ISSN 1392 - 1207. MECHANIKA. 2006. Nr.5(61)

Human errors play a remarkable role in sheet metal industry

M. Ollikainen*, J. Varis**

**Lappeenranta University of Technology, P.O. Box 20, FIN-53851 Lappeenranta, Finland, E-mail: mikael.ollikainen@lut.fi*

***Lappeenranta University of Technology, P.O. Box 20, FIN-53851 Lappeenranta, Finland, E-mail: juha.varis@lut.fi*

1. Introduction

Constructions based on fabricated sheet metal parts are used in a wide range of different types of products. The need to produce growing amount of customized products at condescending expenses for the electronics and telecommunication industry is driving companies to find new ways to improve efficiency of different fabricating processes. One of these ways is to reduce the amount of production errors that add unnecessary production costs. Reducing production errors is not possible without understanding the prevailing situation. Therefore it is important to analyze whole production flow so, that production activities can be focused correctly.

Production error distribution in sheet metal production flow has been studied earlier and results are also published earlier [1]. This paper is based on the same field study carried out in three Finnish case factories [2].

The main objective of this paper is to analyze the origins of production errors (i.e. factor that actually causes detected production error) in the production flow of the sheet metal based constructions. By the word origins in this paper is meant the factor that causes the production error, e.g. malfunction in production machinery, human work error or defective raw material.

The production flow of a sheet metal part fabricating factory can be seen as a sum of four elements in this paper. These elements include materials, manufacturing technology, human work and supporting elements. Materials consist of raw materials, subcontracted components and purchased standard parts and also chemicals, etc. that are needed in different manufacturing processes. Manufacturing technology contains all production machinery needed in various manufacturing activities, tooling for production machinery, software needed in manufacturing processes and also different chemical processes needed in, e.g. surface treatment processes. Human work consists of direct work needed in manufacturing activities and also indirect human activities needed to support manufacturing activities, such as maintenance activities, quality control activities and production planning activities. Supporting elements contain production facilities and warehousing operations as well as logistics arrangements.

2. Production error specification used in field study

In this paper the production error can be seen as a deflection from a planned and “optimal” (production error free) production flow. Planned and optimal production flow can only be achieved when manufactured products are fault free and meet customer expectation in every stage of the production flow, because of that deflection various operations are needed depending on the situation.

- Defective products must be adjusted.
- Defective products must be completed.
- Defective products must be scrapped and new products must be fabricated.

This deflection may be exposed in the same point of the production flow where it is caused or it can progress in the production flow and it may be exposed later on in the production flow.

In this paper production errors are classified into fourteen production error types. The production errors are specified and this specification is presented in Table 1.

Table 1

Production error specification used in field study

PRODUCTION ERROR		ERROR SPECIFICATION
1 Human errors	11	Work error
	12	Interpretation error
	13	Setup error
	14	Incorrect NC-program
	15	Incorrect drawing
	16	Undefined error
2 Machine tool related errors	21	Error in NC-control unit
	22	Machine tool failure
	23	Operating error
	24	Insufficient maintenance
	25	Indefinable error
3 Tool related errors	31	Tool break
	32	Insufficient maintenance
	33	Setup error
	34	Indefinable error
4 Organizational errors	41	Old drawing
	42	Old instruction
	43	Defective drawing
	44	Defective work instruction
	45	Wrong work method
	46	Indefinable error
5 External errors	51	Defective purchase
	52	Defective subcontracting
	53	Corrosion damage
	54	Convulsion of nature
	55	Indefinable error
6 Previous work phase related errors	61	Work error in previous work phase
	62	Product out of tolerances
	63	Handling error in previous work phase
	64	External error in previous work phase

Table 1 (continuation)

