PROJEKTRAPPORT MPR 023

M4Pt 95 04 09

Automized Machining of Air Suspension Brackets at Scania Luleå Shop

The project is to find a simple and inexpensive method to perform face milling, boring, champfering and threading on a newly redesigned air suspension bracket for Scania's rear axle housing.

KARL ANDRÉ KEVIN MCFALL
MALIN LARSSON

TEKNISKA HÖGSKOLAN I LULEÅ

Preface

During the fourth and final year of the education in Mechanical Engineering at the Technical University of Luleå, the course Project in Manufacturing Systems Engineering MPR023, is given. The purpose of this course is to present the students with a real world engineering problem faced by an outside company. By means of solving this problem, the students will gain an understanding of both the operation of a real corporation and the problems encountered. This course shall also develop the ability to plan, follow to completion and present the project all performed as a group.

For our project, we worked with Scania Luleå shop. Our primary contact there was Kenneth Andersson without whose continued patience and support we could never have completed our project. Another whose help and guidance was invaluable is Ewa Lantto. The assistance, especially in the area of technical expertise, of Kjell Lindfors was also instrumental in the completion of our project. We would like to thank Jan Flinkfeldt for finding these projects which we believe have expanded our knowledge and appreciation for real life situations

This course also includes a field trip on which we visited several companies in the south of Sweden. Through this visit and our project work have we broadened our understanding for different types of production managment systems.

Karl André
Malin Larsson
Kevin McFall

Luleå, March 22, 1995

Summary

An integral part of any technical education is most certainly practical experience. Through this project we have been introduced to the types of projects encountered in industry and the problems involved in seeing them through to completion. This project essentially requires a solution for the machining of a redesigned air suspension bracket at Scania's Luleå workshop. After an unsatisfactory trial production of this part in a multi-operational machine, Scania decided on the need for a new machine to perform the required face milling, chamfering, drilling, and threading operations while encorporating an automatic loading and unloading scheme. The layout of this machine was much discussed and ideas from many sources including ourselves, contacts at the Universtity, Scania, as well as the bidding companies were presented a myriad of different solutions. However, a common thread to all these solutions appeared to involve some sort of rotating machine with different stations for the separate operations. Another much discussed point of interest involves the loading and unloading of the bracket. The two major solutions for this are either a pneumatically or robot controlled device.

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1. Introduction

Scania has decided to construct a redesign of an air cylinder bracket for their rear axle casing. There are four of these brackets welded upon each casing and their function is both to support the air suspension and to provide a safety arrangement if the support for some reason fails. The yearly production of these brackets is just over eighty eight thousand which translates to around two thousand per week. Scania has decided to consider two alternatives. One alternative is for an outside firm to perform the machining. This alternative, although simple, could become expensive and also removes Scania´s control of the process. The second alternative involves performing the machining in house.

2. Project Description

Scania's old air suspension bracket for the rear axle casing is illustrated below in figure 1. A drawing of the new design can be found in Appendix 1. However, they have decided to redesign this bracket. A trial production has been performed using a multi-function machine. However, due to the relatively high production rate, this presented problems because of manual loading and unloading. The weight of the brackets, about 2.8 kg, also introduces an ergonomic concern when considering manual loading. Therefore the problem has been given to find an automated solution for the machining of these brackets.

The main goal of the project is to find a simple and inexpensive method for machining the holes for the safety arrangement of the suspension. The operations include boring and threading of the holes in addition to facing around them. Another requirement of the project is that the machine should be flexible as the exact angle of inclination for the bored hole has not yet been determined. The problem includes fastening and correctly orienting the part within tolerances as well as finding machines and appropriate machine tools to perform these operations. As a final step an economical analysis must be performed to decide which solution option is most favorable.

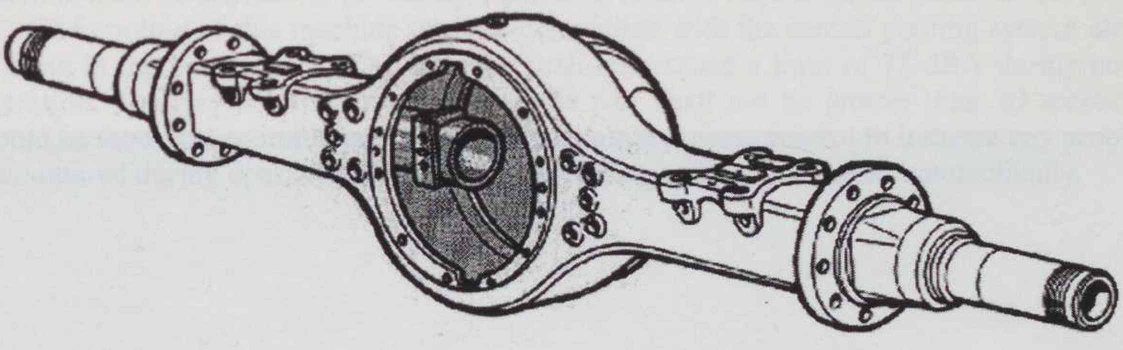

Figure 1. A rear axel casing with the old air suspension brackets

5. Discussion of Cycle Time

The cycle time is defined as the time it takes to produce one part. How the cycle time should be regarded, however, is a complex question. This is mainly a question of the costs involved in having the machine working continuously, as opposed to operating only during a short time every day. Allowing the machine to run for a short period every day reduces costs as the need for operator salaries diminishes. The drawback to this approach is that in order to produce the required number of parts in a short period of time the initial investment in the machine will certainly be higher. A possible machine layout for this solution could involve a rotating table with six stations: loading, boring, chamfering, facing, threading, and unloading. See Figure 2. The machining operations would be performed by stationary double spindle arrangements.

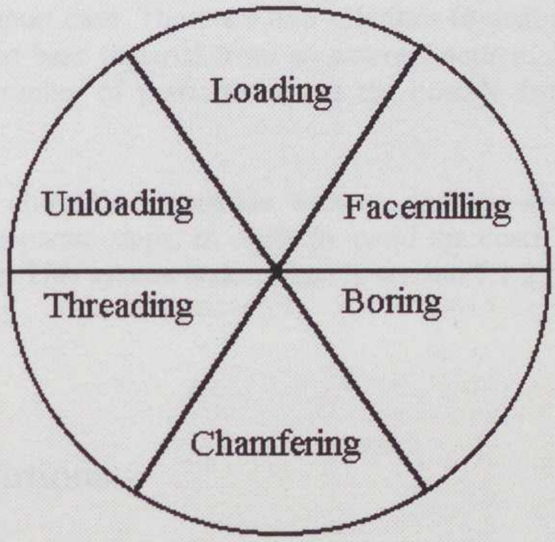

Figure 2. A rotating table with six stations

The other option consists of a machine which will run continuously throughout the day with a somewhat longer cycle time. This case makes better utilisation of the machine and the machine investment would most likely be less than with previous option. A drawback to this option would be encountered if in the future the production demand for these brackets were increased. In this case, it could be possible that this slower machine would not be able to meet the increased demand. A possible machine layout for this approach could consist of a two station table, one for loading and unloading and one where the machining operations are performed by a rotating double spindle arrangement. This solution would increase the cycle time to 30 or 40 seconds, but required current yearly production should still be able to be met with only one shift per day.

