C-2-4　歩行のメカニズム

(1) 歩行サイクル

歩行サイクルは，片足が踵から着地しつま先で蹴って床から足が離れるまでを 1 歩行周期とし，1 歩行周期は 5 段階(Phase)に分けられる。以下に各 Phase における歩行動作と足圧分布図を図 2-4-1 に示す。

＜Phase1＞　足が地面に触れた瞬間で，床との接触は踵によってなされる。

＜Phase2＞　両足接地の期間である。この状態は最初の床接地に始まり，もう一方の足が地面から離れるまで続く。

＜Phase3＞　片足支持期間の前半である。色付きの足の膝・股関節が伸びている間に，もう一方の足が接地している足を越えて前進する。

＜Phase4＞　片足支持期間の後半である。色付きの足の踵が浮くときに始まり，もう一方の足が地面に着くときまで続く。

＜Phase5＞　歩行サイクルの最後の接地状態であり，2 度目の両足接地期間である。

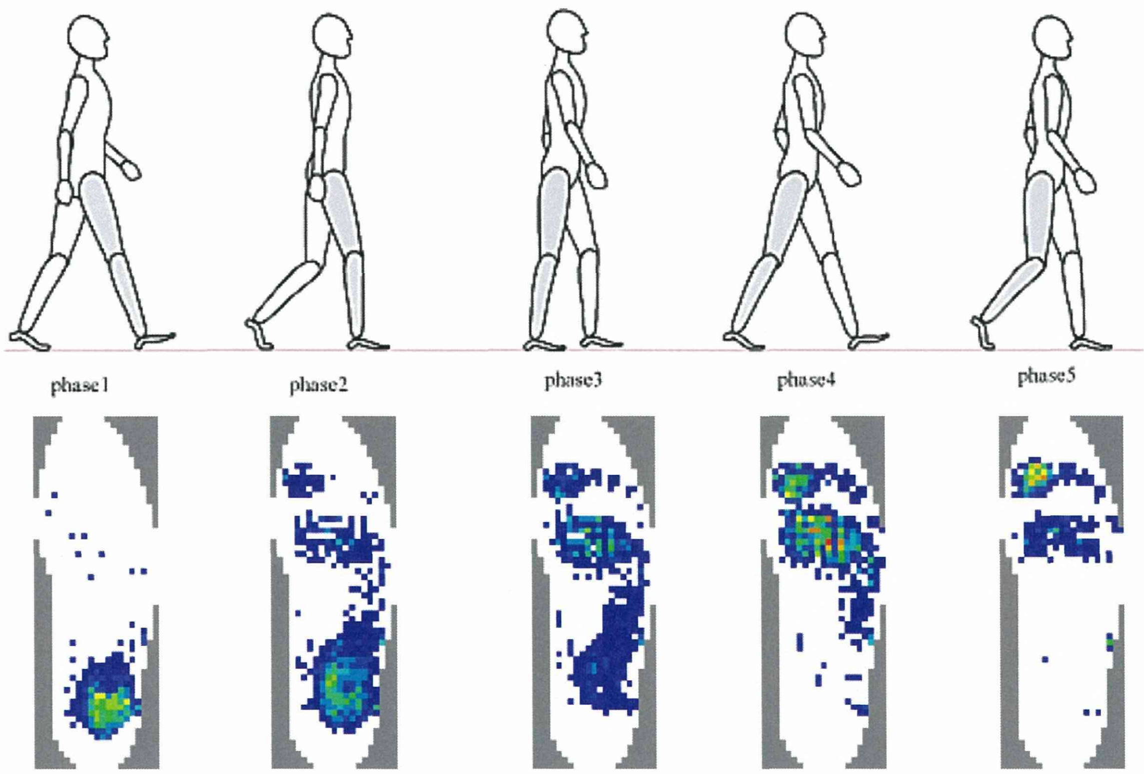


図 C-2-4-1　歩行動作と足圧分布図

(2) 歩行時の足底荷重の時間変化

次に，平坦路における足底が受ける荷重の１歩行周期中の時間変化の例を図 C-2-4-2 に示す。この図のようにM字型を示す。始めに現れるM字の左の山部は，Phase1 から Phase2 にかけて踵の着地時のインパクトを表し，谷部は，Phase3 においてもう片方の足が着地足を越している時で，右の山部は Phase4 から Phase5 にかけてつま先が地面を蹴ることで現われるものである。つまり，平坦路での荷重の時間変化がM字型のグラフで現われる歩行はこの Phase1 から Phase5 のように踵で着地し，つま先で地面を蹴るという理想的な荷重の移動ができていることを表す。一方，スラットコンベア上はうまく歩行ができずにつま先で地面を十分に蹴ることができておらず右の山部が現れず図 C-2-4-3 のようになる。

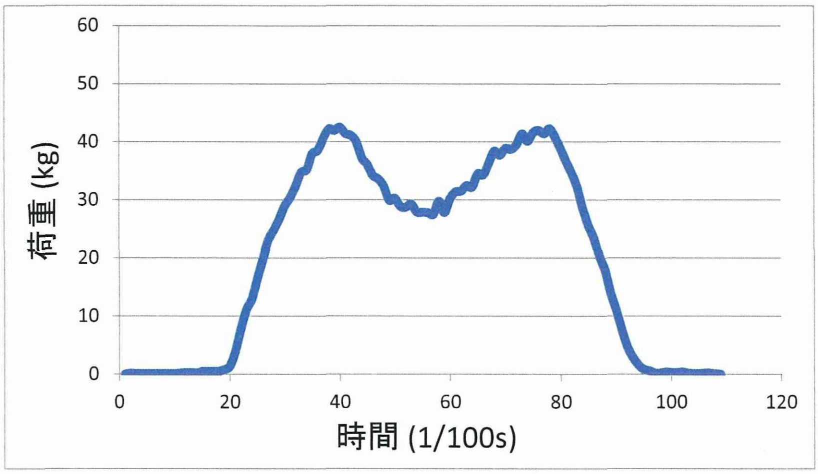


図 C-2-4-2　平坦路の歩行における荷重の時間変化

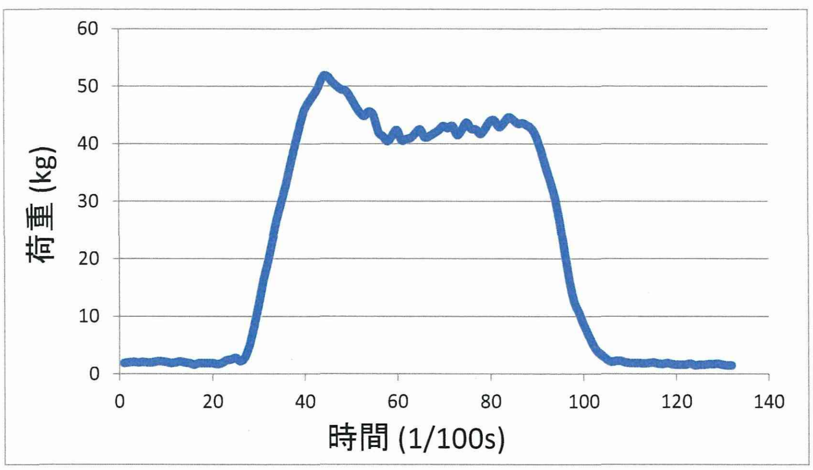
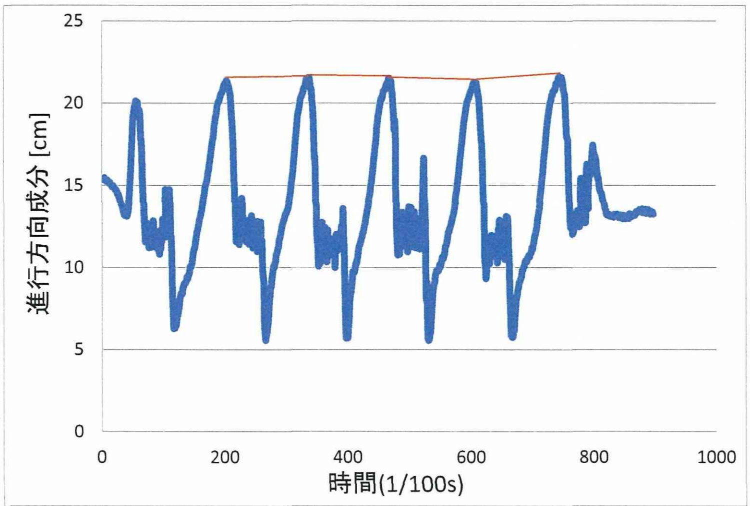