	PRODUCTION ERROR		ERROR SPECIFICATION
		63	Handling error in previous work phase
		64	External error in previous work phase
		65	Indefinable error
7	Design errors	71	Defective construction
		72	Product impossible to manufacture
		73	Functional error
		74	Indefinable error
8	Surface treatment process related errors	81	Defective bath
		82	Soiled bath
		83	Wrong bath temperature
		84	Defective work instruction
		85	Indefinable error
9	Surface treatment equipment related errors	91	Wrong program
		92	Wrong hanging method
		93	Functional error
		94	Indefinable error
10	Warehousing errors	101	Dents / scratches
		102	Water damage
		103	Convulsion of nature
		104	Dirt in product
		105	Indefinable error
11	Transportation device related errors	111	Functional error
		112	Wrong work instruction
		113	Falling
		114	Indefinable error
12	Lifting device related errors	121	Functional error
		122	Wrong work instruction
		123	Falling
		124	Indefinable error
13	Raw-material related errors	131	Wrong material delivery
		132	Water damage
		133	Dents / scratches
		134	Indefinable error
14	Other unclassified errors	141	Write comments in section 4

3. Results

The number of the parts traced in the field study was 732.724 pieces and a total of 84.011 production errors were reported.

The production error distribution by the production error specification in each factories studied is presented in Table 2. Features shown in the table are presenting the percentage distribution of all production errors in each factory. In some cases features "0.0" is used. This feature does express that a production error exists but the share is zero in a one decimal system. Blank cell expresses that no production error exists in that error specification. Rows with no markings have been left out.

Table 2

Percentage distribution of all production errors by error specification in each factory studied (%)

	ERROR SPECIFICATION	Factory A	Factory B	Factory C
11	Work error	0.0	5.3	30.3
12	Interpretation error		0.7	13.5
13	Setup error		7.0	0.5
14	Incorrect NC-program		11.3	
16	Indefinable error			0.2
21	Error in NC-control unit	1.7		
22	Machine tool failure	13.2		
23	Operating error	1.5		11.1
24	Insufficient maintenance	0.0		
25	Indefinable error	0.5		4.7
31	Tool break		2.7	
32	Insufficient maintenance		16.0	
33	Setup error		13.3	
34	Indefinable error	3.4	5.4	0.2
41	Old drawing		0.0	
43	Defective drawing			11.1
45	Wrong work method	43.5	0.0	
51	Defective purchase	0.1	0.4	
52	Defective subcontracting		5.0	2.5
55	Indefinable error			5.7
61	Work error in previous work phase	4.4		0.2
62	Product out of tolerances	0.5		
63	Handling error in previous work phase	2.6		5.7
65	Indefinable error	14.7	0.0	8.9
71	Defective construction	2.7		
72	Product impossible To manufacture	0.3	30.9	
81	Defective bath	0.1		
93	Functional error	0.1	0.8	
94	Indefinable error	1.2	0.8	
101	Dents/Scratches	0.1		
105	Indefinable error		0.0	
113	Falling		0.4	
133	Dents/Scratches	0.5		3.0
141	Write comments in section 4	8.9		2.4

4. Analysis

For analysis the origins of the production errors will be shared into four categories in this paper. These categories are human activity based errors, manufacturing technology based errors, material based errors and other errors category. In this share the following criteria of evaluation has been used.

In the human activity based errors-category the production errors are based on:

- work error;
- interpretation error;
- faultiness of work instruction, drawing, e.g.;
- forgetting of matter;
- lack of interest;
- careless mistake;
- unskilled workforce;

- design error.

In the manufacturing technology based errors-category the production errors are based for:

- malfunction of machine tool, NC-control unit e.g.;
- tool breakage or malfunction.

In the material based errors-category the production errors are based on:

- defective purchase of external part;
- defective subcontracting part;
- defective raw material supply.

Other errors-category includes all other production errors not mentioned above. The production error share based on the share made in this study is described in Table 3.

Table 3

Production error shares in to four categories by error specification

CATEGORY	ERROR SPECIFICATION	
Human activity based errors-category	11	Work error
	12	Interpretation error
	13	Setup error
	14	Incorrect NC-program
	15	Incorrect drawing
	16	Undefined error
	24	Insufficient maintenance
	32	Insufficient maintenance
	33	Setup error
	41	Old drawing
	42	Old instruction
	43	Defective drawing
	44	Defective work instruction
	45	Wrong work method
	46	Indefinable error
	61	Work error in previous work phase
	62	Product out of tolerances
	63	Handling error in previous work phase
	64	External error in previous work phase
	65	Indefinable error
	71	Defective construction
	72	Product impossible to manufacture
	73	Functional error
	74	Indefinable error
	84	Defective work instruction
	91	Wrong program
	92	Wrong hanging method
	101	Dents / scratches
	112	Wrong work instruction
	113	Falling
	122	Wrong work instruction
	123	Falling
Manufacturing technology based errors category	21	Error in NC-control unit
	22	Machine tool failure
	23	Operating error
	25	Indefinable error
	31	Tool break
	34	Indefinable error
	81	Defective bath
	82	Soiled bath
	83	Wrong bath temperature

