ISSN 1392 - 1207. MECHANIKA. 2005. Nr.4(54)

Analysis of bending processes of sheet metal parts and improving them with new investments - a Finnish case study

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

The production machinery of a Finnish sub-contractor of sheet metal parts consists of a press brake from the year 1989. The company has evaluated the press brake to be in satisfactory condition. The press brake is equipped with a 1-axis backgauge (x - axis) and with three backgauge fingers that are set up manually. The tooling system of the press brake is so called traditional, in which tools are slipped onto a tool holder from the end of it.

The company operates in the upper limit of its recourses with this backlog of orders and overload of capacity is 10 - 20 per cent almost continuously. The bending process is considered as one of the worst bottlenecks in the present production.

This strongly empirical article deals with the elements affecting efficiency of the bending process in manually operated bending and studies factors involved with the profitability of investments in a new press brake seen especially from the point of view of a company that runs small batches.

2. Starting point

To evaluate the bending work nature in the company, a tracking of the bending process was introduced (Table 1), which included the size of the batch in each order, the running time of the batch and the set up time. The orders are partially recurring during tracking time, only with different batch sizes by each order. The tracking period consists of 63 orders with the time between order and delivery being 76.6 hours which is approximately 10 working days.

2.1 Current situation analysis

To study and analyse more closely the data the collected orders were divided on the basis of batch size of the order as followed:

- single run; the maximum size of the batch 9 parts to be produced;
- small batch; the size of the batch 10 - 30 parts to be produced;
- medium batch; the size of the batch 31 - 99 parts to be produced;
- large batch; the size of the batch 100 parts or more to be produced.

During the tracking period the orders included:

- single run; 10 individual orders;
- small batch; 37 individual orders;
- medium batch; 13 individual orders;
- large batch; 3 individual orders.

The distribution of the orders by batch size is graphically presented in Fig. 1. More exact information about the orders divided by batch size is presented in Tables 2 - 5.

Table 1

Tracking table of bending process

Order number	Batch size (number of parts)	Working time/order, minutes	Set up time/order, minutes
1	84	102	18
2	20	84	18
3	40	24	18
4	10	18	12
5	64	18	18
6	17	12	18
7	103	30	12
8	64	540	60
9	2	6	12
10	56	60	12
11	52	60	24
12	8	60	36
13	60	18	18
14	24	42	24
15	6	30	30
16	12	12	12
17	6	6	6
18	6	12	18
19	12	18	6
20	12	42	18
21	12	42	18
22	18	18	12
23	20	60	42
24	20	60	24
25	20	18	6
26	20	18	12
27	20	18	12
28	10	108	42
29	17	18	12
30	170	150	18
31	30	36	24
32	34	180	42
33	20	90	42
34	20	18	12
35	20	12	12
36	18	12	12
37	20	12	12
39	25	156	42
40	8	12	18
41	8	12	18
42	5	12	12
43	10	12	12
44	6	12	24

Table 1 (continuation)

Order number	Batch size (number of parts)	Working time/order, minutes	Set up time/order, minutes
45	20	72	18
38	20	18	18
46	320	30	12
47	10	12	6
48	10	6	6
49	82	96	12
50	44	6	6
51	12	42	18
52	40	96	30
53	40	258	60
54	48	234	36
55	30	78	12
56	30	72	12
57	15	12	12
58	15	12	6
59	15	6	12
60	30	18	12
61	10	12	12
62	10	24	12
63	6	18	12

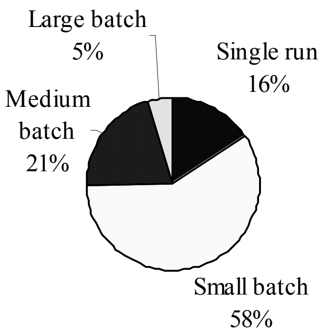

Fig. 1 Distribution of orders by batch size during tracking period

Table 2

Single run

Batch size, average	6	parts		
Working time, average/batch	18	minutes		
Set up time, average/batch	19	minutes		
Working time, average/part	2.95	minutes	=177	seconds
Set up time, average/part	3.05	minutes	=183	seconds
Batch to batch, average	37	minutes		
Batch changes per day, average	13.1	times		