6. Discussion of loading and unloading

According to section 5, the roundtable can be devided in either two or six stations, depending on cycletime.

A favorable solution for the machine consisting of two stations, loading/unloading and machining, would be to use a robot which picks up the parts from either a palette or a magazine. Since the cycle time is the sum of the four revolving machining steps, there would be ample time for the robot to complete its tasks. When using a robot in this manner, some sort of a positioning fixture is needed. This can easily be built using a vertical pocket where the part is dropped for regripping before final positioning in the fixture. When unloading, the part can either be dropped into a case randomly or to be put in a pattern on a palette, depending on the next operation. Using a robot for loading involves the problem of locating the part in the transport case. There are two solutions to deal with this problem. As the parts are bought as forged base material from an external source, one can either manually load a magazine with a number of parts or require the outside firm to ship them in a correctly positioned palette.

In our solution we chosed a roundtable with six stations where loading and unloading are performed as two separate steps. In order to avoid the costs of having a robot, the loading system is pneumatic. This system is described in section 7.1.2.

7. Various Solutions

Presented below are descriptions of the various ideas for designing the machine. Section 6.1 contains the description of the machine design which was sent to the companies for a bid proposal (see also Appendix 3). Following that are short descriptions of each company's proposal and finally in Section 8.5 is the final recommended solution.

7.1 Our Solution

Our idea of solving the problem is to use a round table where the table is divided into six separate stations, one for each operation. The operations are the following: loading, face milling, boring, chamfering, threading and unloading. As an alternative, the operations can also be loading, centering, boring, face milling, threading and unloading.
On the top surface of the round table the six fixtures are mounted horizontally with an incline of +/-15°. This incline and the fixture is further discussed in the section below.

7.1.1 The Fixture

The air cylinder bracket has an incline of the hole surface. However when the project began, it had not been fully decided how large this angle should be. According to our specifications, it

should be adjustable within +/- 15 °. As the project went on, the latest decision was to have an incline of 30°. The first intention was to equip the machine with adjustable spindles but this turned out to be very expensive, and instead the whole fixture is mounted on the round table with an incline.
The fixture can either be mounted on the top surface of the round table or on its side. After several discussions with the companies it was understood that the general intention was to mount the fixture on the table's side.

Our method of fixturing is described as follows:
The fixture is mounted horizontally on the top surface of the round table. As the bracket is pushed into the fixture by two cylinders it is guided into position by two guidebars situated above the bracket, see Figure 3. In the back of the fixture a thin plate is mounted on two springs. This plate together with the springs ensure that the bracket is always positioned correctly.

There is a tolerance on the measure between the centerline combining the two holes and the ground material for safety arrangement (14.5+/-0.5 mm). To ensure that this tolerance is met, there is stop-pad mounted above the part in the fixture.
On the bottom surface, the bracket is balanced on three symmetrically situated pads.

Once the piece is fully positioned into the fixture it is clamped vertically.

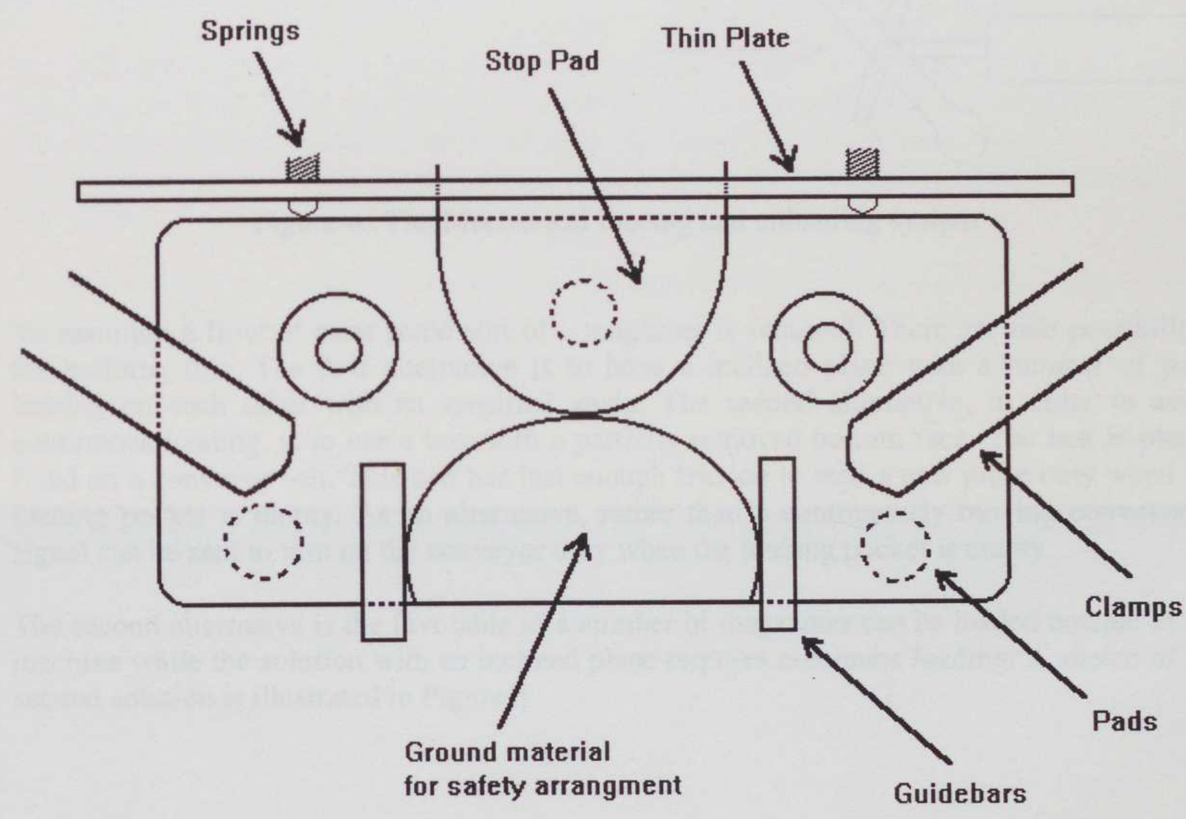

Figure 3. The fixturing of the bracket

7.1.2 Loading and Unloading

In our solution loading and unloading are performed as two separate steps. The intention was to load and unload the fixture using pneumatic cylinders. The loading of the fixture consists of two cylinders which push the part into position. When this occurs the pocket becomes empty and a new part can fall down.
This process is schematically sketched in the Figure 4. In the letter requesting bids on this machine, this possible loading and unloading scheme is outlined, although the decision is left open to the individual companies as to the exact nature of the loading and unloading.