Table 3 (continuation)

CATEGORY	ERROR SPECIFICATION	
	85	Indefinable error
	93	Functional error
	94	Indefinable error
Material based errors category	51	Defective purchase
	52	Defective subcontracting
	131	Wrong material delivery
	132	Water damage
	133	Dents / scratches
	134	Indefinable error
Other errors category	53	Water damage
	54	Convulsion of nature
	55	Indefinable error
	102	Water damage
	103	Convulsion of nature
	104	Dirt in product
	105	Indefinable error
	111	Functional error
	114	Indefinable error
	121	Functional error
	124	Indefinable error
	141	Write comments in section 4

An error specification classification has been used in this share. The share of the origins of the production error categories is presented in Fig. 1. This share has been done by summarizing all errors (Table 2) in each category (Table 3).

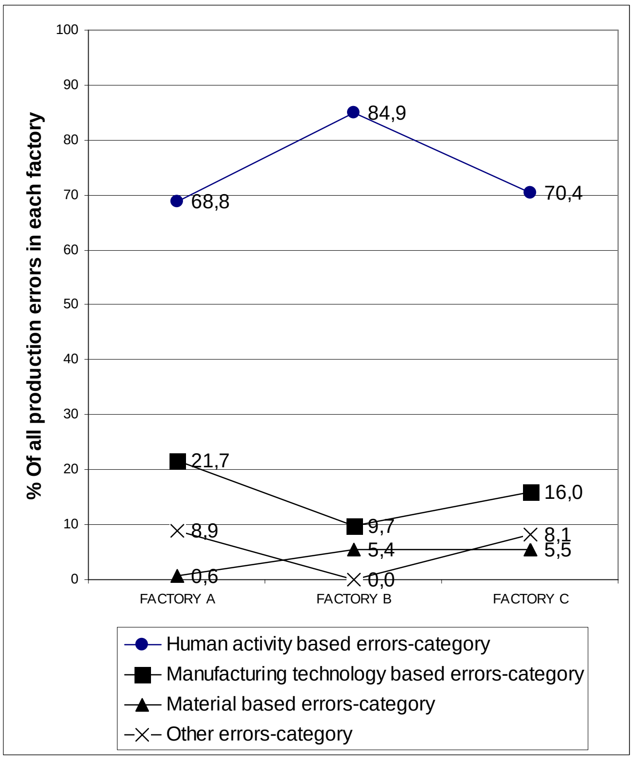


Fig. 1 Percentage distribution of production error categories in each studied case factories

In Fig. 1 it can be seen that most of the production errors in each factory belong to the "human activity based errors category". The figures are 68.8 % of all production errors in factory A, 84.9 % of all production errors in factory B and 70.4 % of all production errors in factory C.

The second largest category is the “manufacturing technology based errors category”. The figures are 21.7 % of all production errors in factory A, 9.7 % of all production errors in factory B and 16.0 % of all production errors in factory C. “Material based errors category” is the smallest in factory A (0.6 % of production errors) and the second smallest in factory B (5.4 % of all production errors) and in factory C (5.5 % of all production errors).

In written papers there is very little if any information available to compare the results achieved in this study to existing results. However, some comparison material can be found. Halevy and Naveh [3] state in their paper that an appreciable portion (some 30%) of the national product in Israel is wasted due to poor quality of planning and workmanship. Results from Halevy and Naveh cannot be compared directly to the results presented in this paper but they confirm that results presented in this paper are truthful.

In order to be able to evaluate the reliability of the results presented in Fig. 1, possible sources of errors interfering the results have to be examined more closely. The possible sources of errors include missing production error data, missing markings in production error charts, selecting wrong kind of products to be tracked in the field study and mistakes in interpreting the production errors during error observation phase.