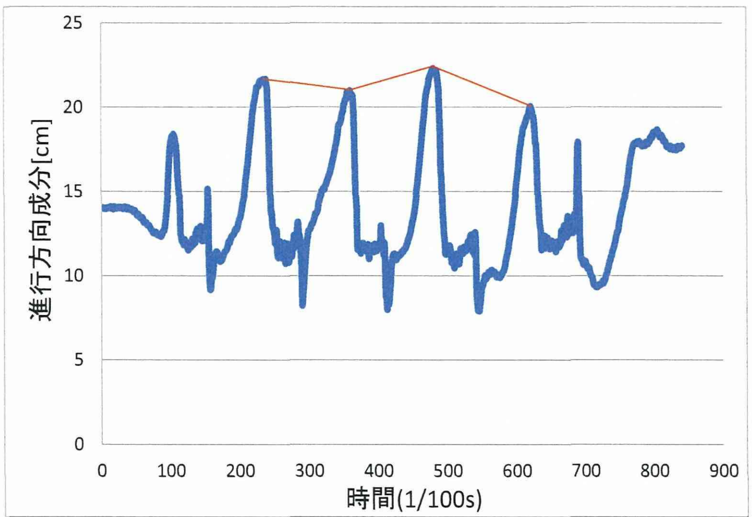
図 C-2-4-3　スラットコンベア上の歩行における荷重の時間変化

(3) 荷重中心移動

足底の圧力分布は，Phase1 から Phase5 へ進むにつれて荷重は踵からつま先の方へ移動している。ここでは，圧力分布の代表値として圧力分布の重心(荷重中心)を用い，その時間変化を比較した。平坦路とスラットコンベア上の歩行の例を図 C-2-4-4 に示す。



(a) 平坦路の歩行



(b) スラットコンベア上の歩行

図 C-2-4-4　荷重中心の時間変化（進行方向成分）

この図ではピーク値は歩行サイクル Phase4 から Phase5 にかけて，つま先が地面を蹴って離れる位置を表している。この位置に着目すると平坦路での歩行はほぼ一定であるのに対して，スラットコンベア上ではゆらぎが現れる。

C-2-5　荷重中心のゆらぎによる安全性評価

ここでは歩行路環境とつま先の荷重中心のゆらぎを比較した。荷重中心のゆらぎは，ピークの位置の標準偏差を用いた。

C-2-5-1　スラット間隔による比較

はじめに, スラットコンベアの間隔 150mm と 100mm で比較したグラフを 3 人の被験者について図 C-2-5-1 から図 C-2-5-3 に示す。左右の足で小さい方の偏差で比べる。150mm に比べて 100mm の偏差が小さくなっており，被験者の印象と一致している。

次に，モックアップ実験においてスラット間隔を 150mm から 120mm，90mm，60mm と段階的に狭めて比較したグラフを図 C-2-5-4 に示す。この図によると 90mm から 60mm の間で大きく偏差が減少している。これも被験者の印象と一致している。