Fig. 2 illustrates the influence of batch size on the proportion of value adding work of the total working time. The graph of the share of the value adding work illustrated in the figure has been calculated based on the averages of batch sizes using information given in Tables 2 - 5. The calculation has been done using Eq. (1) [1].

$$\text{Proportion of value adding work} = \frac{\text{Bending time of the batch}}{\text{Bending time of the batch} + \text{set up time of the batch}} * 100\% \quad (1)$$

Table 6 illustrates the summary of production time and set up time based on the batch size. Fig. 3 includes also graphical representation of the influence of batch size on average working time and set up time per

Table 3

Small batch

Batch size, average	18	parts		
Working time, average/batch	36	minutes		
Set up time, average/batch	17	minutes		
Working time, average/part	2.02	minutes	=121	seconds
Set up time, average/part	0.94	minutes	=56	seconds
Batch to batch, average	52	minutes		
Batch changes per day, average	9.2	times		

Table 4

Medium batch

Batch size, average	54	parts		
Working time, average/batch	130	minutes		
Set up time, average/batch	27	minutes		
Working time, average/part	2.39	minutes	=143	seconds
Set up time, average/part	0.50	minutes	=30	seconds
Batch to batch, average	157	minutes		
Batch changes per day, average	3.0	times		

Table 5

Large batch

Batch size, average	198	parts		
Working time, average/batch	70	minutes		
Set up time, average/batch	14	minutes		
Working time, average/part	0.4	minutes	=21	seconds
Set up time, average/part	0.1	minutes	=4	seconds
Batch to batch, average	84	minutes		
Batch changes per day, average	5.7	times		

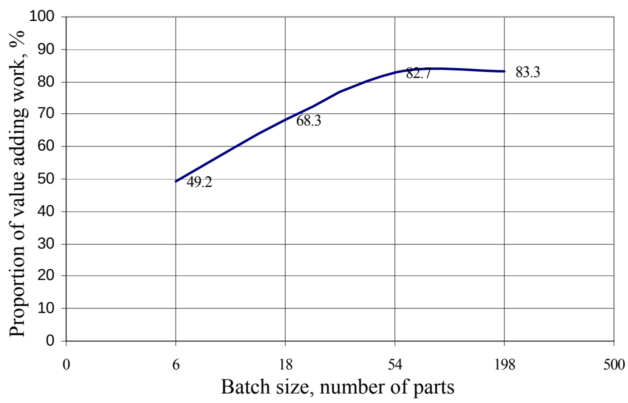

Fig. 2 Proportion of value adding work of press brake out of total working time based on average batch size

Table 6

Summary of production time and set up time based on batch size

	Large batch size [parts]	Average working time, sec	Average set up time/par,t sec
Single run	6	177	183
Small batch	18	121	56
Medium batch	54	143	30
Large batch	198	21	4

part as well as the influence of batch size on total working time per part.

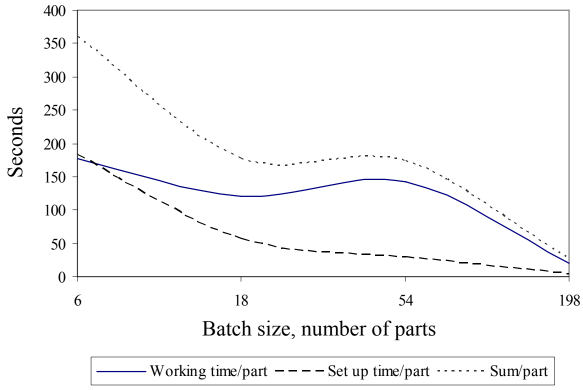

Fig. 3 Graphical representation of the influence of batch size on time spent per part and set up time per part and total sum of them

2.2 Conclusions from the analysis of current situation

When different graphs are studied, the following characteristics are found during the tracking period in the bending process of the company:

• the batch sizes of the products to be bent are very small, 58.7 per cent of all the production is bending small batches, in which the batch size varies from 10 - 30 parts;

• only 4.8 per cent of all the production can be counted as large batch production, where the batch size is 100 parts or more;

• about 80 per cent of the production has a batch size of 40 parts or less.