The production error data collection includes a lot of manual work and human mistakes can happen. However, it is assumed that the amount of the missing markings is minor compared to the collected data as a whole. This assumption is supported by the fact that if employees had not wanted to collect the production error data, as in one case factory, it would have been seen in the results of the whole field study. Presumably, the employees have been motivated enough to collect production error data carefully.

On the other hand, it is supposed that the missing markings divide evenly between all categories. Therefore, it can be assumed that missing markings have no significance in the final results.

There have been a few insufficiently filled lines in the production error charts. In this case the classification has tried to be done during the analysis phase based on available information and other markings in the production error charts. Unsolved markings have been classified under “*14 Other unclassified errors*” and “*141 Write comments other side*”. The amount of unsolved markings is such small that it does not have any effect on the final results.

Every factory was asked to select some products to be tracked in the field study. The products to be tracked were asked to be typical products for each factory. This selection may not have been correct in all respects but the effect of this on the presented results is very difficult to verify.

Mistakes in interpreting the production errors during error observation phase are assumed to be the biggest error-causing factor in the field study. It is presumed that the employee who observed the production error knew in which functional phase and work phase the production error was caused or detected and therefore, these markings are correctly done. The real errors have occurred when the employee has decided the type of the production error and the type of error specification. Because of this, the possible errors in the presented origins of production errors have to be examined from this point of view.

In the first place it is essential to study the mistakes in interpreting the production errors (see Table 2) that reduce the share of human activity based errors. There are no mistakes in interpreting the production error in the production error types “*1 Human errors*”, “*4 Organizational errors*”, “*5 External errors*”, “*7 Design errors*”, “*8 Surface treatment process related errors*”, “*9 Surface treatment equipment related errors*”, “*11 Transportation device related errors*”, “*12 Lifting device related errors*” and “*13 Raw- material related errors*”.

In the production error type “*2 Machine tool related errors*” interpreting mistakes can easily happen. An error interpreted to be caused by a human error and placed under “*24 Insufficient maintenance*” may in reality be caused by faulty operating manufacturing technology and should therefore be classified under “*manufacturing technology based errors-category*”.

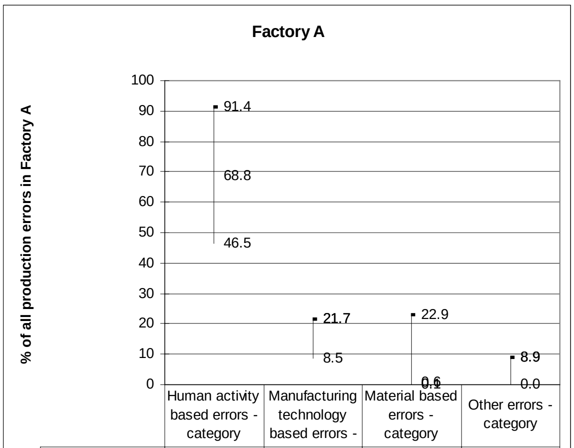
Also, in the production error type “*3 Tool related errors*” interpreting mistakes often can happen. An error interpreted to be caused by a human error and placed under “*32 Insufficient maintenance*” and “*33 Setup error*” may, too, in reality be caused by faulty operating manufacturing technology and should therefore be classified under “*manufacturing technology based errors-category*”.

In the production error type “*6 Preceding work phase related errors*” there is a great possibility to make interpreting mistakes. An error can faultily be interpreted to belong to “*human activity based errors –category*” “*61 Work error in preceding work phase*”, “*62 Product out of tolerances*”, “*63 Handling error in preceding work phase*” and “*64 External error in preceding work phase*” even though the reason can be in defective material and it belongs to “*material based errors-category*”.

Furthermore, in the production error type “*10 Warehousing errors*” there is a possibility to make interpreting mistakes. An error can incorrectly be interpreted to belong to “*human activity based errors-category*” “*101 Dents/scratches*” even though the reason can be in dented and scratched raw material and it should be included in “*material based errors-category*”.