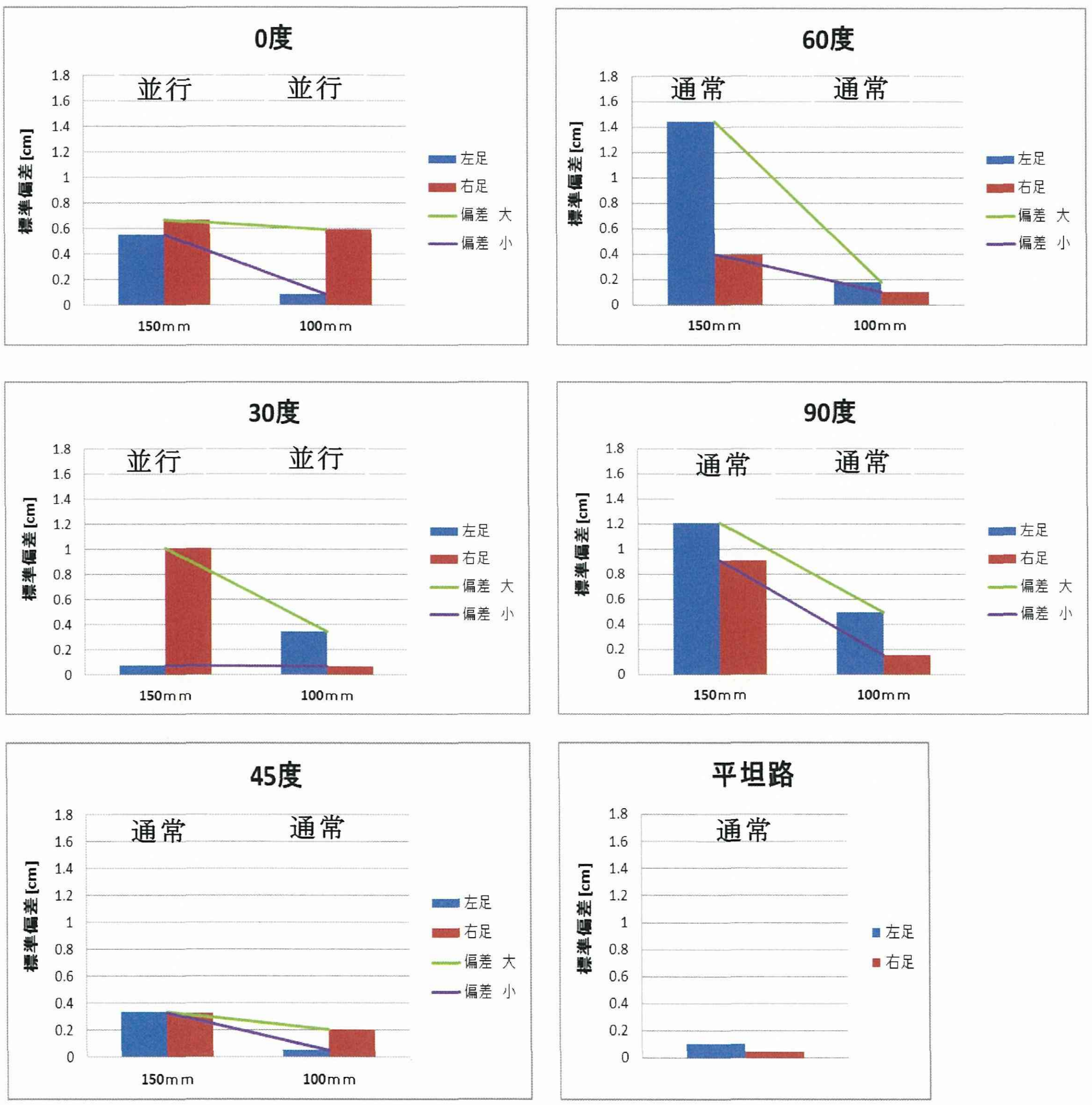


図 C-2-5-1　スラットコンベアのスラット間隔による比較（被験者 A）

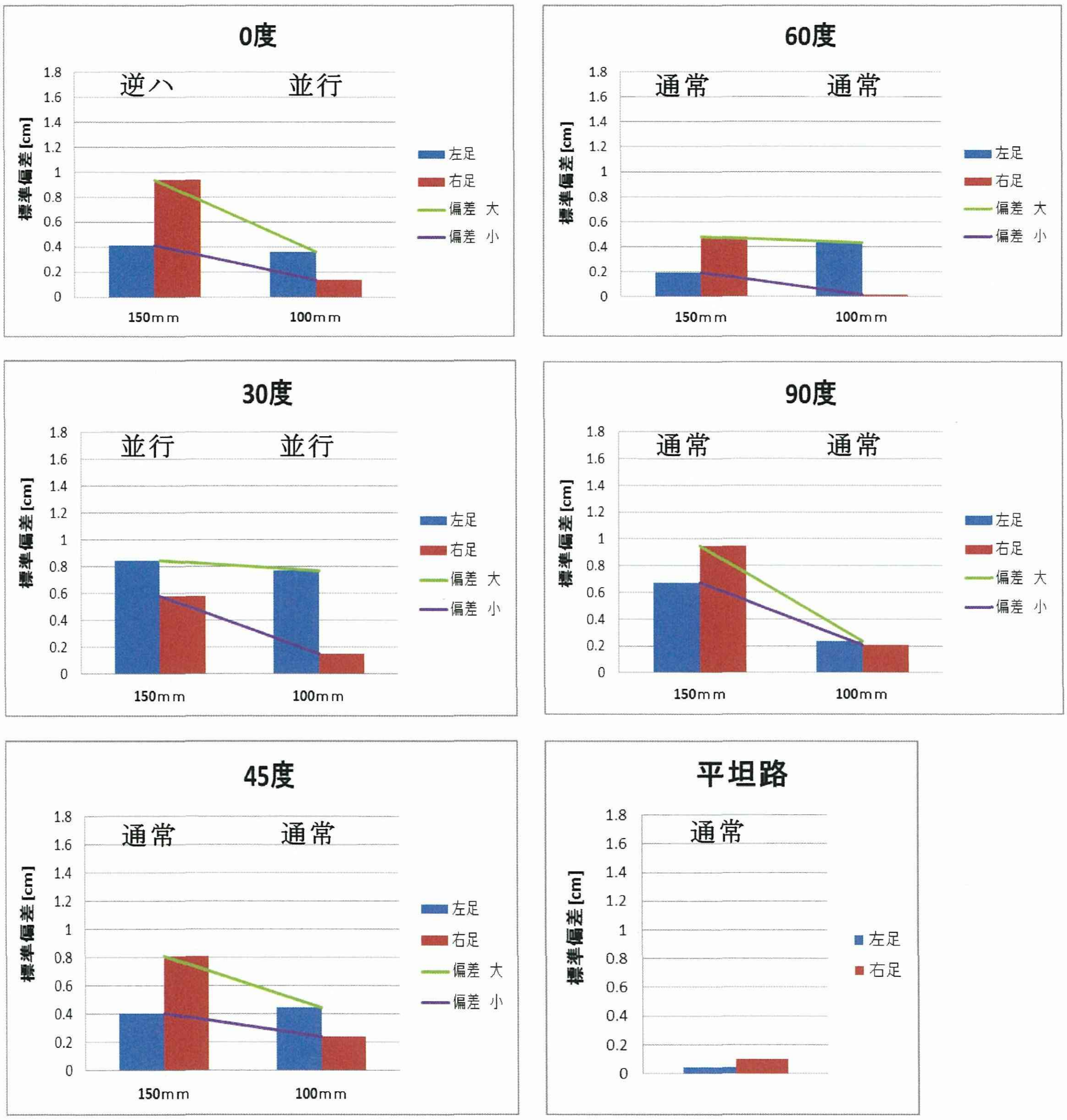


図 C-2-5-2　スラットコンベアのスラット間隔による比較（被験者 B）

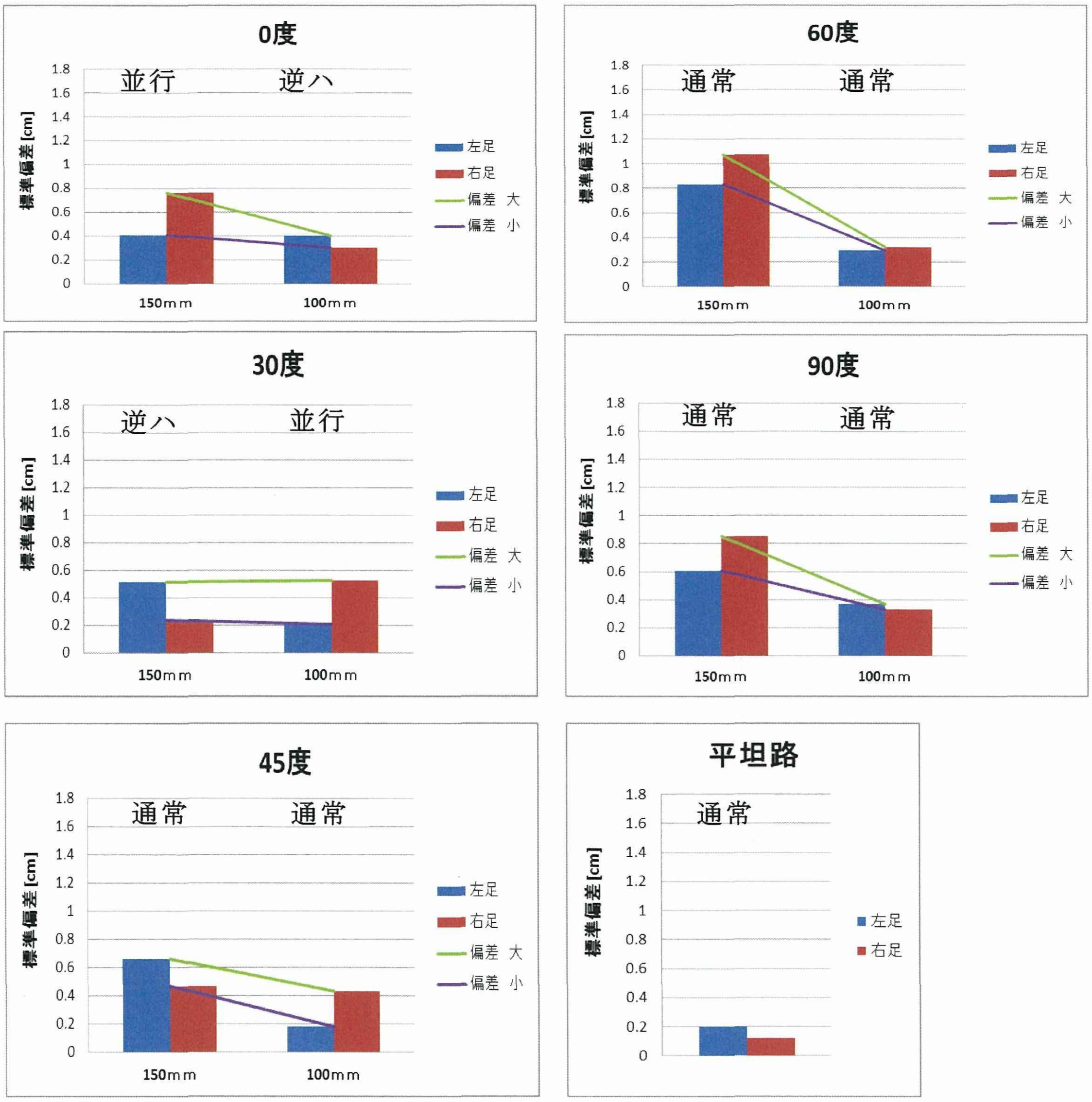


図 C-2-5-3　スラットコンベアのスラット間隔による比較（被験者 E）

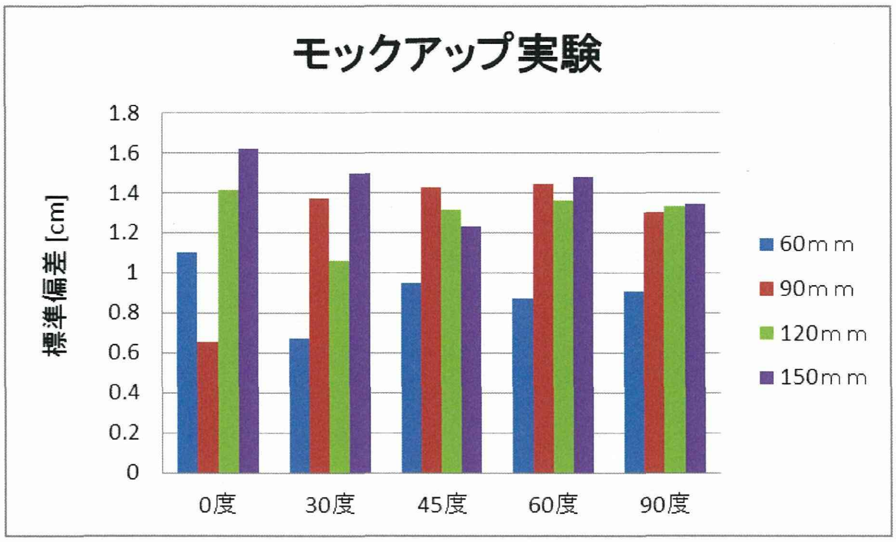


図 C-2-5-4　モックアップのスラット間隔による比較

C-2-5-2　歩行角度の検討

スラットコンベアでの歩行について，歩行角度による変化を比較した。図 C-2-5-5 から C-2-5-7 に示す。この図より，概ね 45 度と 60 度で極小を示す。これはアンケート(表 C-2-5-1)における，45 度，60 度方向によく歩き，歩きやすいと感じている結果と一致する。よって，スラットコンベア上での歩行角度は 45 度以上が望ましく，特に 45 度，60 度で安定した歩行がしやすいことが分かった。

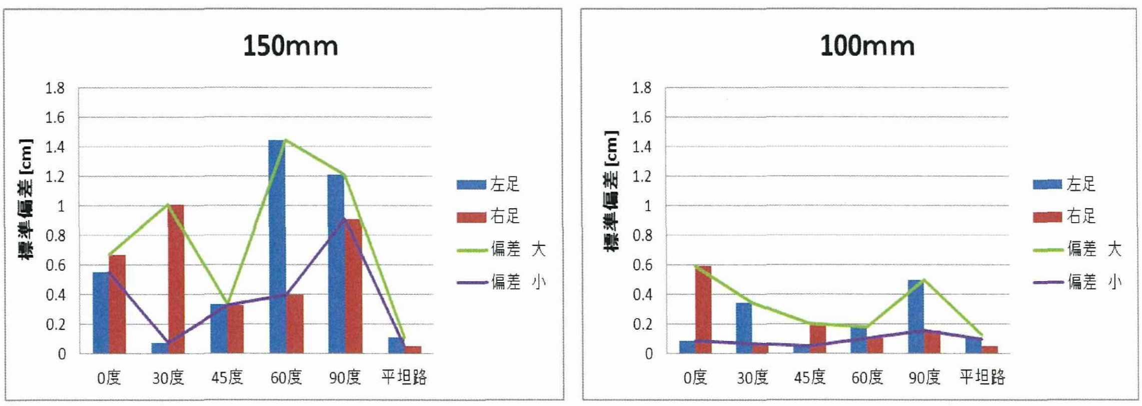


図 C-2-5-5　歩行角度による変化(被験者 A)