The share of value adding work of the total working time with the present press brake remains very small especially when single parts or small batches are produced. Typically, percentages in these cases vary from 49 - 75 per cent. The share of value adding work describes the time that can be utilised to refine sheet metal product within the limits of total working time during the tracking period. The low share of value adding time is the most likely caused by the time spent on set up processes.

Time used per part in bending process is very similar when bending time per part in single runs, small batches and medium batches (177, 121, 143 sec.) are compared. This can be explained with similar products, in which the bending time is about the same. The small differences can first of all be a result of learning to work as far as single parts are concerned: in other words, as soon as it becomes a routine when the batches grow, also, the actual physical bending process grows faster.

The time used per part in the bending process grows significantly shorter (21 sec.) when bending a large batch. This can be explained by a simple bent part, where the work needed for the bending process is very small.

Based on the two previous points it can be assumed that the production of the companies divided into two kinds of parts to be bent: normal (complex) production parts and simple large batch production parts.

Based on all the points mentioned earlier it can be stated that, by nature, the bending work of the company is extremely variable small batch production, where the efficiency of the bending process depends largely on the features of the actual press brake that can be utilised, as for example of the set up process speed.

3. Discussion

Bending is often seen as a bottleneck when producing sheet metal parts [2]. Especially, in small batch production where it is often not possible to collect works in accordance to set ups, efficiency suffers significantly when the set ups have periodically to be redone in between the batches.

3.1. Factors affecting the efficiency of the bending process

Efficiency of the bending process often does not depend on only one factor but on a sum of several factors. By eliminating these factors in the bending process or minimising the time spent on them it is possible to reach significant improvements in productivity of the bending process.

Bending efficiency can be improved with very simple methods and not all of them necessarily demand new investments on the present machinery. One of these methods includes simple set up instructions for every part, which accurately document previous set ups (tools, tool order and tool locations on tool holder, position of back-gauge, TDC etc.) The set up instructions can be added to a work order or they can be stored for each press brake by each application number, for example. The point is that information is available for the operator any time needed. Another effective method, either used alone or included in to instructions for each part, is using a large number of photos. Photos show used set ups in easy virtual form. A digital camera for each operator is an effective and low cost way of being sure the set ups are being recorded for future use either in electronic form or as paper prints.

Production control can also be used as a method to improve efficiency of the bending process. In the production information it has added parameters describing materials and bendings which enables to group jobs based on specific material and the same kind of features to be bent after each other. In this way, recurring new set ups can be avoided and the bending process becomes significantly more effective. Unfortunately, this kind of working method is not often possible in small batch production, where the time between on order and delivery is as short as possible and the buffer stock is as small as possible.

If a new press brake is to be purchased for a small batch production, the press brake can be equipped in the way it is suitable for future jobs already at the time of purchase. Tools as well can be chosen for the demands of future jobs.

The tooling system is of great importance for of the press brake efficiency [3], especially in small batch production. If the tools are of a model that are slipped from the end of tool holder, the set up work is slow and practically, the whole set up needs to be disassembled even when smallest changes are done for the present set up. It is advisory to use modular quick change tools that are loaded or unloaded in the middle of the tool holder. With modular quick change tools always the most suitable setting can be built for the specific job and separate tools for specific lengths are not needed. One of the benefits of modular tooling is the easy handling of separate tools (size, weight) where the operator does not need any help for changing tools and also, the safety is improved. Modular tooling is also extremely accurate in measuring (no need for shimming) and often, almost always, they have surface hardening to lengthen their life. Also, clamping the tools and tool centring needs to be made as quick as possible. In practice, this means push-button safety clips and hydraulic tool clamping. In changing small batch production the hydraulic tool clamping system is probably the quicker and safer option, but anyway, the additional price of hydraulic tool clamping system has to be able to be justified economically and otherwise, mostly with quality and safety reasons. The tools to be used need to have common shut height (standard lower end of the stroke in working movement), when different combinations of tools can be used in the same set up without a need to use separate custom risers and special shims.