In the second place, it is essential to go through other categories in error specification and examine the influence of the interpreting mistakes on “*human activity based errors-category*”. In the production error type “*2 Machine tool related errors*” “*22 Machine tool failure*” and “*23 Operating error*” there is a possibility to make interpreting mistakes. An error can incorrectly be interpreted to belong to “*manufacturing technology based errors-category*” even though in reality it is caused by a human error, for example lack of maintenance, and should be placed into “*human activity based errors-category*”.
Also, in the production error type “*3 Tool related errors*” the interpreting mistakes can easily happen. An error interpreted to be caused by tools and placed under “*31 Tool break*” may in reality be caused by lack of tool maintenance and should therefore be classified under “*human activity based errors-category*”.

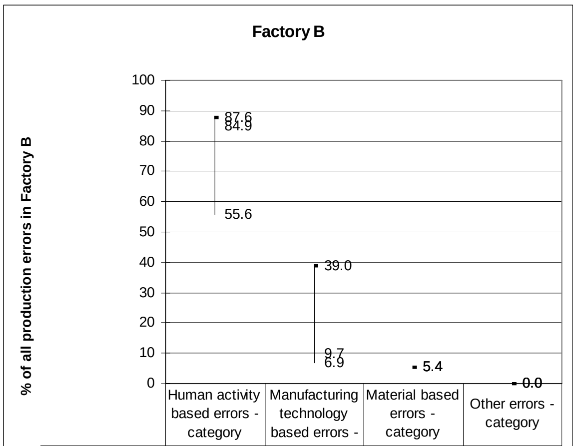
In the production error type “*8 Surface treatment process related errors*” it is also easy to make interpreting mistakes. Wrong bath temperature selection can be seen as a manufacturing technology based error but in reality it is



	Human activity based errors - category	Manufacturing technology based errors -	Material based errors - category	Other errors - category
Min	46.5	8.5	0.1	0.0
Calculated value	68.8	21.7	0.6	8.9
Max	91.4	21.7	22.9	8.9

Error -categories

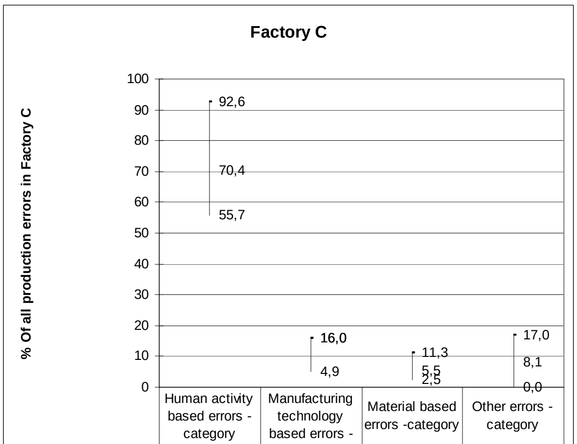
Fig. 2 Origins of the production errors in factory A taking into account possibilities of interpreting errors



	Human activity based errors - category	Manufacturing technology based errors -	Material based errors - category	Other errors - category
Min	55.6	6.9	5.4	0.0
Calculated value	84.9	9.7	5.4	0.0
Max	87.6	39.0	5.4	0.0

Error -categories

Fig. 3 Origins of the production errors in factory B taking into account possibilities of interpreting errors



	Human activity based errors - category	Manufacturing technology based errors -	Material based errors -category	Other errors - category
Min	55,7	4,9	2,5	0,0
Calculated value	70,4	16,0	5,5	8,1
Max	92,6	16,0	11,3	17,0

Error -categories

Fig. 4 Origins of the production errors in factory C taking into account possibilities of interpreting errors

caused by a human error. Therefore, "*83 Wrong bath temperature*" should be included in "*human activity based errors-category*".

Furthermore, in the production error type "*13 Raw-material related errors*" the interpreting mistakes can happen. An error interpreted to be caused by raw material and placed under "*133 Dents/scratches*" may in reality be caused by wrong handling of raw materials and should therefore be classified under "*human activity based errors-category*".

Finally, in the production error type "*14 Other unclassified errors*" "*141 Write comments other side*" is the most questionable category because all the unsolved markings are classified under it. Because the production errors included in this category can be caused by human errors the situation should be examined from the point of view where these errors are placed under "*human activity based errors-category*".

The Figs. 3, 4 and 5 show origins of the production errors in each factory taking into account possibilities of interpreting errors. In each figure the calculated value from production error database as presented in Fig. 1 is shown and minimum and maximum values considering the possibilities of interpreting errors as mentioned above are presented.

