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STUDY ON LEAD TIME IMPROVEMENT FOR PRODUCTION OF BEARING COMPONENTS

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ABSTRACT

Production of bearings is based on different mechanical processing of metallic or nonmetallic materials. The process flow is composed of two main processes: hot processes and cold processes. Hot processes are forging, hot rolling, primary and secondary heat treatment. Cold processes are mainly turning and grinding operations. Deep-drawing processes are used also in bearing cages manufacturing. Rollers are obtained by cold pressing processes. In this study it is presented a comparative analysis about the influence of the raw material shape on the production time. Also an analysis of the predominance of the set-up time in total production lead time was developed for all manufacturing processes of a complete bearing. Experimental tests were performed. The material used in experiments bore quality steel tubes and steel bars. In the experiments were used samples catted from tubes and forged rings. The improvement of the total lead time due to the shape of the raw material was determined. The lead time was improved by 11%.

Keywords: tubes, bars, bearings, lead time, process flow, set-up time

1. INTRODUCTION

1.1. Problem definition

In the last years one of the most important problems in industries was cost saving.

The automotive industry has experienced a competitive environment and has been striving hard to find methods to reduce manufacturing cost, waste and improve quality [Hemanand, 2012].

A fundamental challenge that companies are facing today to become global competitors is that of devising and implementing strategies aimed at satisfying customers who require better levels in price/cost, quality, product design, delivery speed and reliability and on-time delivery [Villarreal, 2009].

Currently, bearing industry is one of the main suppliers for automotive industry. In order to assure that the spare part or the original equipment is delivered on time, some project or studies were developed in terms of lead time improvement. In a production environment, there is a relationship between lot sizes and the lead times [Noblesse, 2014].

Several approaches are used to achieve the objective of reducing the lead time: Reduction of the WIP (Work In Process), synchronization of production, ensuring the continuity in the flow of work, elimination of variability [Simeonovova, 2012]. A study on how the value mapping can be used to visualize graphically the flow of material and flow of information from customer order to finish product was developed by [Saraswat, 2015].

For most organisations, reduction in cycle time of product development involves a significant change in development process, thinking from the standardised development processes popularised in the 1980s to the more flexible procedures used today [Patel, 2015]. It is known that the lead-time depends on lot size and set-up time [Hariga, 2000].

The relationship between lot size and quality of product is assumed while producing a lot. During long production process, machinery systems may produce low quality products, which may result in revenue loss and an impugned industry reputation [Ritha, 2015].

In terms of designed lead time different approaches were defined as stopwatch time study, expert opinion standards, predetermined time standards, work sampling time standards [Patel, 2015].

In this study it was analysed that the influence of the process steps defined in process flow on the total production time.

Two different ways of approaching this subject were followed in this study. One way is to analyse the influence of set-up time of each production step on the total lead time. The second one is to analyse the influence of the raw material shape on lead time.

The start point of this study was the current flow chart for a standard bearing components, outer and inner rings. Based on this flow chart were calculated the designed production time for the existing flow chart and also for the proposed flow chart. The flow charts for rollers and cages were considered the actual ones. It is well known that a standard bearing is composed by different elements as: inner and outer rings, rollers, cages and rivets.

2. EXPERIMENTAL EQUIPMENT AND MATERIAL

2.1. Experimental conditions

Experimental tests were carried out in order to characterize the influence of the raw material shape on total production lead time.

Two different shapes for raw material were used: catted tubes and forged rings.

The bearing which was analysed is a radial cylindrical roller bearing NU 206ES. The geometry of this bearing is designed in RULMENTI Barlad. All dimensions and components are shown in figure 1.

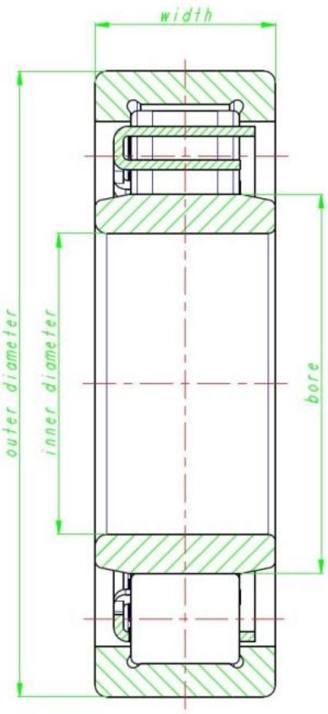


Fig.1. *Radial cylindrical roller bearing components*

The process flow was analysed taking into account for each production step the added value from the timing point of view.

