lighting
- Shadows
- Glare
- Height of Mounting
- Spacing between Lights

2.General Information

The use of natural light at the workplace is always desirable but most of the time it may not be adequate for the requirement. In such situations, supplemental light is needed and is acceptable. This should not introduce glare or a severe imbalance of brightness in a visual environment, otherwise, it may create discomfort and fatigue. At the same time, eye comfort is equally important. Certain basic characteristics of illumination must be kept in the mind at the planning stage. Light intensity decreases by inverse square law, i.e. for the twice increase in distance, the illumination decreases by four times. The methods of artificialillumination also matter significantly towards energy consumption. Filament lights produce 18 to 22 lumens per watt, while fluorescent lights produce 70 to 80 lumens per watt. However, fluorescent light decreases in efficiency with age.

2.1 Levels of Light Intensity

To decide lighting intensities for specific industries (e.g. foundries, dairies, bakeries, sheet metal works, etc.) various standards are available such as ANSI/ IESNA RP-7, As 1680.1-2006 Interior and workplace lighting, EN 12464-1:2002: Light and lighting- Lighting of workplaces- Part 1, IS 3646 (Part 1):1992, Code of practice for interior illumination, CIE S 008/E: 2001/ISO 8995-1:2002(E): Lighting of workplaces- Part 1, etc. Table – 1 shows recommended values of illuminance provided by IES from the “Recommended Practice for Lighting industrial facilities,” ANSI/IESNA RP-7-01 [4].

Table. 1. Recommended Values of Illuminance provided by IES

S.N.	Area/activity	Lux(fc)	S. N.	Area/activity	Lux(fc)
1	**Aircraft manufacturing** (a) Drilling, riveting, screw fastening (b) Layout and template work, shaping and	750(75)	4	**Paint manufacturing** (a) Processing (b) Mix comparison	300(40) 1500(150)

	smoothing small parts for the fuselage, wingsections, cooling, etc. (c) Scribing (d) Plating	 750(75) 1500(150) 300(30)			
2	**Electrical equipment manufacturing** (a) Impregnating (b) Insulating: coil winding	 300(30) 750(75)	5	**Sheet metal works** (a) Miscellaneous machines, ordinary bench work. (b) Presses, shears, stamps, spinning, medium benchwork (c) Punches (d) Tin plate inspection, galvanized (e) Scribing	 750(75) 750(75) 750(75) 1500(150) 1500(150)
3	**Foundries** (a) Annealing (furnaces) (b) Annealing (furnaces) (c) Core making fine (d) Core making medium (e) Grinding and chipping (f) Molding: medium (g) Molding: large (h) Pouring (i) Sorting (j) Cupola (k) Shakeout	 300(30) 300(30) 1500(150) 750(75) 1500(150) 1500(150) 750(75) 750(75) 750(75) 150(15) 300(30)	6	**Textile mills** **(i)Staple fiber preparation:** (a) Stock dyeing, tinting (b) Sorting and grading (wool and cotton) **(ii)Yarn manufacturing:** (a) Opening and picking (chute feed) (b) Carding (non-woven web formation) (c) Drawing (d) Combing (e) Roving (slubbing, fly frame) (f) Spinning (cap spinning, twisting, texturing) **(iii)Yarn preparation:** (a) Winding, quilling, twisting (b) Warping (beaming, sizing) (c) Warp tie-in or drawing-in (automatic)	 300(30) 750(75) 300(30) 300(30) 300(30) 300(30) 750(75) 750(75) 750(75) 1500(150)

2.2 Brightness, contrast, and reflectance

Contrasts control the visibility besides other factors. When the object has a similar background, it becomes difficult to recognize the object distinctly. A higher level of object contrast is required for good visibility.

2.3 Recommended optimum "brightness ratio"

IESNA has recommended the following brightness ratios for workplaces where reflectance may be controlled but control of the remote surrounding is limited. [5]

Table. 2. Recommended optimum brightness ratio.

S.N.	Particulars	Recommended brightness ratio
1	Tasks to adjacent darker areas	3 to 1
2	Tasks to adjacent lighter areas	1 to 3
3	Tasks to more remote darker areas	20 to 1
4	Tasks to more remote lighter areas	1 to 20
5	Between light fixtures or windowsand the surfaces next to them	20 to 1

2.4 Glare control

'Glare' is defined as the loss of visual performance or discomfort produced by an intensity of light in the visual field greater than the intensity of light to which the eyes are adopted. Glare is a common source of visual discomfort at workplaces and industrial organizations. This reduces the efficiency of the workers at workplaces. Glare can be controlled to some extent by changing positions of lighting, reflectors, and Louvers, [6]. As and when the brightness ratios increase more than the recommended value, disturbing glare takes place[7].