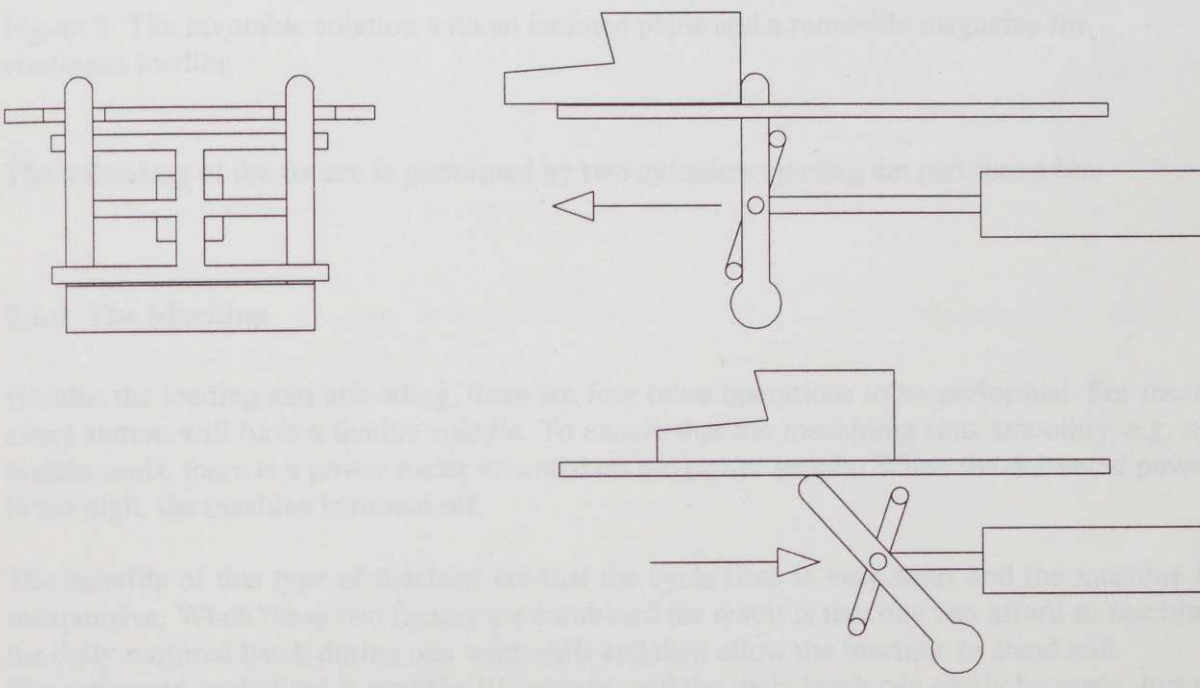

Figure 4. The Mechanical loading and unloading system

To maintain a flow of parts some sort of a magazine is required. There are two possibilities for building this. The first alternative is to have a inclined plane with a number of parts leaning on each other with an specified angle. The second alternative, in order to avoid continuous loading, is to use a box with a partially removed bottom face. The box is placed fixed on a conveyor belt. This belt has just enough friction to feed a new piece only when the loading pocket is empty. As an alternative, rather than a continuously moving conveyor, a signal can be sent to turn on the conveyor only when the loading pocket is empty.

The second alternative is the favorable as a number of magazines can be loaded outside of the machine while the solution with an inclined plane requires continuos loading. A sketch of the second solution is illustrated in Figure 5.

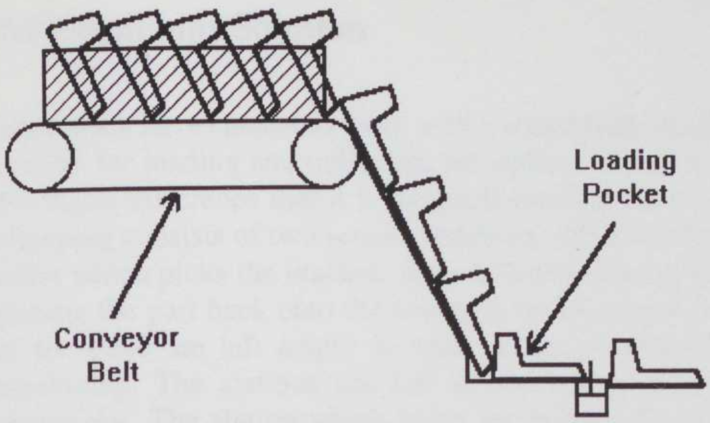

Figure 5 The favorable solution with an inclined plane and a removble magazine for continous loading

The unloading of the fixture is performed by two cylinders ejecting the part into a bin.

7.1.3 The Machine

Besides the loading and unloading, there are four other operations to be performed. For these, every station will have a double spindle. To ensure that the machining runs smoothly, e.g. no broken tools, there is a power meter mounted on the power supply. When the delivered power is too high, the machine is turned off.

The benefits of this type of machine are that the cycle time is very short and the machine is inexpensive. When these two factors are combined the result is that one can afford to machine the daily required batch during one work shift and then allow the machine to stand still.
The estimated cycle time is roughly 10 seconds, and the daily batch can easily be made during one work shift.

There are several drawbacks to this type of machine. The loading and unloading is quite complicated if it is performed mechanically. In the long run, the inclined plane solution is impossible to use as it takes up a lot of space and requires a continuos loading. Therefore the magazine solution is preferable.

Regarding of the next step of manufacturing it could be favorable if the parts are put in some sort of a pallet upon completion. If ejectors are used in the fixture there would be no ordered orientation of the parts when ejected.

7.2 Neumanns Solution

Neumanns have chosen to work with a round table machine with six stations. The first station is used for loading and unloading the fixture, which is of a construction similar to ours with the major difference that it is mounted standing on its side rather than laid flat on table. The clamping consists of two screws which are tightened by a motor. The loading is managed by a robot which picks the brackets from a feeding conveyor. Unloading is performed by the robot placing the part back onto the conveyor to be carried away. The second and the sixth stations of the table are left empty in case further development of the bracket requires additional machining. The stations not left empty will be used for centering, boring and threading operations. The station which bores the holes will utilise a special tool which will perform face milling as well. Each of these three stations are equipped with double spindles.

Neumanns has a simple although very interesting solution for transportation of chips and burrs as well as a return system for the cutting fluid. Around the table is a trough where the cutting fluid will drain while carrying any chips or burrs with it. There will be two rubber blade traversing the trough as the table rotates, carrying the foreign material to a hole in which the fluid, in order to be reused, will be separated from the metal. See Figure 6 for an illustration.

To handle the incline of the two holes the spindles are to mounted at the appropriate angle. The cost of this type of system is around 930 000 SEK. For further information and sketches of the machine, see Appendix 4.