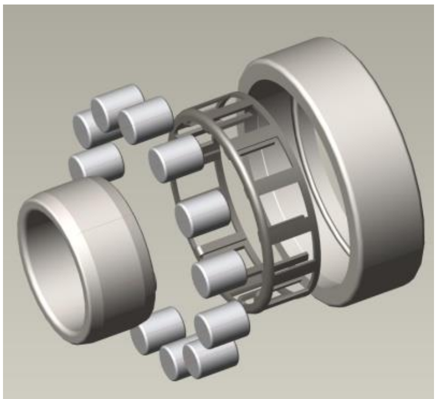


Fig. 2. *Radial roller bearing components-3D view*

The production lead time was measured in accord with the designed flow charts for both types of raw materials.

A comparison regarding the influence of the raw material shape on the production lead time was performed.

The preponderance of the set-up time on the total production time was developed.

2.1.1. Designed dimensions for catted samples

Steel tubes are cold catted in order to obtain the samples used for turning processes. Shape and dimensions of the catted samples can be observed in figure 1 and table 1.

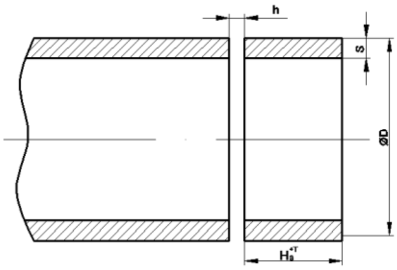


Fig. 3.*Samples dimensions*

Table 1. *Outer ring sample cutting details*

Sample dimensions [mm] **NU206 E-10 (outer ring)**			Cutting tool
DxL	Hs	s	h
Ø68.3x9.9	$18^{+0.5}$	5	2

Table 2. *Inner ring sample cutting details*

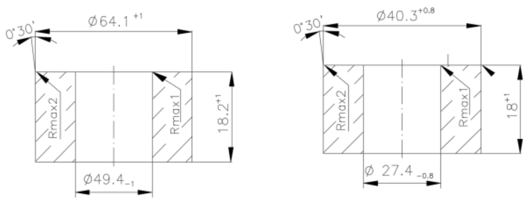
Sample dimensions [mm] **NU206 E-20 (inner ring)**			Cutting tool
DxL	Hs	s	h
Ø44.3x9.5	$18^{+0.5}$	5	2

Cutting process was performed on an automatic controlled CNC cutting machine [7-18].

Fig.4. *Cutted samples*

2.1.2. Designed dimensions for forged samples

Forging process is performed using steel bars which are heated directly on the automatic press. For this process the heating temperature of the bars are inside of the interval [850-1173]°C.



Outer ring Inner ring

Fig. 5. *Forged samples:shape and dimensions*

Process parameters used to forge steel bars in this study were defined according to Automatic Pressing Machine capability AMP 30.

Table 3. *Forging process parameters*

Bar diameter	Pressing force [kN]	Heating power [kw]
Φ28	2300	1100

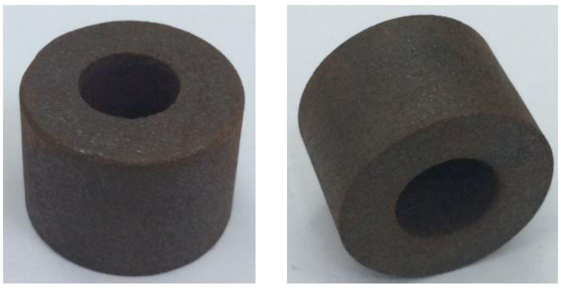


Fig. 5. *Forged samples*

2.2. Materials

The raw material tested was 100CrMnSi6-4 tubes and bars steel. This steel is used in bearing production for rings and rollers. Materials used to produce cages are: steel sheet and brass, depending on the application of the bearings. Construction NU 206ES use the steel sheet cage which is processed by cold forming process as deep-drawing and cold cutting.

Internal cross-check is performed for raw materials. All chemical and metallographic parameters are checked and compared with requested values and also with supplier measurements. In this study the material used was approved for series production.

2.2.2. Consumption norms

In order to produce rings according to technical specifications and customer requirements for all components are calculated the consumption norms. Table 3 shows the consumption norms for raw material used to produce outer and inner rings.

Table 3. *Consumption norms*

Norm consumption [kg/pcs]		
	Steel tube	Steel bar
Outer ring	0.314	0.320
Inner ring	0.180	0.133

2.2.4. Manufacturing process flow

Flow charts for manufacturing processes are described schematically for both types of raw materials.

The influence of the process steps on the total lead time was evaluated from technical norms for all processes described in the flow diagrams.

A bearing component can be processed following different process steps.