If the press brake is equipped with vertical movement of the bottom die on advantage can be taken of 2V dies or various special tools, where the first movement is the pre-bending and the finishing (e.g. "flattening" of the edge) is made with second movement taking advantage of the features of the special die.

Tool identification needs to be notified to speed up set up processes and to eliminate faults [3]. Most tools are already identified by the manufacturer with some ID system, e.g. laser-etched with the ID-number of the tool (often the so called catalogue number), tip angle, radius, V-opening, length and tonnage ratings. Clear tool identification reduce time spent on searching tools and eliminate scrap from incorrectly formed parts caused by the usage of wrong tools as well as tool breakage.

Tool storage needs to be paid attention to, as well [3]. There should be an opportunity to store tools as near the press brake as possible but in the way they are not causing inconvenience to the bending process. The tools should be stored in special shelves or tool carts where it is easy to find the right tool and extra searching job is not needed. The clear way of storage also increases safety when the right tools can directly be taken from where they are stored and there is no need to go through "heaps". The clear way of storage also makes it easier to maintain the tools, as it is possible to monitor all the tools with one visual check up and identify all worn and damaged tools.

New press brakes offer many advanced features which can directly be taken as an advantage to make the bending process more efficient. One of these features is the ability to store job specifications in the memory of the NC-controller of the press brake. In the memory, e.g. tools used, location and parameters involved with bend sequences can be stored. Another function that increases efficiency in the newest press brakes is the automatic material thickness sensing. When precision-ground tools are used, the press brake can sense changes in material thickness and make bend calculations on-the-fly to reduce overbent and underbent parts.

The bending process can be made more efficient by downloading programs from separate NC programming software. In this case the existing CAD knowledge can be taken as advantage to program the bending process. Efficiency of the bending process improves with the time spent on programming the work at a machine. The modern NC programming software is equipped with 3D simulation opportunity, which allows the operator to make sure the program works as soon as it is set and this way eliminate possible faults during the bending process. Even programming single parts can thus profitably be done without specific test parts and resetting the program.

The backgauge of the press brake has significant importance to use the machine in an effective way. As a minimum requirement in small batch production with changing runs can be seen NC-controlling of the 4 -axis of the backgauge (numerical X - and Z - movements), even though NC - controlling of 6 - axis (numerical X -, R - and Z - movements) the operating features are improved even more. The criteria have to be the construction of produced parts. 4 - and 6 - axis backgauges make it possible to use multiple tool set-ups in a press brake. A multiple tool set up means a tool set up where several different set-ups have been set in the tool holder for various bendings of the produced part. In this case the part can be bent on one handling and no separate temporary store or intermediate set ups are needed.

The NC - crowning possibility of the tool holder is also a useful feature which makes bending process quicker in some situations. If crowning can be done either with a manual crowning machine or a numerically operated crowning machine the operator avoids manual shimming of the tool holder. This feature is useful if the features of produced part (length and accuracy demands of the bending) ask for it.

The type of the press brake can be considered to have some kind of influence on efficiency of the work through work ergonomics. Press brakes can be divided into two classes according to their way of action; down stroking and up-stroking. If the press brake is up-stroking, the bottom tool holder makes the working movement and the top tool holder act as a gauge, when in a down stroking press brake the top tool holder makes the bending movement and the bottom tool holder act as a natural gauge. When using a down stroking press brake the part to be produced always rises as much as the working movement where in the up-stroking press brake the part remains in its position.

Press brakes can also be divided into three classes according to their driving power; mechanical (eccentric), hydraulic or electric (servo powered) press brakes. In practice, only hydraulic and electric press brakes are available nowadays. How the driving power is produced has only minor effect on the efficiency press brakes. A more frequent need of maintenance of the hydraulic press brake may slightly affect the usability. Both types have enough accuracy and speed for changing small batch production. Electric press brakes, however, are less loud and need less maintenance.