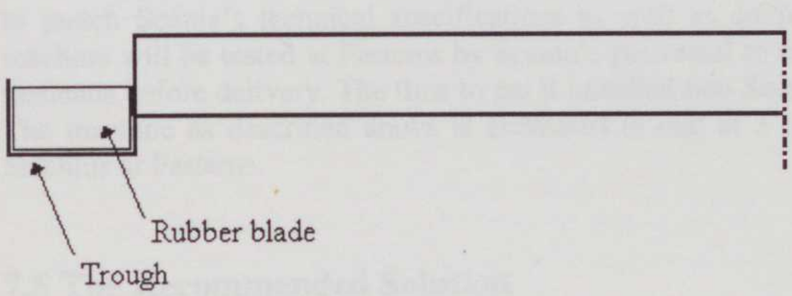

Figure 6. Chips and burrs are carried away by two rubber blades traversing the trough.

7.3 Bellows Solution

Bellows believes that the problem should be solved similarly to the trial production at Scania with some sort of multi-operational machine. In their main catalog they have, as they refer to it, a multi-operational module equipped with a tool changing apparatus and a turning table with two stations. One station for loading and unloading and one where the machining is carried out. The drawback in the trail production was, as Bellows considered the problem, that too many parts had been mounted upon the fixture at the same time (12 on each side, 48 in total). The problem then became positioning so many parts and matching the machine's cycle time. Their solution is to mount up to four parts in the fixture. Each part should be correctly oriented in the fixture, before it is tightened. The loading and unloading is carried out by a robot. This module is already designed with a cooling liquid system which is compatible with the central cooling system at Scania. The advantage to using this idea is that one receives a more flexible machine, and any other redesign of the bracket will probably only be a matter of software. The price of the whole module with tool changing device and a robot for loading and unloading would end up at 2.3-2.5 million SEK according to Bengt Skoglund at Bellows.

7.4 Fastems Solution

Fastems did not employ the proposed idea for solving the problem, as they believed there was a discrepancy between the proposed cycle time and yearly production. Their solution includes a turning table with only two stations, one where the loading and unloading is performed by a portal gripping device and the other equipped with rotating spindles which carry out all four of the machining operations: facing, boring, chamfering and threading. The spindle is numerically controlled in every direction. From a standpoint of cutability, this solution is advantageous as facing operations are better performed by approaching from the side rather than the top. The cycle time of this machine is approximately 30 to 40 seconds and is designed to match Scania's technical specifications as well as conform to EC standards. Also the machine will be tested at Fastems by Scania's personnel to ensure that it complies with their demands before delivery. The time to get it installed into Scania's shop is two to three weeks. The machine as described above is estimated to end at 3 million FM, according to Reino Salenius at Fastems.

7.5 The Recommended Solution

After evaluation of all the ideas and bids, the recommendation is to accept the bid offered by TT Harald Neumann AB. Not only is this the least expensive of the options, but it also provides for the possibility of further redesign and/or expansion by leaving two stations of the table unused. Two other points of interest are the inventive loading scheme which utilises a conveyor feeding the parts to the positioning robot, and the practical solution for collecting and separating burrs, chips, and cutting fluid.

8. Difficulties and Experience with the Project

Working with the project has not been easy, as there have been many problems. However, it has also provided a lot of valuable experience.
Today Swedish industry is going through a period of high demand with a lot of large investments in new equipment. This means that companies working in industry are pushed to or beyond full capacity.
One of the main goals with this project was to invite a number of companies to provide us with a bid on a solution to the problem, in order to be able to make a cost analysis. As time went by, we had to accept that this goal was not possible to achieve according to the economic rise in industry. We had to be satisfied with simply obtaining their solutions and a rough cost estimate.
It could be argued whether we should regret the high demand in industry or simply be happy, as within less than a year we will probably be out there working. In any case, however, this project at Scania has to be completed in the present.

One problem, which at first we were apprehensive of, never arose. We thought that it could be difficult to convince companies to work seriously with a "student project" but there were never such problems as it was a real Scania project.

Another lesson which we have learned is how to produce a demand specification. We chose to describe our own solution briefly in order to get a price offer on it, but still left the door open for the companies' own ideas and solutions. In retrospect, we would probably have done it differently. Instead of presenting our own idea, we would have simply given a demand specification and allowed the companies to produce their own solutions. We noticed that one company chose to withdraw from bidding as they felt too restricted by the demands.

It can be noted that our proposed solution involves working with a small firm rather than a large and established one. We believe that working with a smaller operation has been conducive to a creative and appropriate solution. The larger companies, like Bellows for instance, rather than custom designing a machine for our needs, has simply presented a catalog from which to select various pre-fabricated machine components to solve our task. While this sort of solution performs the job, it is not the most appropriate machine for the job and, although perhaps more flexible, comes at a higher price. One drawback with dealing with a small corporation however, is the certain amount of risk that the service, guarantees and economic stability will not be on par with the larger and more established companies.