The following measures are suggested to reduce the glare effect at a workplace:

- By using lower wattage electrical individual fixtures.
- Increase the height of bright fixtures above the normal vision line.
- Chance the direction of some lighting fixtures towards the ceiling to reduce the contrast between fixtures and ceiling.

2.5Vision and Productivity

The capability to observe and perform depends on several factors. One of the factors is 'age'. An aged person may require twice or thrice as much light to do a job as a young man [8]. The size, nature of the job, and time available affect the quantum of light.

2.6 Suggested Reflectance values of the surface

Reflectance values of the surface depending on the color and smoothness of the surface. The following reflectance values are suggested for various components of a building.

The ceiling of the room: 50 to 70 %

Wall of the room: 40 to 60 %

Working Platform: 25 to 45 %

The floor of the room: 20 %

2.7 Task lighting

In a workplace, certain hobs require higher intensity light than at other places. In such places, a lighting source may be located close to the working bench. This will provide higher light intensities and eliminate shadow.

2.8 Automated lighting control

Now, it is feasible to avoid over-illumination in an industry by proper illumination design. This reduces power consumption and increases the efficiency of workers. Proper design and planning have central control of all lights within an industrial or commercial building. This permits execution of scheduling, occupancy control, and proper usage of daylight. A system of "Demand Response" (DR) is also quite popular and convenient and the light intensities are automatically controlled. This system has the advantage of cost savings [9].

Several recently developed systems have adopted wireless mesh open standards. One of them is Zigbee [10], which has easier installation and requires no wires. It has the advantage of interoperability with other systems.

Taking advantage of daylighting technology, daylight-based automated response systems have been used. This reduces power consumption to a considerable extent. These systems have some shortcomings also. At times, quick and frequent switching of the lights on and off may take place during changing weather conditions, or daylight changes. This creates a problem for the occupants as well as lamp life is also endangered. A variation of this technology is the 'differential switching or dead-band photoelectric control which has multiple illuminances; it switches from, so as not to disturb occupants as much. [11, 12]. Occupancy sensors may be used to scan an area to locate the person (s) and hence the lighting of the area can be controlled effectively. The passive infrared occupancy sensors can be used for wide and open spaces. Open areas needing 360-degree coverage can be managed best by ultrasonic sensors. Passive infrared and ultrasonic technology can be combined in sensors, but they become costly. They are used to control one or several fixtures at a time [13].

2.9 Effect of light intensity on health:

Lighting influences the health of people under its coverage and the environment. Over illumination of a working space creates psychological imbalances and has adverse effects on human health, besides an increase in the energy bill. The adverse health effects i.e. headache, stress, and change in blood pressure may occur to the occupants by a higher intensity of lighting. Glare may reduce the workers' efficiency.

2.9.1.1 Background

The sufficiency of lighting should be judged or decided in the background of its surroundings and the task to be performed. In compliance with the above objectives, the following general guidelines are provided:

2.9.1.2 Action

Assessment to determine the effectiveness of a lighting system should include the personal interviews of the worker, health problems if any, and accidents/ incidents. In general, the assessment should include the following information [14].

(A) The intensity of lighting. It can be measured using a Lux meter at the working points and marked on a map.
(B) Quality of Light: A good quality lighting system should not have poor illumination, glare, visual fatigue, and shadows as they contribute adversely to safety. The following information should be collected during the investigation:

(a) Worker:

Age: Vision is likely to be improved with the increase in age.

Health: Suffering from any ailment causes depleted vision.

Productive Equipment used: They require a higher degree of illumination.

(b) Nature of Work:

Rigrocity: Light quality and amount vary with rigrocity of work.

Size of the object: Smaller objects require a high intensity of light to visualize and work upon.

Time Limit: A fast-moving object provides lesser time to inspect and act upon.

Contrast: The difference in color and intensity of light between an object and its background is termed contrast. The poor contrast requires a higher level of illumination.

(c) Light Source Orientation and Environment: Record the location, the time of day, weather, etc.

Space details: Record the size of the working space including height, color, and texture of the surrounding.

(d) Any other specific Problem, it any.

3. Present Study

The present study was conducted in a busy workshop where artificial lighting set up under a lathe machine was arranged so that light intensity could be varied as per the requirements of the study. The light intensities were measured by two nos. of Luxmeter to get an average value. The lathe machine was being used to turn a standard job. The job was repetitive for compliance of very large numbers of the turned components of the same specification.

At a light intensity, the productive time (such as centering the job, turning the job, removing the finished job, etc.), the time for minor delays (delays less than 5 minutes), and the time for major delays (more than 5 minutes) were noted by stopwatches for several days.

Similarly, the observations were taken for various activities at several varying light intensities.

The lathe operator was of 33 years with normal vision (i.e. 6/6).

3.1 Observations

The observations are summarized in Table – 4 and represented in the form of Pie-charts and Bar-chart (Figs. 2 & 3).