3.2. Demands on press brake in changing small batch production

In this case, the following demands were made on press brake meant for changing small batch productions also the features affecting efficiency of the bending process and special features of the production of the company were while taken into account.

• Basic machine

Bending length between 2000-2500 mm.
Press tonnage 500-850 kN.
Front table supports, 2 pieces.
Electric servo driven or hydraulic way of action; down stroking.
CE approval.

• Control unit

Transferring programs via net connection, RS 232 or Ethernet.
3D graphic processing of the part to be produced.
Simulation of the bending order/bend sequence.

• Backgauge

4 axis numerically controlled (X, Z1/2, R) or alternatively 6 axis numerically controlled (X1/2, Z1/2, R1/2).

• Tooling system

Quick clamping of tools.
Hydraulic tool clamping.
NC - crowning of the bottom tool holder.

• Options

User and maintenance education.
Off-line programming software for bending.
Numerically controlled vertical movement of the bottom tool holder, if available.

3.3. Alternative press brakes available

Press brakes that meet the requirements are quite well available in the Finnish market. As a result of the invitation seven manufacturers offered twelve (12) separate models or variations of the press brake. All the offered machines met the requirements for the press brake meant for small batch production and their comparable price range with features wanted was from 85 000 - 150 000 € (January, 2005).

3.4. Recommendations to increase efficiency of bending process in the company

The production of the company is very variable small batch production, where the most typical batch sizes lie between ten and 30 parts. Because of this, the time spent on set ups lengthens the total working time and decreases the maximum productive capacity of the machine.

The following two recommendations were given to increase efficiency of the bending process.

The first recommendation is to focus the work of the existing press brake to produce long runs with relatively simple parts where set up times are not significant based on efficiency of the machine. This means that it may be possible to use same standard set-ups as a matrix die for production of all the products.

The "over" capacity of the existing press brake can be utilised in evening out the peaks in the production and it can be utilised as a reserve machine in the production. The old press brake serves the production also in the ramp up stage of the new press brake, when the production is started up with the new press brake, so called learning stage.

The functions mentioned above call for the investments in user education needed for running the press brake. It is natural to educate existing reserve personnel to be main operators of the old press brake and to update their knowledge so that they can be used as reserve operators in the new press brake.

The second recommendation is that the company invests in a new press brake where special attention has to bepaid to quick and easy set-ups. At the present stage the production time is significantly spent on the requirements set by various batches; to set-up backgauges, to change tools by slipping them from the end of the tool holder and to find a program or to download a new program. It is believed that a new press brake helps to eliminate totally the need for set-up of the backgauge. And the changing time of the modular quick change tools are in many cases only microscopic compared to the time spent on loading and unloading present tools. This requires the new press brake to have modular tooling, quick tool clamping and backgauge that can be programmed in versatile ways. The utilisation rate can be made even better by using off-line programming with separate software.

Fig. 4 illustrates an estimate of the share improvement of the value adding work with new investment. The lower continuous line illustrates the share of the value adding work with the old press brake and the upper dashed line shows an estimate of the share of the value adding work with the new press brake. The estimation is based on the following presumptions:

• manual set-ups of backgauge are not needed;
• significantly less time is spent on changing tools;
• no online - working time is spent on programming;
• graphic user interface speeds up working and decreases faults;
• several tool set-ups and "ready with one handling" - principle is possible;
• the new press brake has slightly quicker movements as well as rapid movements.

There is a grey lining in the figure in the area where the effects are estimated to be the strongest (~25 - 15 per cent of improving effect) to the share of the value adding work which is producing small batches. According to the calculations and estimations made with the purchase of the new versatile press brake it is possible to rise the share of the value adding work significantly especially in the batch size level which is typical for the production of the company at the moment. It is estimated that the capacity of the new press brake cell is about 1.2 ~ 1.3 times the capacity of the present press brake cell so it can manage the present continuous overload. The situation is even better when the long runs are guided to the old press brake.