Appendix 1

Bracket Drawing

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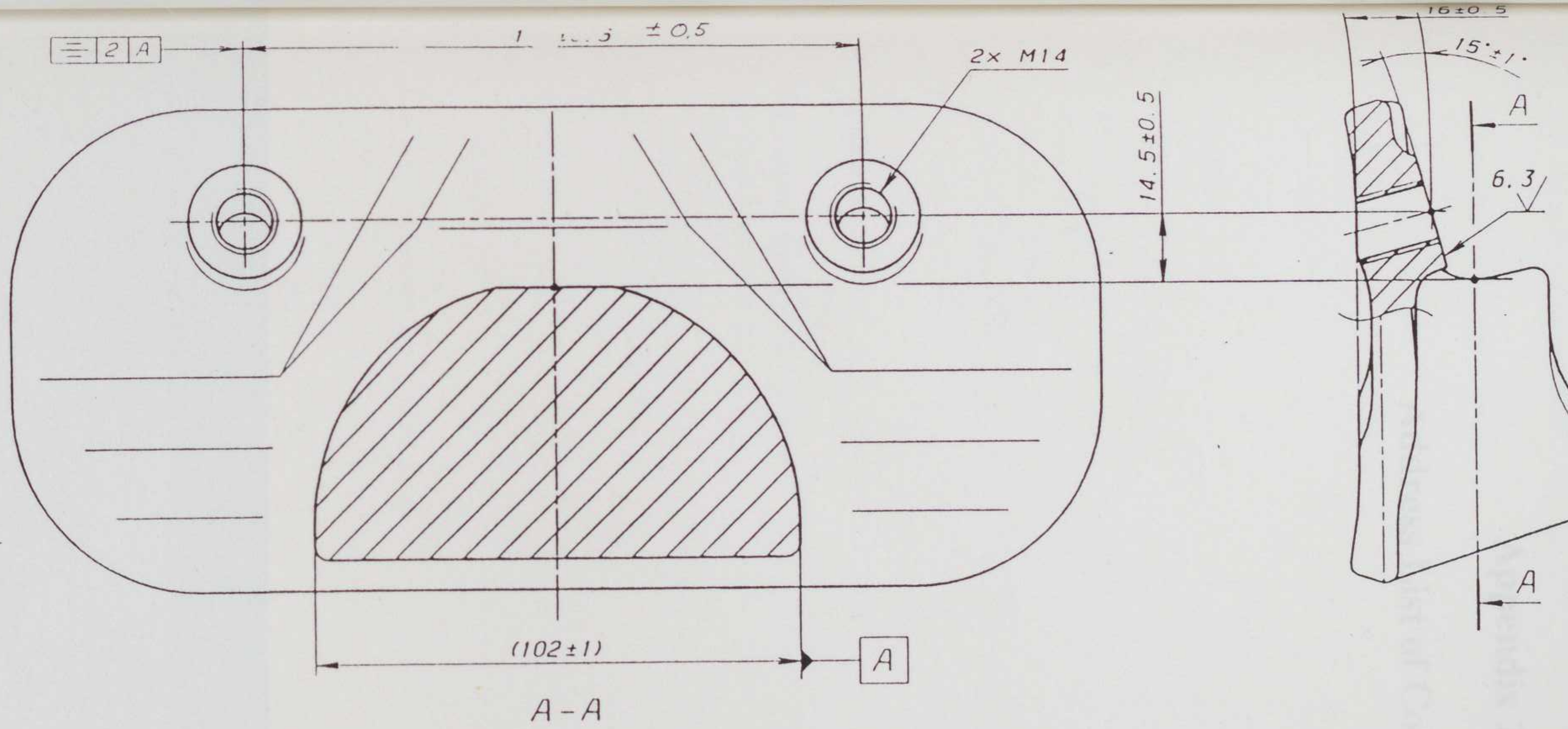


Unless otherwise stated the following applies

Tolerancing STD 3162

Symbols, designations and drawing methods STD 12

Surface treated -

Metric ISO threads ISO 724, ISO 965-1

Tolerance class 6H/6g

Surface rough. R_a - µm

Size tolerances - -

Burrs not permitted

Edges broken -

Type (Steel)

Blank/Dimension - 1362932

Material

Class/Quality (2225-03)

Condition (Hardened and tempered HB 205-250)

Proj method

Marking Acc to STD 19

At -

In - line Char.h - -

Trademark type -

Part No -

Moreover - - -

Change	Zone	CO number	3D	Nature of change	Date	Sign
A	-			Changed according to the forging	940317	Gaj

CO number 48243, Introduced

- 3D Model available

CAD

Scale	Designed	Design ch	STD ch	Date	Approved
1:1	Arne Johansson	LNO ASJ	-	931228	-

Description: Bracket

Status P

SCANIA

1364709

Sheet 1 (1)

Code S -

SV1106-03 8 7 6 3 2 1 A3

Appendix 2

Address List of Companies

TT Harald Neumann AB

Contact: Harald Neumann
Handelsvägen 3
640 25 Julita
Tel. 0150-916 60

Dankab

Contact: Johan Rydström
Fortvägen 32
Box 5025
183 05 Täby
Tel. 08-732 02 90

Fastems

Contact: Reino Salenius
Linnavuorentie 12
SF - 37240
Linnavuore, Finland
Tel. 009 35831-3417526

Bellows

Contact: Bengt Skoglund
Box 2103
145 02 Norsborg
Tel. 08-531 889 30

Appendix 3

Bid Request

Karl André
Tunastigen 88
973 44 Luleå
0920 - 22 82 20 (hem)
0920 - 917 22 (dagtid)
fax 0920 -722 28

Hejsan!

Vi är tre studenter, som nu går sista året på maskinteknisk linje vid Högskolan i Luleå. Under slutet av höstterminen och början av vårterminen löper en kurs kallad Produktionsteknisk projektkurs, där vi i samarbete med ett företags produktionstekniska avdelning driver ett projekt. För vår del kom detta projekt att bli, automatiserad bearbetning av luftfjäderfäste vid Scania Luleåverkstaden, avdelningen för bakaxeltillverkning. Syftet är att ta reda på om det är möjligt att räkna hem en eventuell legotillverkning.

Vi begär härmed, på uppdrag av Scania, in en budgetoffert från Er.
Som underlag har ni vår kravspecifikation och lösningsförslag, men även andra förslag på lösningar är av intresse.

Det vore önskvärt om vi kunde få svar från Er senast den 10/2 - 1995.

Med vänlig hälsning

Karl André

Kravspecifikation

Bakgrund

- Maskinen ska enbart bearbeta ämnen till luftfjäderfästen, enligt ritning. Tidigare försök har gjorts vid Scania, då i en fleroperationsmaskin. Svårigheten vid detta försök var att, allt för lång tid åtgick för att lossa och ladda de stubbar som användes (12 detaljer spändes på var sida, inalles 48 detaljer). Det var framför allt uppriktningen av detaljer som var tidsödande. Följden blev att maskinen stod stilla i väntan på en ny stubbe. (Skärdata från detta försök finns i bilaga 1.)

- Årsbehovet är beräknat till knappt 90 000 detaljer per år. Varje detalj väger ca. 2,8 kg.

Tekniska data

- Vi har, efter samråd med Scania, kommit fram till att lösa problemet med en rundtaktmaskin (helt mekanisk eller till viss del numeriskt styrd), där detaljerna automatiskt matas in i fixturen och samtidigt riktas upp. Maskinen ska ha sex stationer, enligt figur 3, laddning, planförsänkning, borrning, försänkning, gängning och lossning.

- Maskinen bör anpassas till ett befintligt centralt skärvätskesystem. Kylning genom verktyget.

- Enkel processkontroll i form av effektmätare både på borrning och gängning. Denna skall slå ifrån vid överbelastning såväl som vid noll effektuttag. Denna låsning ska dock kunna överbryggas manuellt, så att maskinen kan tömmas.

- Ekvivalent ljudnivå får ej överstiga 75 dBA vid normalproduktion.

- Takttiden bör ej överstiga 20 sekunder.

Spindlar

- Samtliga spindlar skall kunna lutas i lägen om 15°, inom intervallet -15° till 15°.

- Maskinen bör ha dubbla spindlar vid varje bearbetningsstation.

Fixtur

- Förslag på stödpunkter och spännjärn enligt skiss på ritning.

- Spännjärnen lossas med hjälp av tryckluft alt. mekaniskt.