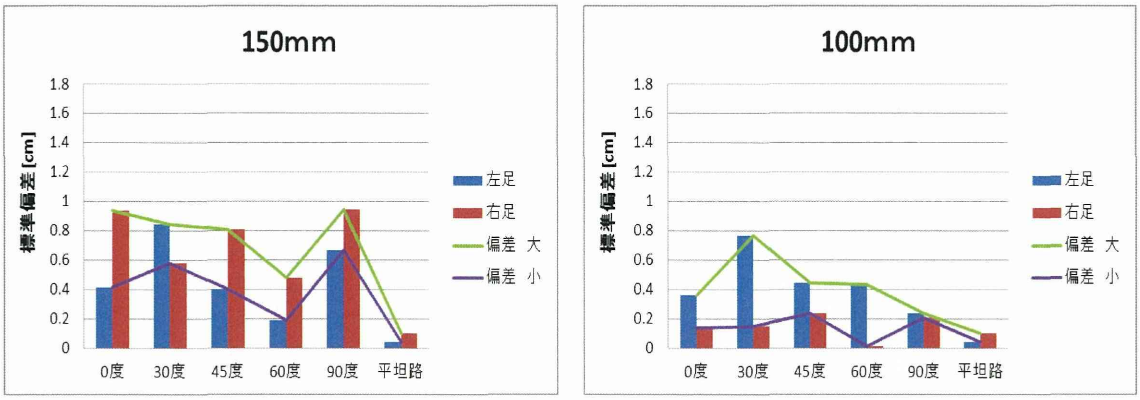


図 C-2-5-6　歩行角度による変化(被験者 B)

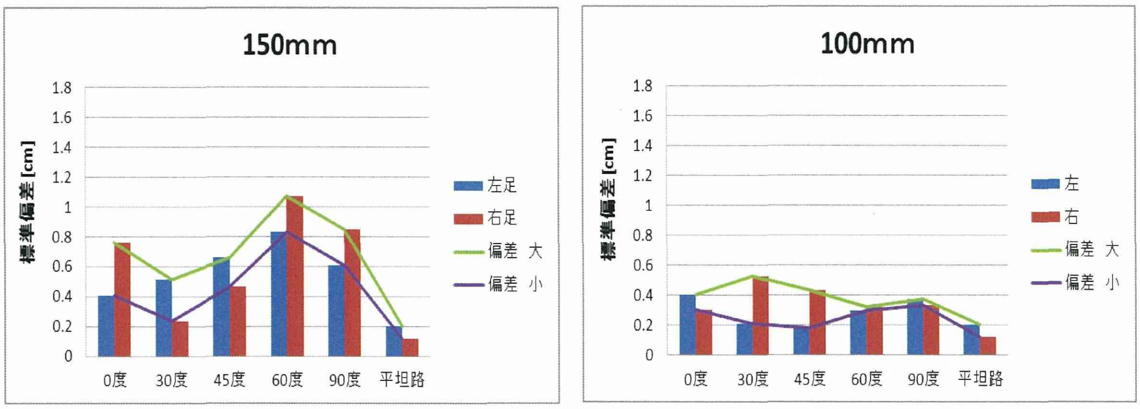


図 C-2-5-7　歩行角度による変化(被験者 E)

表 C-2-5-1　アンケートによる被験者がよく歩く角度

スラット間隔 150mm		歩行角度 0 度	30 度	45 度	60 度	90 度
被験者	A			○	○	
	B					○
	C				○	
	D			○		
	E				○	
	F	○	○			

スラット間隔 100mm		歩行角度 0 度	30 度	45 度	60 度	90 度
被験者	A		○			
	B				○	
	C		○		○	
	D			○		
	E		○	○		
	F			○		

D　考察

（1）リスクアセスメントツール

昨年度において，　作業・安全のためのリスクアセスメントについて，PDA 作業・安全観測ツールを造船所現場での適用性への改善や，リスクアセスメント手順書の整備によりリスクアセスメントの定型化，安全対策案を立案する手助けとなるハザード・対策展開法による対策の立案方法の検討からリスクアセスメント手法の整備を行い，今年度は実際の造船所への現場の適用から課題点の抽出を図った。主な適用工程としては，造船所の鋼材切断向上での鋼板切断工程と，この工場内の搬送工程として，以下を確認した。

- PDA 作業・安全観測ツールは作業や安全の定量化から「見える化」には有効なツールであることが分かった。
- 得られた観測データについて幾つかの集計方法の検討を行った。主には要素作業と不安全状態，および不安全状態での要因について検討を行い，安全上の課題を抽出する際に有効な方法であることを確認した。
- ハザード・対策展開法による対策の立案方法の検討を行い対策上の課題抽出に有効であることを確認した。

（2）計測に基づく安全歩行の評価方法の検討

計測に基づく安全歩行の評価方法の検討として，スラットコンベヤ上の歩行やモックアップ上での歩行について足圧センサーを用いた検討を行った。

- 安定な歩行路環境である平坦路上の歩行の際に現れるゆらぎの特徴量とスラットコンベヤ上の歩行のゆらぎの特徴量について偏差を用いて検討を行い，スラット定盤上の歩行路環境の安全性の評価について検討を行った。
- 昨年度のゆらぎの一致度による検討と同様な結論が得られた。
- 身体バランスのゆらぎを小さくし，身体バランスを崩すリスクを抑えるために，リスクコントロールオプションとして，スラット間隔の検討の必要性とスラット定盤上での歩行角度の取り方について，効果の推定を行った。
- 実際の現場に設置されているスラット間隔の異なる定盤での実際の計測とモックアップでの実験による比較を行い同様の結論を得た。

今後は造船所での工程での適用例を増やすことや，他の歩行環境状態について計測方法の検討を行う計画である。

E　結言

本研究では，作業・安全の向上ためのリスクアセスメントのシステム構築を行い，PDA 作業・安全観測ツールを造船所現場での運用性を高める改善や，リスクアセスメント手順書の整備によりリスクアセスメントの定型化から整備を行い，安全対策案を立案する手助けとなるハザード・対策展開法による対策の立案を提案してきている。これらを基にして作業安全のためのリスクアセスメントを実際の建造現場の切断工程に導入して試験的な運用

を行い手法の有効性を確認した。さらに，切断工程での安全対策への課題として，定盤上の身体バランスの問題に対して，モックアップ実験や実際での造船所での歩行計測を行い，歩行時の安全性の評価の検討を行った。リスクアセスメントから対策の検討までを一貫して行い，適用した方法の有効性を確認した。

F　健康危険情報

該当なし。

G．研究発表

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H．知的財産権の出願・登録状況

なし

Ⅱ．研究成果の刊行に関する一覧表

雑誌

発表者氏名	論文タイトル名	発表誌名	巻号	ページ	出版年
Takeshi Shinoda, Takashi Tanaka	Development of Risk Assessment Methodology for Occupational Safety in Using Work Observation Technique	Proceedings of SNAME Annual Meeting	2012	221-232	2012
田中 太氏，篠田岳思，柳原 史希，熊田 徹	造船工場の作業・安全向上のためのネットワークカメラ観測システムの構築に関する研究	日本船舶海洋工学会講演会論文集	第15号	131-132	2012
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竹内淳，　篠田岳思，松尾充洋	造船所における暑熱下作業環境の評価に関する研究	日本船舶海洋工学会講演会論文集	第14号	429-430	2011

Ⅲ．研究成果の刊行物・別刷

Development of Risk Assessment Methodology for Occupational Safety in Using Work Observation Technique

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Abstract

It is a challenge to prevent an occupational accident in any industrial activities. The aim of this study is to improve the safety and reduce the risk of occupational accidents at shipyard through developing a risk assessment.

This paper describes the concept and methodology of risk assessment for occupational safety and its application. The methodology introduces an effective and useful assessment procedure to construct the database based on the past occupational accidents occurred at shipyards. Quantitative methodology is developed to understand the unsafe working conditions and environment at the shipyard by the convenient handheld to collect the data with Information Technology. Some examples of effective hazard countermeasures are suggested and a feasibility study is conducted to improve a walking environment at shipyards.