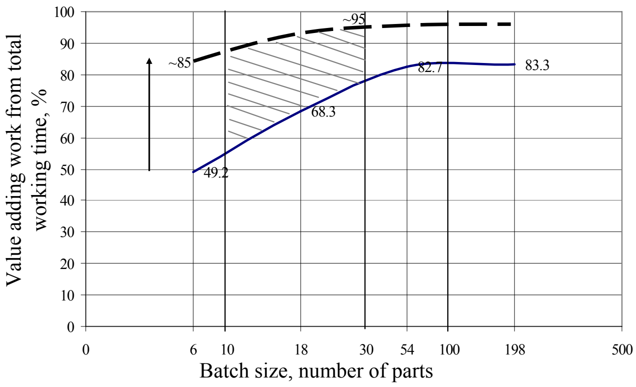

Fig. 4 Change of share of value adding work from total working time with investment on new press brake cell

Naturally, the purchase of a new press brake and effective use of it also demands thorough education of the personnel to run the new press brake to be purchased. The most natural would be to educate the main operator of the present press brake to be the main operator of the new press brake and to educate the present reserve operators to be the reserve operators of the new press brake, also. Thus the new press brake can be run during the whole effective working time. If the new investment is to be used in two shifts, the education is naturally needed for two main operators. Then previous experience on press bending can be taken as an advantage when personnel is chosen for the new press brake.

3.5. Economic examination of investment

When the investment on a press brake is examined from economic point of view it is to be remembered that according to the starting point the capacity of the press bending is almost totally used so more capacity is needed, anyway.

Table 7

Costs based on annual payment principal

Size of investment	85 000 €	100 000 €	115 00 €
Amortisation and rate/month (€)	1 324	1 558	1 792
Total of rates (€)	26 285	30 924	35 562
Total of rate + capital (€)	111 285	130 924	150 562

The calculation has been made on the basis of 8 per cent interest rate and a pay-back period of 7 years. The guideline estimations for investments has been 85 000, 100 000 and 115 000 € in order to estimate the effect of optional features on the final result.

The cost per month based on annuity method is as presented in Table 7.

1 Shift

Costs in one shift can be counted (one month has 21.5 working days a´8 hours, 1 shift; a year has 12 working months) as presented in Table 8:

• energy cost (incl. energy used to run the machine, lighting, heating) 0.8 €/h;

• space cost (42 €/m2/year, room needed 30 m2) 105 €/month (0.9 €/h);

• salary cost including sub costs 18 €/h.

Table 8

Costs in one shift

Investment	85 000 €	100 000 €	115 000 €
Art of cost	€/h	€/h	€/h
Cost for investment	7.7	9.1	10.4
Energy cost	0.8	0.8	0.8
Space cost	0.9	0.9	0.9
Salary cost	18	18	18
Total of costs	27.4	28.8	30.1

If a minimum of 20 per cent of profit is required for the investment, the minimum sales price is formed as in Table 9.

Table 9

Selling price with 20 per cent of profit for the invested capital in one shift

Investment	85 000 €	100 000 €	115 000 €
Costs (€/h)	27.4	28.8	30.1
Profit requirement	1.5	1.8	2.1
Sales price (€/h)	28.9	30.6	32.2

2 Shifts

Costs in two shifts can be counted (one month has 21.5 working days a´8 hours, 2 shifts; a year has 12 working months) based on table 10:

• Energy cost (incl. energy used to run the machine, lighting, heating) 0,8 €/h.

• Space cost (42 €/m2/year, room needed 30 m2) 105 €/month (0,5 €/h).

• Salary cost including sub costs 18 €/h.

Table 10

Costs in two shifts

Investment	85 000 €	100 000 €	115 000 €
Art of cost	€/h	€/h	€/h
Cost for investment	3.9	4.6	5.2
Energy cost	0.8	0.8	0.8
Space cost	0.5	0.5	0.5
Salary cost	18	18	18
Total of costs	23.2	23.9	24.5

If a minimum of 20 per cent of profit is required for the investment, the minimum sales price is formed as in Table 11.