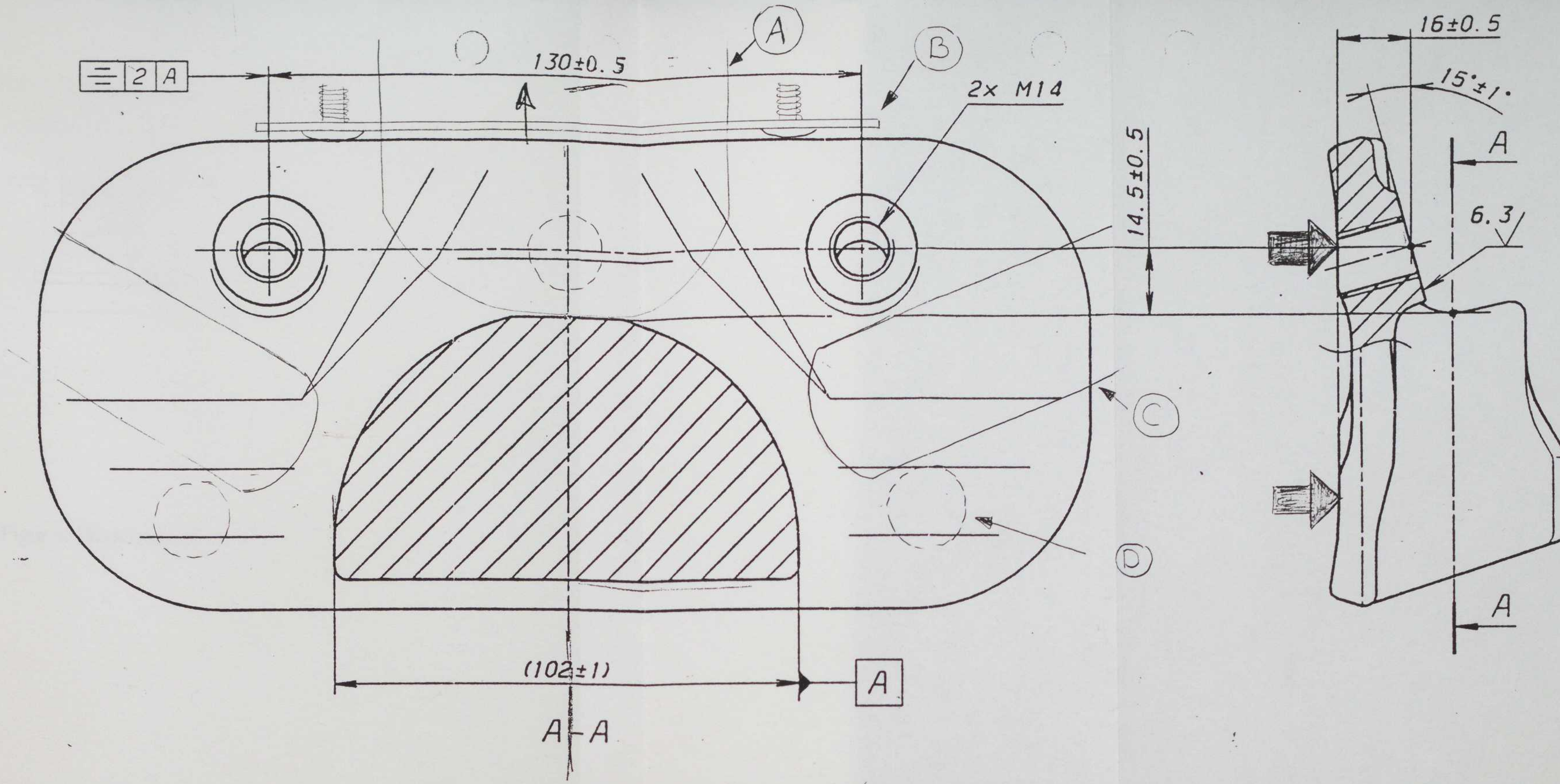
- Detaljerna riktas upp då de matas in i fixturen, där styrklackarna i inloppsdelen gör att lägeskravet innehålls, stoppet innehåller måttet 14,5 ± 0,5 och den fjädrande linjalen ser till att detaljen inte kan snedställas i fixturen.

- Laddning sker automatiskt enligt figur 4.

- Lossning med hjälp av utstötare i varje fixtur.

Övrigt

- Maskinen bör vara utrustad så, att ett högre skärvätsketryck kan tas ut och användas för renspolning av varje fixtur, efter det att detaljen lossats och stötts ut.



1364709

A: STOPP

B: FJÄDRANDE LINJAL

C: SPÄNNKLAMPAR

D: STÖDPUNKTER

Unless otherwise stated the following applies

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Symbols, designations and drawing methods	STD 12
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Tolerance class	6H/6g
Surface rough. R_a	- µm
Size tolerances	-
Burrs not permitted	
Edges broken	-
Type	(Steel)
Blank/Dimension	- 1362932
Material Class/Quality	(2225-03)
Condition	(Hardened and tempered HB 205-250)

Change	Zone	CO number	3D	Nature of change	Date	Sign
A	-			Changed according to the forging	940317	Gaj
		48243		Introduced		

3D Model available — CAD

Proj method	Scale	Designed	Design ch	STD ch	Date	Approved
	1:1	Arne Johansson	UNO / ASJ	-	931228	-

Marking Acc to STD 19

At ◇ -

In - line Char.h - -

Trademark type -

Part No -

Moreover - - -

Description: Bracket

SCANIA

Status: P

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Sheet 1 (1)