Key words: *Occupational safety, Risk Assessment, Work and safety observation system*

1. Introduction

In recent years, occupational accidents at the shipyards have been increasing with the increasing volume of shipbuilding in Japan as shown in Fig. 1. While total number of occupational accident stays steady, the occupational accident severity rate remains still high level in a situation that is compared with other manufacturing industries [1]. This type of accident has been reported widely in the media in Japan that the shipyards are urged to take an action to improve occupational safety with the manner that doesn't interfere with the productivity. In order for the ship building industry to be sustained, succeeded, and progressed, it is the prime issue to enhance the occupational safety at the working place, while it is equally important to succeed its heritage and the techniques.

This study aims to formulate a safety improvement measures through developing methodology of risk assessment. We take the following steps:

1) Development of methodology of risk assessment
2) Creation of an occupational accident occurrence model to satisfy the flow of developed risk assessment
3) Development of handheld work and safety observation system to satisfy the created occupational accident occurrence model
4) Implementation of developed work and safety observation system to an actual shipyard
5) Risk assessment by actual data from observation system
6) Consideration of safety improvement by experiment for working circumstances

Above steps are described in the following section.

2. Risk assessment by introducing work/ safety observation Method

The annual report from Shipbuilder's Association of Japan reports work-related injuries from occupational accidents of various causes at the shipyard including death accidents. In the report, a number of "human related factors" are noticed as the cause of the accidents such as a human error in operation procedures and careless actions, and insufficient maintenance. Generally, occupational accident is often treated as an independent cases of individual mistakes, and it is a seldom case to be considered as an occupational disaster.

At the shipyard, the state and the kind of unsafe working condition have been difficult to assess because, in general, the workers perform their job independently while it is important to grasp the type of unsafe manner and its frequency when the risk assessment methods are introduced.

Some or the risk assessment methods recently introduced in a number of shipyards are often focusing on "the frequency of risk" or "the degree of danger". The primary evaluations of these methods rely on some subjective and sensual judgment instead of more objective measure, such as quantitative measurement.

In order to quantify the job security factors that are lurking at the working place, this study uses a small mobile device such as PDA (Personal Digital Assistant) to observe the safety level at the working place. PDA records simultaneously the samples

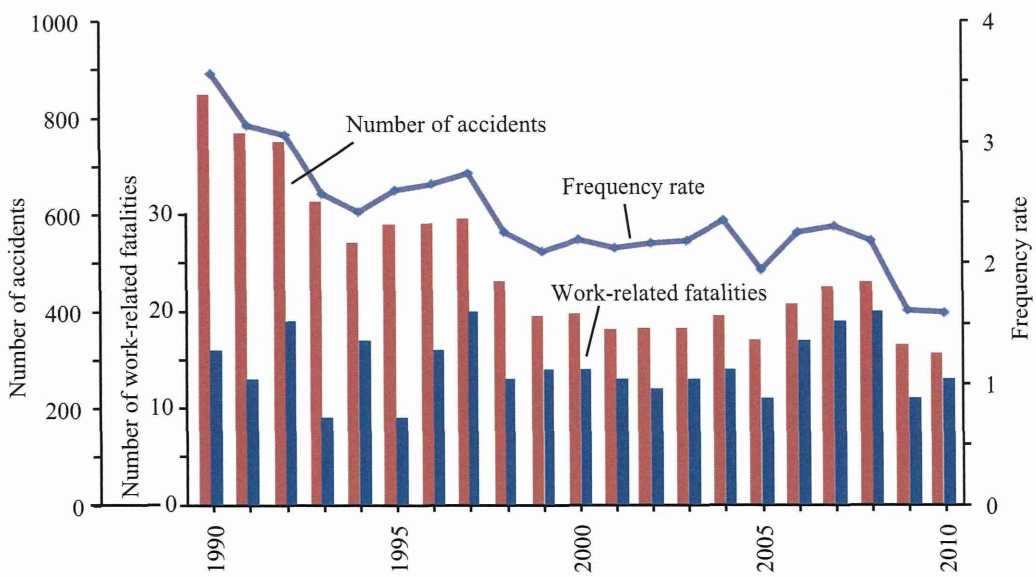


Fig. 1 Number and frequency rate of occupational accidents of shipbuilder's sector in Japan

of the types of works and the unsafe work conditions. It is the application of work observation based on IE (Industrial Engineering). By developing this tool, the work safety level at the shipyard was measured and the quantification of the work safety factors was attempted.

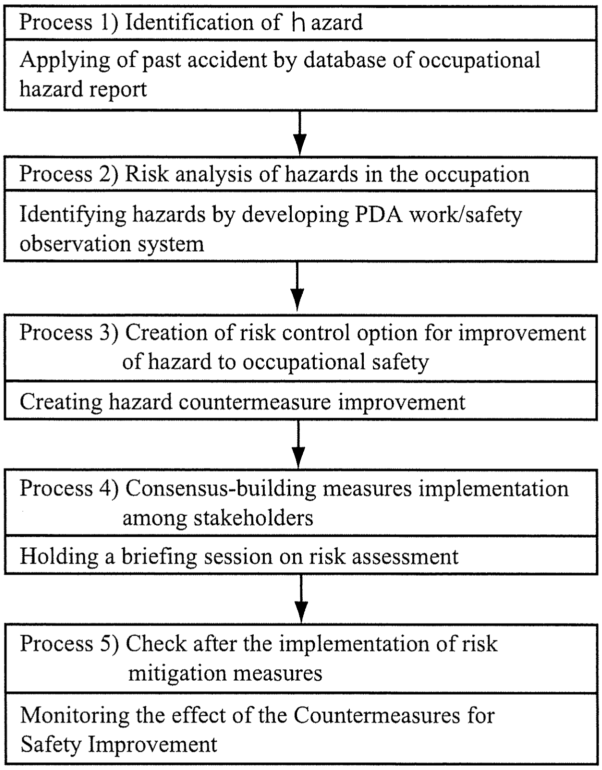


Fig. 2 Flow of developed risk assessment for improvement of occupational safety

2.1 Flow of risk assessment

The method of risk assessment is described in this chapter. The process and configuration of developed risk assessment is shown in Fig. 2 [2]. Each process is described as follows:

Process 1) Identification of hazards:
This process is to identify the potential hazards in the work which cause personal and material loss. The identification of lurking hazards should be determined by the references of the past cases of industrial accidents, near misses, violations found during safety patrols and work-site observations. In this case, the past occupational accidents reported at the test site were data based and hazard items are extracted.

Process 2) Risk analysis of hazards in the occupation:
This process is to examine the potential hazard in the work and analyze the risk based on the probability of accidents and the loss by given hazard. Here, by developing PDA work/safety observation tool, the quantification of the frequency of the lurking work hazards in aggregating is attempted. The work/safety observation items are simplified and stylized. Ingenuity of the operation of PDA tool is studied.

Process 3) Creation of risk control option for improvement of occupational safety:
This process is to study the measures to improve safety or reduce the lurking hazards in the work. In order to create the hazard mitigation, the methodology of hazard-countermeasure deployment is developed.

Process 4) Consensus-building measures implementation:
This process is to make the consensus among stakeholders with the risk for occupational accident at shipyard. A debriefing session among stakeholders is held after execution of each risk assessment to make the consensus to implement the measures to improve safety.