Table 11

Selling price with 20 per cent of profit for the invested capital in two shifts

Investment	85 000 €	100 000 €	115 000 €
Costs (€/h)	23.2	23.9	24.5
Profit requirement	1.5	1.8	2.1
Sales price (€/h)	24.7	25.7	26.6

Calculatory pay-back time

If the investments can be utilised as planned the real pay-back time of the investment in one shift is approximately 2.5 - 3 years depending on the size of the investment and the current pricing per hour for bending in Finnish sheet metal industry.

4. Conclusions

A replacement investment in modern bending technology seems to be highly profitable for a company. One essential point is that the share of value adding work from the total working time increases which increases the production capacity with 20 - 30 per cent in this case. If an investment in a press brake is considered, an attention should especially be paid at the easy set-ups. This highlights especially quick tool set-ups and versatile backggauge that can be programmed.

References

1. **Berkhahn, G., Miyakawa, N.** Developing a unit-based production system.-The Fabricator, 1993, v.23, No.10.
2. **Ollikainen, M., Varis, J.**. Ohutlevy-teollisuuden kehittämistarpeiden kartoitus.-Tekes Teknologiakatsaus, 2004, 159/2004. ISBN 952-457-173-0.
3. **Shultz, S.** How to reduce press brake set-up times.-The Fabricator, 2004, v.34, No.8.

M. Ollikainen, J. Varis

LAKŠTINIO METALO DETALIŲ LENKIMO PROCESŲ ANALIZĖ IR JŲ GERINIMAS NAUJOMIS INVESTICIJOMIS – SUOMIJOS ATVEJO STUDIJA

R e z i u m e

Lankstymas dažnai yra „siaura“ gamybos vieta gaminant detales iš metalo lakšto. Šis eksperimentinis straipsnis nagrinėja elementus, veikiančius lankstymo proceso efektyvumą bei štampavimo presų investicijų pelningumą smulkių serijų gamyboje.

Investicijų papildymas modernioje lenkimo technologijoje gali padėti kompanijai siekti didesnio pelningumo smulkių serijų gamyboje. Turi būti kreipiamas dėmesys įrenginio derinimo lengvumui pasiekti didinant gamybos proceso vertę. Tokiu atveju realus investicijų gražinimo laikas gali labai sutrumpėti.

M. Ollikainen, J. Varis

ANALYSIS OF BENDING PROCESSES OF SHEET METAL PARTS AND IMPROVING THEM WITH NEW INVESTMENTS - A FINNISH CASE STUDY

S u m m a r y

Bending is often a bottleneck when producing sheet metal parts. This empirical article deals with elements affecting the efficiency of bending process and the profitability of the investment in a new press brake in small batch production.

A replacement investment in modern bending technology seems to be highly profitable for the company making small batch production. Attention should be paid specially for easy set ups to increase value adding time in production process. In such a case real pay-back times can be very short.

М. Олликайнен, И. Варис

АНАЛИЗ И УЛУЧШЕНИЕ ГИБОЧНЫХ ПРОЦЕССОВ ДЛЯ ДЕТАЛЕЙ ИЗ МЕТАЛЛИЧЕСКОГО ЛИСТА НОВЫМИ ИНВЕСТИЦИЯМИ – СТУДИЯ НА ПРИМЕРЕ ФИНЛЯНДИИ

Р е з ю м е

Часто гибка бывает слабым местом при производстве деталей из металлического листа. В этой экспериментальной статье исследуются элементы, влияющие на эффективность гибочного процесса и прибыль инвестиций в мелкосерийном производстве штамповочных прессов.

Увеличение инвестиций в модерные гибочные технологии содействует компании в увеличении прибили в производстве мелких серий. При увеличении значения производственного процесса очень важно, чтобы устройство можно было легко перенастраивать, тем заметно сокращая реальную продолжительность возврата инвестиций.

Received December 27, 2004