The process steps are designed in order to obtain a bearing component ready to be assembled with inner or outer ring, rollers and cages. During the process flow the raw material is supposed to different mechanical processes or special processes as primary and secondary heat treatments.

The approach of scheduling the manufacturing processes according to the designed flow diagrams, figures 6 and 7, means that both raw materials are processed in similar ways starting with turning operations. In case of bars three more sub-process steps are necessary in order to obtain the same sample as in case of steel tubes.

A comparison between these flow diagrams lead to the conclusion that tubes request only cutting tools and cooling liquid, in the same approach the forging process contain heating bars and forging, primary heat treatment process and shoot blasting process.

It is known that for forging process are requested different work parameters as: heating power and pressing tools.

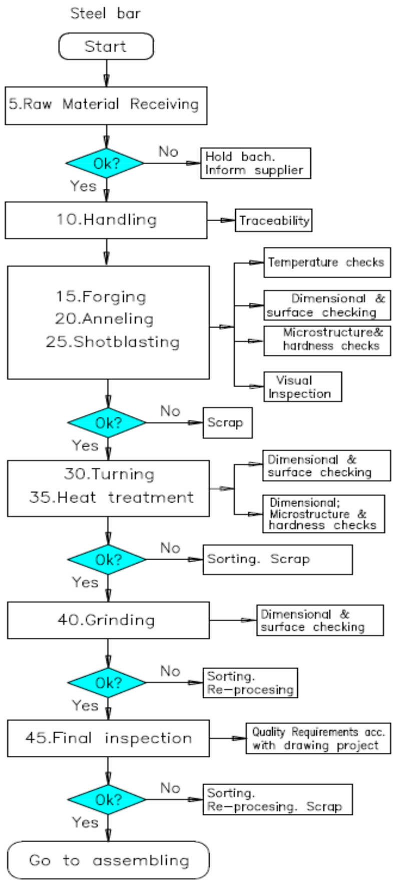


Fig. 6. *Actual flow diagram for rings processes*

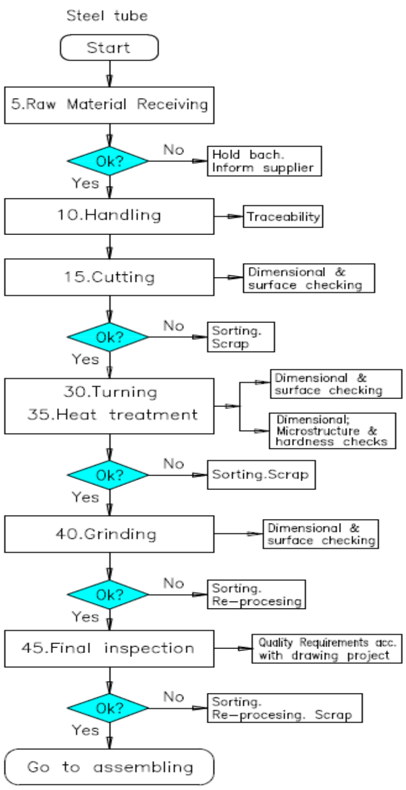


Fig. 7. *Proposed flow diagram for rings processes*

3. Results

3.1.1. Lead time evaluation

The influence of the raw material type on the lead time was analysed.

Considering that both kind of raw material are used for the same production quantity it can be observed in table 3 that the total lead time was improved with 20%.

Figure 8 showed that the forging process has the main influence on total production lead time. The analysis of a complete process in case of an outer ring shows an improvement in total production lead time around 14%. This improvement was obtained only by replacing the steel bars with steel tubes.

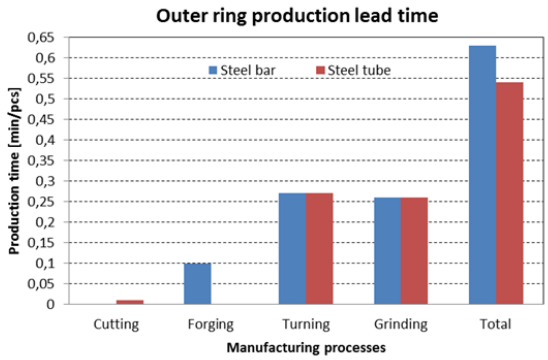


Fig. 8. *Total production lead time improvement for the outer ring*

In case of an inner ring, figure 9, the analysis of collected data shows an improvement in total production lead time around 21%, considering the replacement of the steel bars with steel tubes.