Process 5) feasibility check after the implementation of risk

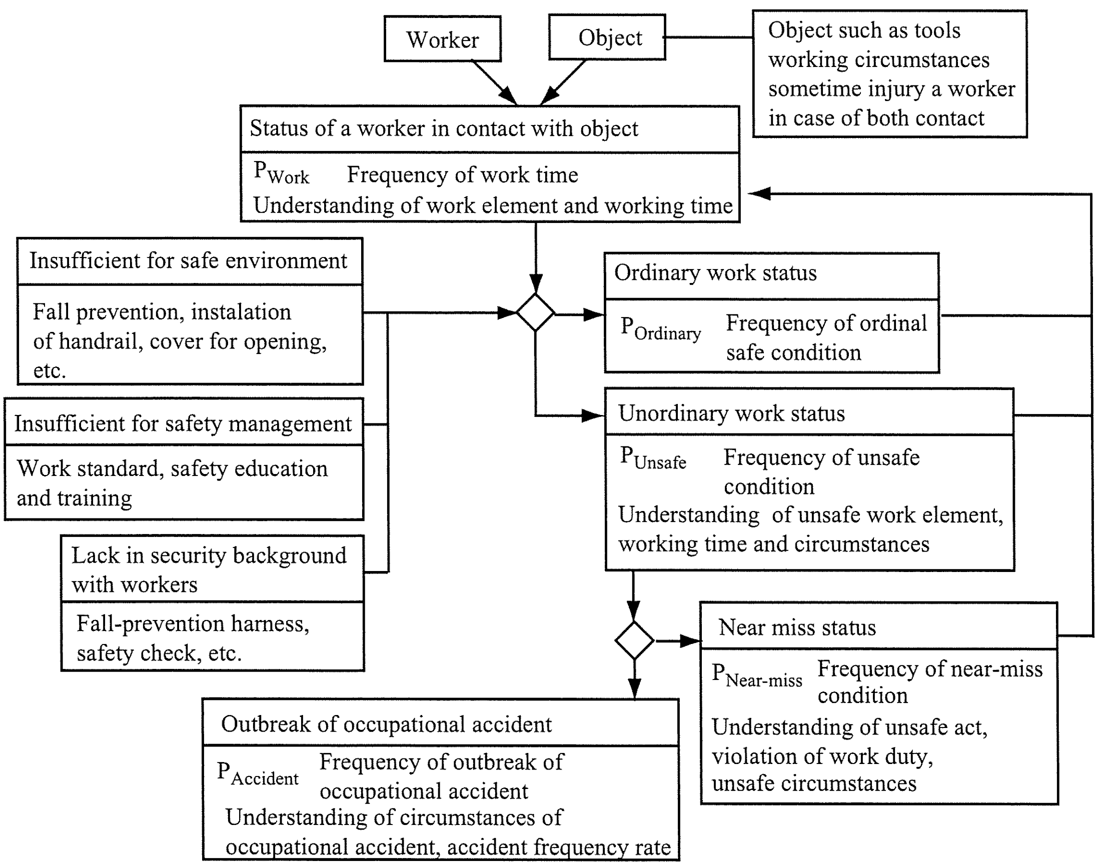


Fig.3 An occupational accident occurrence model

Table 1 Representative nine elements of observation items

Observation items	Purpose of obtainning observation data
1) Observation date	Comprehension of observeation time and hour
2) Name of observer	Implementation of interview after observation for comprehennsion of the reason why a person feels, reriability check of observer´s impression
3) Name of ship´s block	Comprehension of unsafe condition and working efficiency in the ship´s block
4) Process of shipbuilding	Comprehension of unsafe condition in the ship construction process
5) Unit work (person in charge)	Details of process of shipbuilding, person in charge
6) Element work	Details of unitwork or person in charge
7) Unsafe affairs	Human related affairs, safety management or affairs against the regulation at the shipyard
8) Circumstances at work site	Equipment, facilities, or working floor condition and so on.
9) Safe level	Judge of safe level according to the personal opinions by observer

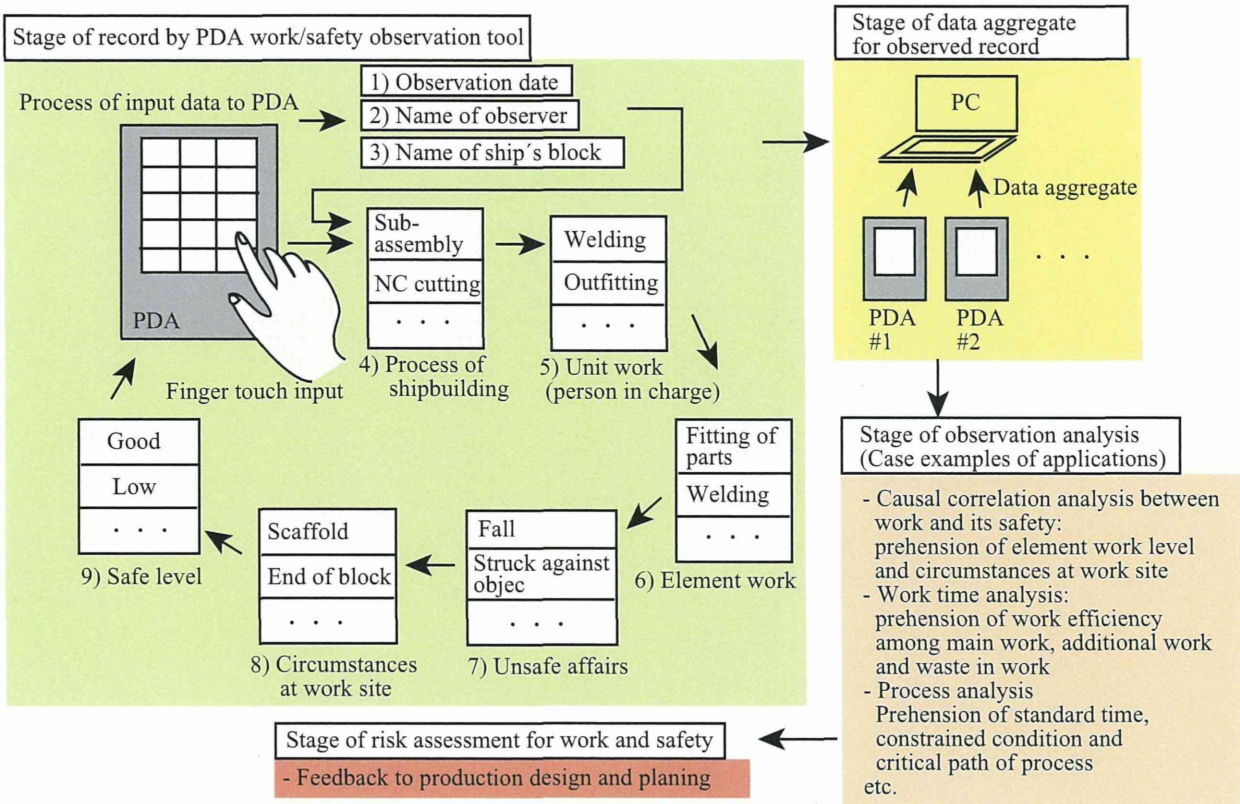


Fig. 4 A concept of PDA work/ safety observation system

mitigation measures:
This process is to evaluate the safety improvement after the implementation of measures and to verify the hazard risks to be maintained under acceptable level.

The feasibility of process 1 to 4 is examined at actual shipyard and the problems of application of created methodologies are examined. In addition, manual of risk assessment procedures is prepared to introduce to the shipyard. A flow of application for risk assessment from the selection of an occupational hazard, the PDA work/safety observation method, and the study for measures to improve safety is systematically organized.

2.2 Concept of the occupational accident occurrence model and the work and safety Observation

The concept of occupational accident occurrence model is illustrated in Fig. 3. The flow of this concept starts from the first contact of worker and object. Worker is inflicted by an injury when contacted in poor condition of either or both parts. When the safe circumstances are kept at working place, the ordinary status is maintained. But, unsafe circumstances such as insufficient safety condition of environment, insufficient safety management and workers without basic security knowledge would bifurcate to the unusual work status. Furthermore, a severe case of near miss status appears. If the worst happens, the flow would bifurcate to an outbreak of occupational accident. When factors concerning occupational safety are measured, the status of unsafe circumstance can be grasped. We address development of the methodology to measure unsafe condition such as frequency of P_{Unsafe} on the created accident occurrence model basis.

2.3 IE applied PDA work/ safety observation method

As a way to increase productivity, Industrial engineering (IE) has been applied in a various way at each shipyard in Japan. While maintaining a certain quality level, IE is a solution to reduce the waste of "personnel, materials, equipment and energy" in production. It improves the productivity and proposes the ways for cost down. In addition, the observation method is used to quantitatively assess the work status of current production.

In this study, in order to identify the risks lurking in the work

Table 2 Example of past occupational accidents in the process of NC cutting at the shipyard

Date Site of accident Type of accident	Summary of accident
August 9, 2007 Slat conveyor Fall on same level	He was engaged in steel plates cutting work as NC cutting machine operator. When he was crossing on a slat conveyor on the way to the house phone, he stumbled on the edge of slat and fell down to the conveyor.
March 22, 2008 Sorting area for cutting plate Struck against object	He was engaged in the transportation work of steel cutting plates. He was standing on an edge of the second plate from the bottom of six-tier plates. When he hoisted the two top plates by the electro magnet crane, the crane hoisted all six plates by strong magnetic power, but the two bottom plates which he was standing fell off onto the floor. The plates was bounding and strike his heel.
May 24, 2010 Slat conveyor Fall on same level	He was engaged in the finishing work on the slat conveyor. When he had stepped on a steel member (14mm x 330mm x 585mm), he almost fell backward. Although he tried to keep his balance up, he stepped off the conveyor and got his foot stuck into spaces of the slats.

(a) Slat type surface plate for NC plasma cutting machine

(b) Warped slat by thermal deformation

(c) Slat on the surface plate for NC laser cutting machine

Fig. 5 Circumstances around surface plate of slat type conveyor for NC cutting machine

quantitatively, a safety observation method is designed for observing the job performance and the unsafe work conditions at the spontaneously. It is an easier way to implement for workers. Also, conducting this method and watching each others' work provides the workers with better understanding or the job and safety.