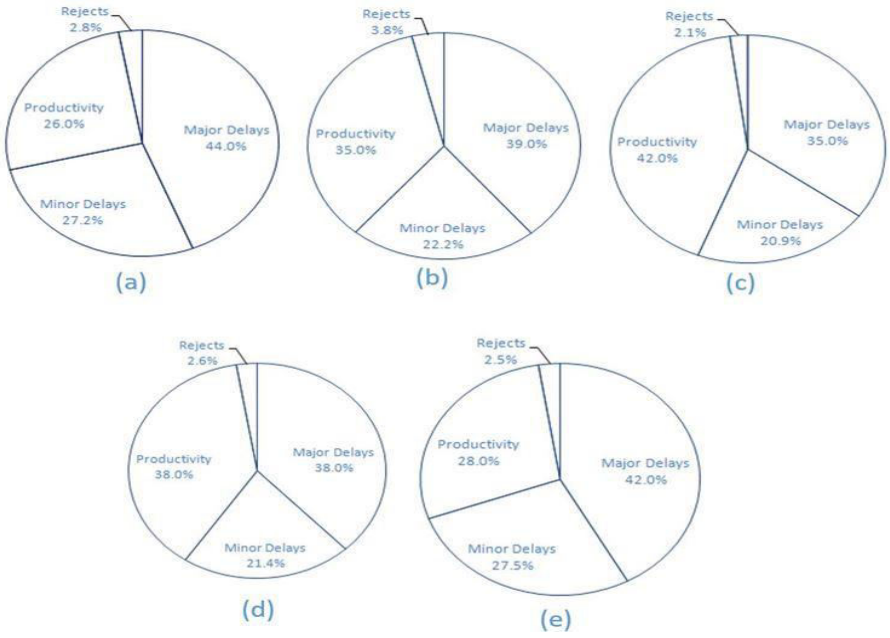

Figure. 2. Motion and Time study showing productivity at various ranges of Illumination.

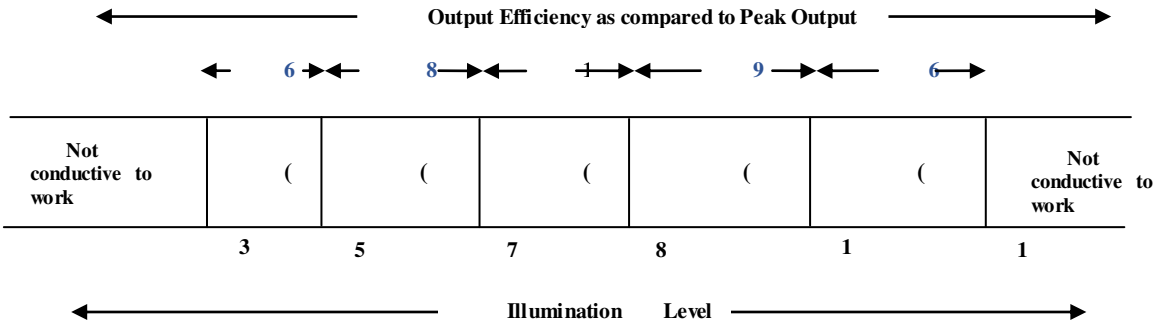

Figure. 3. Output Efficiency (for Peak Output) Variation with Illumination Level.

Table.4. Observations

S.N.	Light intensity range at the working level (lux)	Productive time (%)	Efficiency reduction as compared to a peak value (%)	Job rejects (%)	Modified efficiency reduction including rejects (%)
1	< 360	Not conducive to work	------	------	-------
2	300 – 500	26	38.10	13	41.15
3	500 – 700	35	16.66	08	17.16
4	700 – 820	42	---	05	0.00
5	820 – 1100	38	9.52	06	9.62
6	1100 – 1400	28	33.33	09	34.66
7	>1400	Not conducive to work	------		-------

4. Conclusions

1. The present study indicates that the output is maximum in the illumination range of 700 to 820 lux. It gets reduced in the range 300 to 700 lux as well as in the higher range of 820 to 1400 lux.
2. There is a considerable reduction in productivity if the illumination level is less or more than this standard illumination range of 700 to 820 lux. The reduction is higher at lower ranges than the reduction at higher ranges.
3. The percentage of rejected jobs is lowest in the standard range and increases in lower and higher ranges.
4. It is concluded from the present study that a certain range of illumination intensity is required for optimum output if other conditions remain the same. However, this range varies with the nature of the job to be performed.
5. Thus, the desired illumination range must be determined for each job under a given condition to have optimum productivity.
6. The provision of the intensity of the lighting range is bound to be most economical as compared to high or low-intensity lighting ranges. A high lighting range requires more voltage and less output, whereas the lower lighting range may consume less power but at the cost of low output and adverse effects on the workers.

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