As a result the Figs. 2, 3 and 4 display that "*human activity based errors-category*" is clearly the largest production error category in each case factory and therefore, it can be argued that human activity based errors cause most of the production errors in the case factories.

5. Conclusions

In the starting point it was unclear where and when the production errors occurred. This indicates that a systematic production performance measurement is needed when development activities are considered. The production error data collected can be used as a tool when the production flow performance and revenue are improved in each case factory. Without knowing the real problematic areas it is impossible to start any improvement activities.

The origins of the production errors are shared into four categories in this paper. These categories are "*human activity based errors category*", "*manufacturing technology based errors category*", "*material errors category*" and "*other errors category*".
Most of the production errors in the case factories studied belong to the "*human activity based errors category*". A smaller part of the production errors belongs to the "*manufacturing technology based errors category*", the "*material based errors category*" and "*other errors category*".

The differences in the "human activity based errors category" can be explained by different manufacturing strategies and automation level in each factory.

The result indicates that most of the problems in the production flow are closely related to employees or work organization. Development activities must therefore be focused to the development of employee skills or to the development of work organization.

The result also indicates that production machinery in case factories is working at an acceptable level and materials are useful for common production of sheet metal part based constructions.

Furthermore, a regular, periodic performance measurement should be carried out to find out, how effective the possible development activities have been.

The selected functional approach is useful when production errors are studied from a quantitative point of view or when the distribution of production errors is examined. However, this approach does not give information about the effects of the production errors on total costs of the products. Any production error causes extra costs and disturbance into a production system and it can be said that by reducing production errors the whole production flow can be made more effective and therefore, this chosen approach gives proper tools for improvement activities.

References

1. **Ollikainen, M., Varis, J.** Production error distribution in sheet metal industry.- Mechanika, 2005, v.55, No5, p.56-61.
2. **Ollikainen, M., Varis, J., Kälviäinen, H.** Quality Control in Sheet Metal Industry (Levytuotetuotannon laadunvalvonta – LELA *in Finnish*).- Research Report EN 38, Lappeenranta University of Technology, 2003, p. 152-161.
3. **Halevy, A., Naveh, E.** Measuring and reducing the national cost of non-quality.- Total Quality Management, 2000, v.11, No8, p.1095-1110.

M. Ollikainen, J. Varis

ŽMOGAUS KLAIDOS VAIDMUO GAMINANT GAMINIUS IŠ METALŲ LAKŠTŲ

R e z i u m ė

Dauguma gamybos įmonių netenka dalies pelno dėl prastos gaminio konstravimo ir darbo proceso kokybės. Straipsnyje nagrinėjamos gamybos paklaidų atsiradimo gamybos srautuose, gaminant konstrukcijas iš metalo lakštų, priežastys. Ši studija grindžiama moksliniais tyrimais, atliktais trijose Suomijos gamybos įmonėse, ir gauta išvada, jog darbuotojai ir darbo organizavimas turi nemažą įtaką gamybos procese atsirandančioms klaidoms.

M. Ollikainen, J. Varis

HUMAN ERRORS PLAY A REMARKABLE ROLE IN SHEET METAL INDUSTRY

S u m m a r y

In many manufacturing companies an appreciable portion of profit within reach is wasted due to poor quality of design and workmanship. This paper concentrates to the origins of production errors in the production flow of sheet metal based constructions. This study is based on a field study carried out in three Finnish case factories and the conclusion is, that workforce and work organization related human activity based errors cause most of the studied production errors.

М. Олликайнен, И. Варис

ЧЕЛОВЕЧЕСКИЕ ОШИБКИ ЗНАЧИТЕЛЬНО ВЛИЯЕТ НА ПРОИЗВОДСТВО МЕТАЛЛИЧЕСКИХ ЛИСТОВ

Р е з ю м е

Во многих производственных компаниях значительная часть прибыли теряется из за низкого уровня навыков конструкторов и рабочих. Статья посвящена определению происхождения начальных производственных ошибок в производственных потоках изготовления изделия из металлических листов. Студия основана на научных исследованиях, проведенных на трех производственных предприятиях Финляндии, а получен вывод гласит, что рабочие и организация труда влияют на появление ошибок в производственном процессе.

Received February 10, 2005