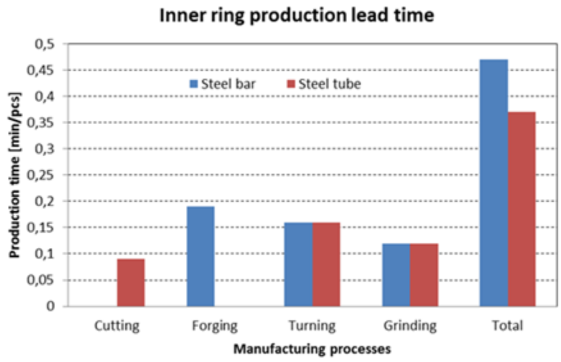


Fig. 9. *Total production lead time improvement for the inner ring*

Considering that the total production lead time is influenced only by raw material shape for rings production, the rest of bearing components manufacturing process was considered in this study as standard/constantfrom lead time and cost point of view.

The forging process which includes forging, primary heat treatment and shoot blasting sub-processes has the main influence on the total production lead time.

Replacing the entire forging process with cold cutting process due to the new approach was obtained a total lead time improvement for a complete bearing around 11%.

For these experiments we considered that for turning, secondary heat treatment and grinding processes conditions (tools, cooling liquid, devices and machines) are the same for both types of raw material.

3.1.2. Preponderence of set-up time

In the series production, one of the major influence in total production lead time and production total cost has the set-up time. Set-up time of the necessary machines for process development influence directly the results of manufacturing processes.

A simulation of the preponderance of the set-up time in total production lead time was developed considering the minimum order quantity of 100, 500, 1000, 5000 and 10000 pieces.

As a consequence of this analysis, the set-up time has the main influence if the process is set for a production under 1000 pieces. The preponderance considered as optimum is under 20%, figure 10.

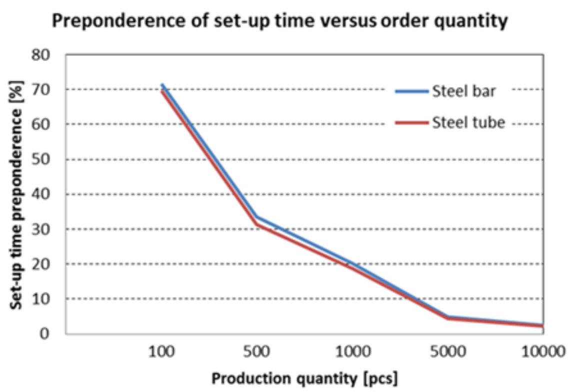


Fig. 10. Preponderence of set-up time in total production lead time

For both types of raw material, the obtained influence is under target, but the steel tube show that the set-up influence is smaller than in case of steel bar under a production about 5000 pieces. This can be explained by the fact that set-up of one cutting machine is 15 min compared with the necessary time to set-up one forging machine and a shoot blasting machine is 165 min.

The analysis of set-up time necessary for a complete manufacturing process of a bearing, including, cage, rollers and assembly shows that the roller manufacturing process has the main influence on total set-up time.

Analysis on the necessary set-up time for a complete bearing is around 3031 min for steel bars and 2731 min for steel tubes, figure 11. These set-up times were calculated for entire process flow (inner and outer ring, steel cage and roller) according to the flow diagrams.

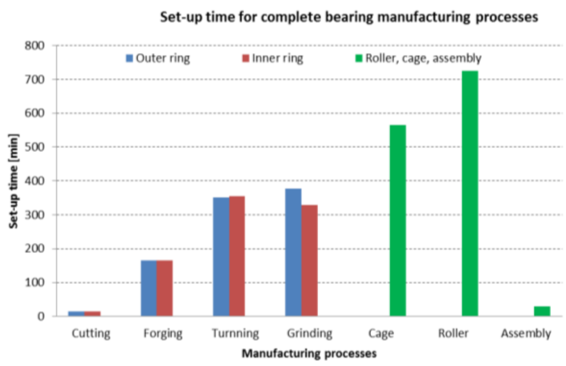


Fig. 11. *Set-up times for a bearing manufacturing processes*

5. CONCLUSIONS

1. In bearing manufacturing processes, two different raw materials shapes can be used: steel tubes and bars.
2. By using steel tubes, the total lead time for a radial cylindrical roller bearing is improved by around 11%.
3. This study shows a correlation among raw material shape, order quantity and set-up time exists in series production.
4. Analysis of the influence of the set-up time on the total production time shows that for a minimum order quantity up to 1000pieces the preponderance of the set-up time in total lead time is below 20%.
5. This analysis was conducted under the hypothesis that an order could be placed in production for a set-up preponderance of maximum 20%.
6. In case of tube used as raw material the preponderance is around 16%, for an order of 1000pieces.

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