2.3.1 Work observation methodology in IE

There are mainly two ways of job observation in IE such as continuous observation method and the instantaneous observation [3].

Continuous observation method is tracking and observing the behavior of workers at all times. This makes it possible to measure the work factors at actual working time without omitting any work factors. On the other hand, the negative side is that it takes time and labor to analyze the process as the observation that is made by one observer to one worker at a time.

In contrast, the instantaneous observation method prepares the observed items in advance and observes at random times. It records the observations on the action of the worker at the moment. The frequency of each work item is summarized and the ratio for the work that has been observed is calculated. This method makes it possible to observe more than one person and one can estimate the ratio of accuracy in a short time depending on the work element. The disadvantages are that observers have to prepare for the observation works in advance in order to observe the required items. Also, the observers must be familiar with the work that is applied to observation object.

Also, since momentary observations are summed to analyze in the instantaneous observation method, it may be difficult to convince as the results of the observation depends on stochastic process. Especially, when implementing the observation, staffs and engineers at shipyard want to study the relationship with works and the detail of status of works. In the case to increase the reliability on the short works, as it is shown in Appendix 1, it shows the problem processing large amount of data. In general, it takes lots of effort and work to aggregate the observations.

In this study, we developed the work/safety observation based on instantaneous observation method by introducing the portable PDA that is advantageous in collecting huge data for observation.

2.3.2 PDA work/safety observations system

When observing the field work at shipyards, it is often the case that the items to observe become wide variety from the needs to know the various work items and the relations among them. In general, the accuracy of the contents of the work enhances with increasing numbers of the work factors. On the other hand, taking a large volume of work elements requires a balance with increasing number of observations. Therefore, in preparation of the work/ safety observations, continuous observation is conducted to examine a minimum number of items and organizes the work factors concerning unsafe conditions.

Fig. 4 shows the system concept of PDA work/ safety observation. This system has four main stages: stage of record by PDA, stage of aggregate analysis for observed record, stage of observation analysis and, stage of risk assessment for work and safety. Detail of these stages are described as follows:

(1) Stage of record by PDA

In this stage observation items are sequentially shown at each step based on representative nine-elements observation items as shown in Table 1. The 1st item of the observation day is auto-

Table 3 Observation items of expected unsafe condition for NC cutting process

Categories of occupational accident Items of unsafe affairs	Explanation
Fall to lower level - Fall to pit for remaining materials	The worker is liable to fall to pit due to be taking their bad standing position.
Fall on same level - Fall down on the floor, slat conveyor	There is a dangerous occasion for worker to fall down on the floor and the slat conveyor due to stumble or slip.
- Riding on the moving conveyor	A worker is sometimes riding on the moving conveyor because they want to continue to work before the conveyor stop moving.
- No use of walking support plate	Walking support plate to keep safety on walking support plate was created through consulting workers each other, but they sometimes don' t use.
Struck by object - Clear person away from suspended load	Workers should clear away themselves from suspended load or indicate fellows to do, but they sometimes don' t do.
Struck by moving object - Struck by machine	Mainly NC cutting machine is liable to strike workers during their duties on conveyor.
Caught in or compressed by equipment or objects - Caught in by conveyor equipment	A worker is liable to be caught in conveyor roller or chain due to be taking their bad standing position.
Rubbed or abraded by friction or pressure - Rubbed by grinder	A worker sometimes moves to another working site without a stop to operating the grinder hand tool. It is liable to injure himself or other worker.
Contact with temperature extremes - A burn	A worker sometimes comes by sparks caused by NC plasma cutting machine and their cutting work with hand gas burner, or they touch to temperature extremes during their cutting duties on conveyor.
Others - No use of protector	A worker obligates to wear the fume mask to avoid a lung disease of pneumoconiosis, also wear the welding goggles.
- Forgetting of action of pointing and calling	The action of pointing and calling is a safety method for avoiding mistakes by pointing out at important things on safety with calling loudly. This action should be taken through consulting workers each other.

matically inputted by PDA. The 2nd item of name of observer working at shipyard is chosen from pre-registered name data. The 3rd item of ship block is also chosen from pre-registered block data. These three items are fixed at the event of start of observation. Next item is mainly concerned about relationship between work and safety to understand the status under the existing circumstances, finally the item of safety level is inputted based on the personal opinion by the observer. These items from 4th to 9th are circularly inputted until grasping circumstances at the observation site.

(2) Stage of aggregated analysis for observed record
The work/ safety observation record is aggregated from all PDA devises which is used to be observed at shipyard, and aggregated record is sorted in chronological order to build a database of the work/safety observation for analysis.

(3) Stage of observation analysis
The observation analysis are conducted depending on the aim of analysis such as pretension of causal correlation between work and its safety, work time analysis to find a waste time and an obstacle item to main work, and process analysis to comprehend standard time.

(4) Stage of risk assessment for work and safety
All results of analysis are made the most use of risk assessment for work and safety.

In this way, by using PDA work/ safety observation tool, the element works are quantitatively associated with unsafe condition.

This PDA system is developed by the program language of Microsoft Visual Basic. NET. And the flow of screen of PDA is designed to be controlled by XML (Extensible Markup Language). It is easy to apply and modify for another observation items. Furthermore, the developed system provides the work/ safety observation database based on XML because it is easy to exchange the database to CVM (Comma Separated Value) file and convenient to analyze the database by a merchandise spreadsheet application software.

The PDA as an input device is an iPAQ212 made by Hewlett-Packard. As the size of the screen is limited to 4 inches (83 mm x 62 mm), considering the clarity as well as the convenience in data input, touch the screen panel is designed. Maximum of 15 elements could be proceeded in one observation item in the program.

3. Implementation of PDA work/safety observations

In the shipyard of the research field, in order to chase the increase of production, the new cutting factory is established in February 2008. It is equipped with three NC (Numerical control) plasma arc cutting machines and two laser cutting machine. In this factory, the work processes is divided into 12 such as the process of unloading steel plate from ship, the process of NC cutting, the process of cutting by eye tracer, the process of shaping groove surface for welding, the process of leading to each assembly shipped by trailer to the work process stage and so on. The work is staffed with 56 workers in total. This paper mainly describes a risk assessment applied to the process of NC cutting, using an example of accident, in which job is performed on unsteady steps.

3.1 Identification of hazard on the process of NC cutting

There are some potential hazard and some occupational accidents in the process of NC cutting at shipyards in Japan. At shipyard where is introducing PDA work/safety observations, 3 cases of occupational accident have occurred since 2008 when

Table 4 Input items into PDA work/ safety observation

Observation items	Details of imput items		
1) Observation date	Automaticaly imput by PDA		
2) Name of observer	Selection from registration name list		
3) Name of ship's block	(Skip in this observation)		
4) Process of shipbuilding	- NC cutting process		
5) Unit work	- NC operator		
6) Element work	NC machine related work - NC operation - NC data check -NC machine monitoring	Aditional work - Code writing on cut members - Grinder tool work - Work of finishing touch with hand gas burner - Cutting work to remaining materials with hand gas burner - Preparation for tools - Conveyor operation	Assistance work - Crane transportation assistance Others - Moving on conveyor - Moving - General safety confirmation - Cleaning - Rest, Standby
7) Unsafe affairs	Same unsafe items as Table 3		
8) Circumstances at work site	Observing mainly following working floor condition: - Large size steel plate - Small size steel plate - Slat conveyor for plasma cutting machine - Slat conveyor for laser cutting machine - Pit side at the ends of conveyor	- Safety aisle - Walking support plate - Stairs - NC control platform	
9) Safe level	A observer's subjective assessment: - Good - Somewhat insufficient - Insufficient	- Violation of safety regulation - Near miss accsident	

new factory are established through analyzing the database of that factory during 10 years from 1989 to 2011. And the other 13 cases of occupational accident are found in this process at the shipyards in Japan through analyzing our constructed database during 5 years from 2004 to 2008 [4][5].

Some cases of occupational accident are shown as examples in Table 2. Especially typical accident of the process of NC cutting are concerning mainly on the slut type surface plate of NC cutting machine. The main causes are closely related to losing balance and crane operations. The sluts mounted vertically on a conveyor are used to support the steel plate under cutting by plasma or laser torch ejecting high temperature gas.

Fig. 5 shows photos of the slut type surface plate around the site of NC cutting machine. On the plasma arc cutting machine, the space between each slat is150 mm. The shape of slats are highly deformed after plasma arc cutting processes as shown in Fig. 5(b). On the other hand, on the laser cutting machine, the space between each slat plate is 100 mm as shown in Fig. 5(c), and the shape stays unchanged after laser cutting processes. The accidents mainly have occurred around these spaces. It can be assumed that the slats might provide the cause of accidents. We focused the risk assessment on this working area.