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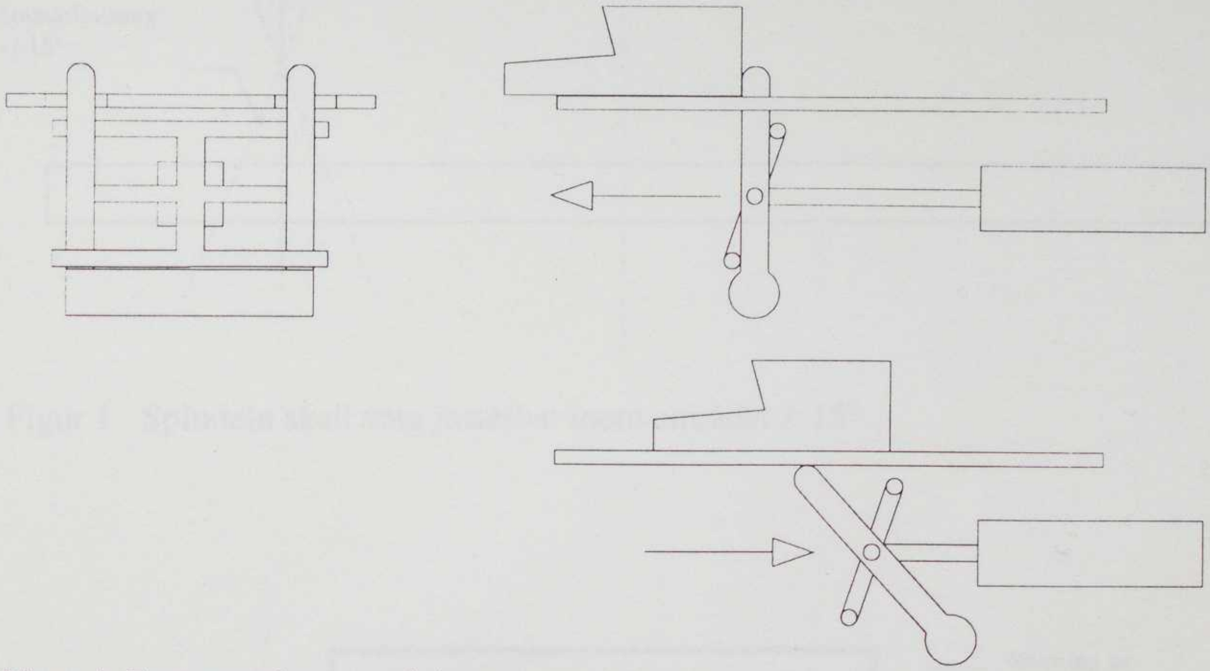
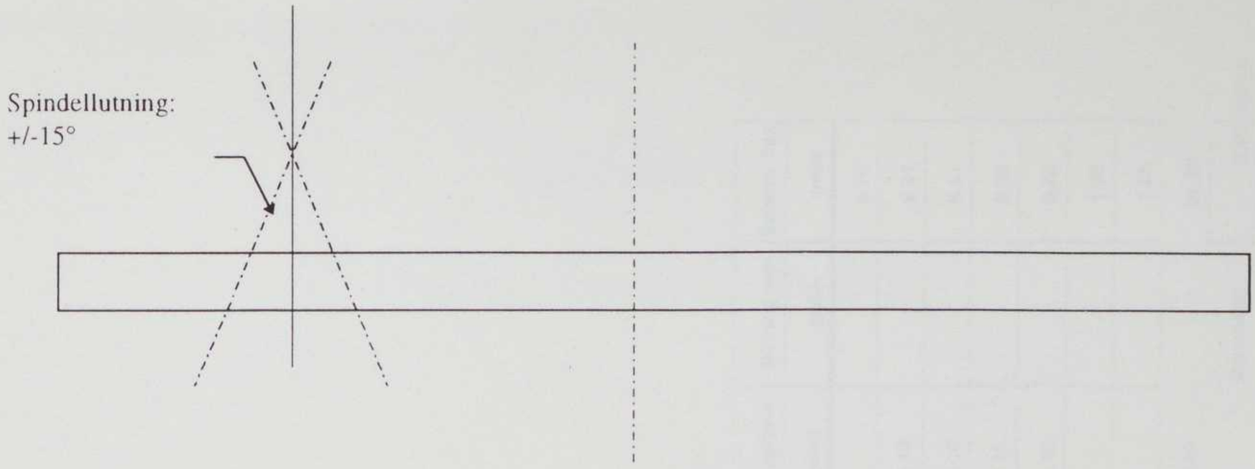
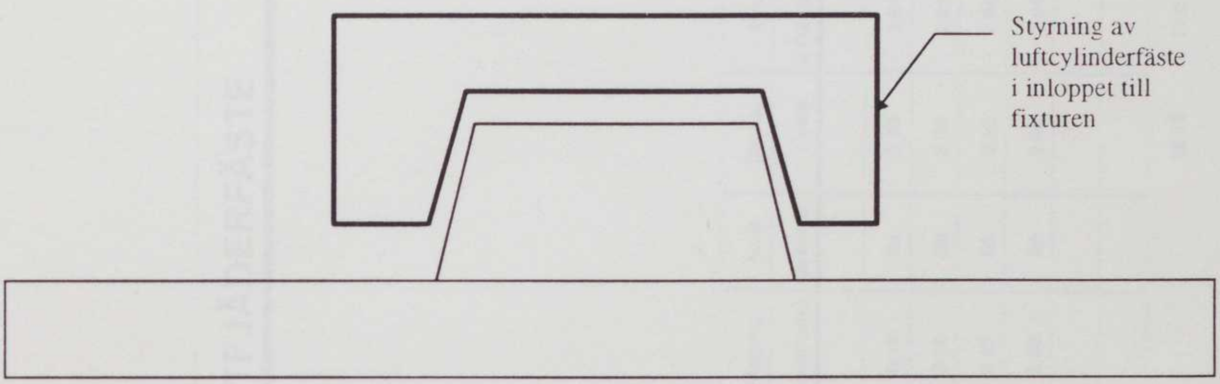


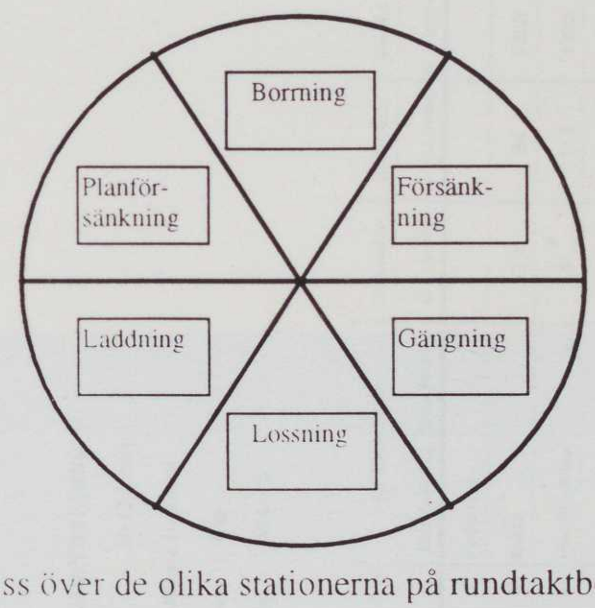
Figur 4. Frammatningsanordning



Figur 1 Spindeln skall vara justerbar inom området ± 15°.



Figur 2 Luftcylinderfästet styrs in i fixturen med styrklackar placerade ovanför inloppet till fixturen.



Figur 3 Schematisk skiss över de olika stationerna på rundtaktbordet.