There are some following hazards that are caused by the gas cutting work with gas burner: 1) a burn, a fire, a clothing fire and explosion by scattered regulus or spatters with spark, 2) a burn on hand, foot, skin, eyes by spark, 3) onset of metal fume fever or welder's pneumoconiosis, 4) thermal fever by work in hot environment.

We extracted some expected unsafe manners of worker by analyzing the past cases of occupational accident and observing worker's acts at working site of implementation of observation study. After this study process, we defined the items of unsafe affairs as shown in Table 3. It was classified into the 21 categories of occupational accidents of Ministry of Health, Labor and Welfare. The items of unsafe affairs are including security background with workers, work safety regulation in the working site through consulting with workers themselves such as the safety movement of use of walking support plate, observance of pointing and calling. Pointing and calling, which is common sign to remind cautions in Japan, is to keep occupational safety for avoiding mistakes by pointing at checking points and calling out.

3.2 PDA work/safety observation items

Risk analysis of hazard in the process of NC cutting was carried out by introducing the PDA work/ safety observations tools through 2009 to 2011.

The staff in the NC cutting process is dived by unit of the work such as NC operators, crane operators. The element work of unit work, unsafe confirmation and working circumstances in each working role were decided by pre-obseration. Table 4 shows the items of PDA work/ safety observations for NC operators as a practical example.

In addition, fifteen element work items were defined including the main task of NC operator such as NC operation, NC data confirmation, moving on conveyor, crane assistance and so on. Six items were defined as unsafe condition concerning to this work including falling to pit for remaining materials, falling on same level as on the slat conveyer, contact with NC machine, burn by using hand gas burner, fail to wear protection equipment and wraparound by roller chain of conveyer.

Six working circumstance items were defined according to the state of the floor such as on the surface plate, steel plate, conveyer and so on.

On the basis of a subjective assessment by observer's own safety impression, the safety levels are defined. The safety level of "good", "somewhat insufficient" and "insufficient" are added to "violation " for violating safety regulations in the factory and "near miss to accident" for the event directly related to the accident. In addition, when observing inadequate safety action at working and violation to work safety, the observer was to call attention to workers at the scene.

3.3 The result of PDA work/safety observation

Some effective results by the PDA work/safety observation are shown in this chapter.

Fig. 6 shows change of ratio of element work by an effect of number of observation in the process of NC plasma cutting.

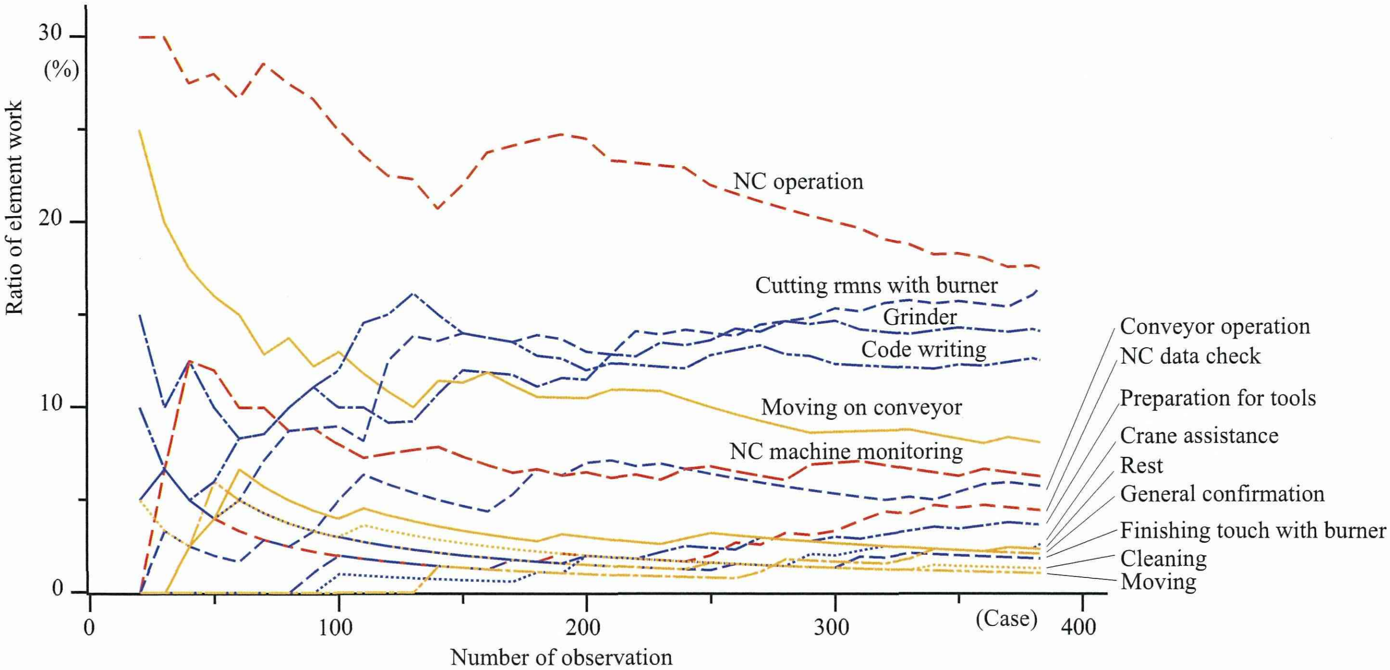
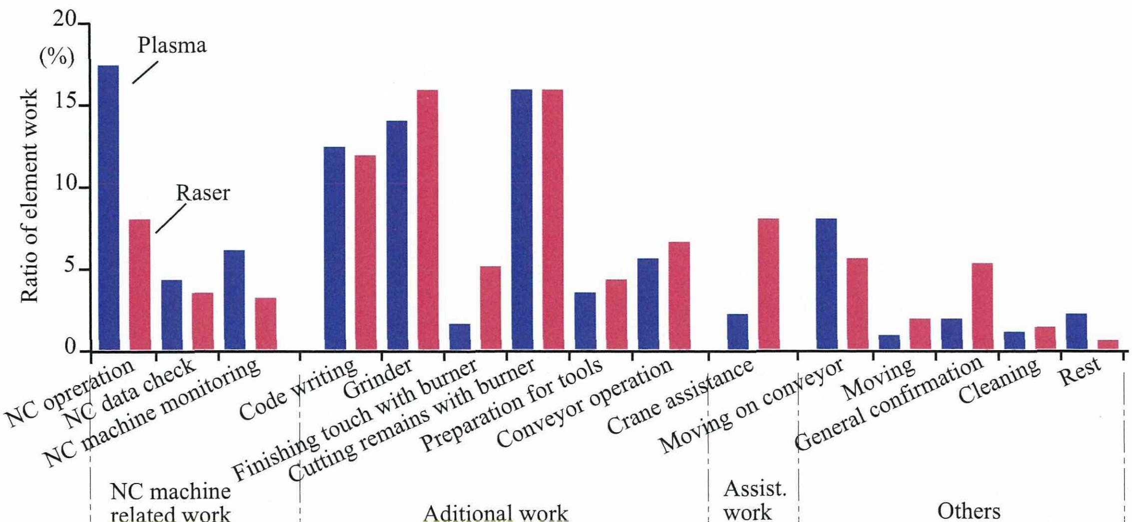


Fig. 6 Change of share of element work by PDA observation
under the process of NC plasma cutting process



	NC machine related work	Aditional work	Assist. work	Others
Plasma	28.2	53.8	2.6	15.4
Raser	15.1	61.3	7.9	15.7

Fig. 7 Comparison with ratios of element work by PDA observation
under the process of NC plasma and raser cutting

These curves converge certain percentages of each element work after approximately 160 cases of observation with moving slight ups and downs. This result also suggests that necessary number of observation would be approximately more than 160 cases. These converged values show the ratio of each element work for this process.

The details of ratio of each element work are shown in Fig. 7. The values at the point of 380 cases and compare with the values in the same point of the observation result that is similarly gained under the process of NC laser cutting. The trend of ratio is almost identical for both observations, but some differences are found. The NC machine related work which is major work in this process shared around 28.2% on plasma cutting and 15.3% on laser cutting. NC operation on element work showed substantial difference in both ratios, so did crane assistance for crane operators.

The main reason of the difference is machine operation. In the item of NC operation, NC plasma cutting machine needs more expendables than laser cutting machine. So the difference appears in this item. And in the item of crane assistance, the cutting members of large size with thick plate are cut by NC plasma cutting machine. On the other hand, the cutting members of small size with relatively thin plate on NC laser cutting machine, so cutting members are increase. Furthermore, in the item of finishing touch with burner, the laser cutting process needs to additionally chamfer the corners in order to correspond to the PSPC regulation that is Guidelines for Performance Standard for Protective Coatings contained in IMO Resolution.

As shown in this example of observation, this observation method makes it easy to analyze the work status on such difference of NC cutting machines.

Table 5 shows some of the results that are aggregated to find