SAAB SCANIA AB
Scania Trucks & Buses
Luleåverkstaden
BI I BT/S Roos
Dat 940415

Kalk001

KALKYL FÖR BEARBETNING AV LUFTFJÄDERFÄSTE

Bearbetningen utförs i fleroperationsmaskin SV 17916 , 48st detaljer placeras i fixtur med fyra sidor som indexas , 12 st detaljer på vardera sida

VERKTYGSUPPSÄTTNING

1. Borr : D-12,5 mm

2 Planforsänkare D=30mm

3 Försänkare 45gr

4 Gängtapp M14x1,5

Op	Pos	Verkt	OPERATION	Diameter	Skärhast.	Varvtal	Bearb längd	Matning	Antal	Skärtid	Pos	Indexering	Verktygsbyte	Mätning mm	Summa TID
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	1		Laddning												0,70
	2	1	Borra	12,5	94	2300	25	0,18	96	5,80	2,91	0,40	0,10		9,21
	3	2	Planforsänka	30	113	1200	4	0,10	96	3,20	2,91	0,40	0,10		6,61
	4	3	Försänka	45 gr	113	1200	4	0,15	96	2,13	2,91	0,40	0,10		5,54
	5	4	Gänga	M14	15	340	30	1,50	96	5,65	2,91	0,40	0,10		9,06
	6		Lossa detalj												1,20
	7		Fördelningstid 5%												1,05
			SUMMATID=							16,78	11,64	1,60	0,40		32,38

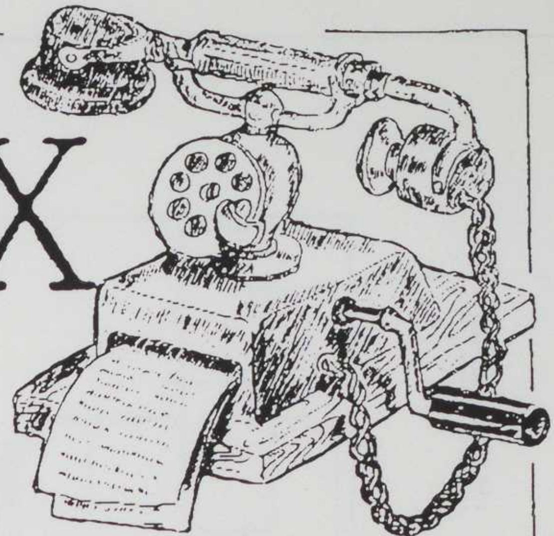
OBS* 'Pos X/Y/Z = 97 ggr / Pos tid =0,03 min

Summatid: 0,67 min/st

Appendix 4

TT Harald Neumann's Proposal

TELEFAX



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Antal sidor / Nb. of pages / Anzahl Seiten : 1+2

Mottagare / Reciever / Empfänger: Karl André

Avsändare / Sender / Absender: TT Harald Neumann AB /me

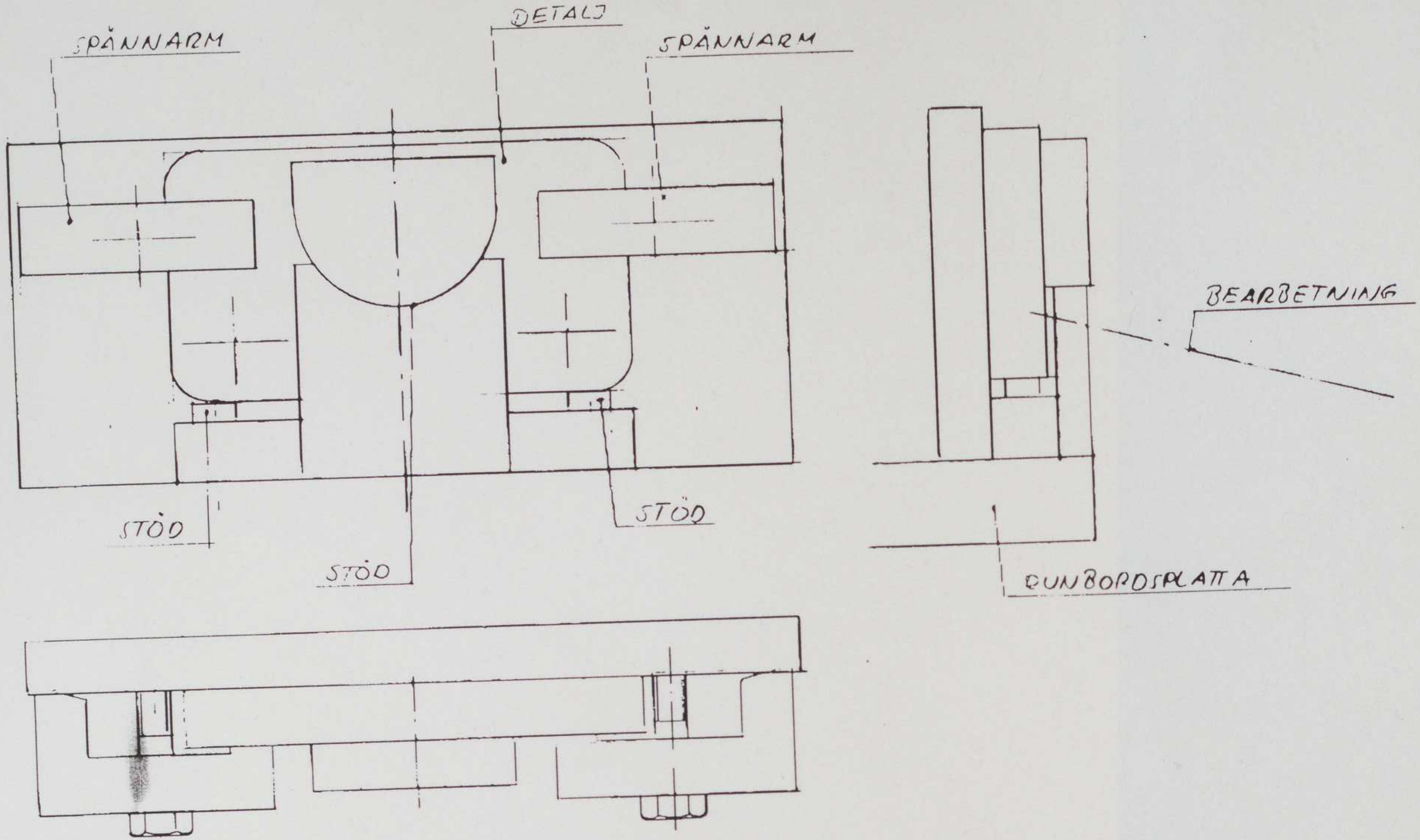
FÖRSLAG BEARBETNING SCANIA DETALJ

BEARBETNINGSFÖRLOPP:

STATION 1: ILÄGGNING/FASTSPÄNNING AV DETALJEN
STATION 2: TOMT
STATION 3: CENTRERING
STATION 4: BORRNING
STATION 5: GÄNGNING
STATION 6: TOMT

CA PRIS: MASKIN ca 390.000
BEARBETN. ENHETER ca 200.000
STYRNING ca 160.000
KONSTR + MONT. ca 180.000

NÄRMARE DETALJER PER BREV
MVH. H NEUMANN



Material	Ytbehandling		Värmebehandling	
Konstr. KN	Ritad	Kop.	Måttl mensioner $\frac{IT14}{2}$ Samtliga kantebrutna spader	Skala 1/.	Ersätter	Ersatt av
TTHARALD NEUMANN AB Handelsv. 3, S-640 25 JULITA Tel 0150/915 00	UTFÖRANDE FIXTUR			Ort	
				Ritn nr	