Waste reduction by implementation of CNC machining center and Lean Manufacturing

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Abstract. In the context of increasing competitiveness, the companies from manufacturing industry are constrained to provide quality products at a lower price and a shorter delivery time. This brings new challenges during the manufacturing process. One of the main challenges is to reduce or eliminate waste during the production stage. The actual paper presents methods and solutions through which the waste from the manufacturing process is identified and eliminated. As a consequence, increased productive efficiency and higher profit have been gained. The objective of this study is to implement Lean manufacturing tools, in order to improve the production process carried out within a manufacturing company, with a small manufacturing batch. Based on real data from the manufacturing process, the current value stream mapping (VSM) was built, identifying both operational and non-operational times. After waste identification, an optimal solution was chosen for the manufactured parts required by the customer. Implementing the best solution resulted in a productive efficiency increase by 90.93%, which significantly reduces the manufacturing time.

1. Introduction

With the digitization of companies, new challenges have emerged in the operational activities of manufacturing companies, aiming to increase performance by waste reduction. In this context, an important role is played by the tools and the ways that companies use to increase their performance, reducing the waste (different type of waste) within the manufacturing processes. [1-3]

Lean Manufacturing has proven to be one of the best practices that manufacturing companies adopt within organizations to increase their performance by reducing, respectively eliminating waste [4-5].

According to Arunagiri and Gnanavelbabu (2014), a study was conducted on the main waste from automotive industry, ranking the 7 waste defined by Taichi Ohno (overproduction, waiting, transport, over-processing, stocks, unnecessary movements, defects). The most common losses that affect the production process are: transportation, waiting times and unnecessary movements [6-7].

Subsequently, two other types of waste were added (in addition to the 7 waste defined by Taichi Ohno), namely the improper use of human talents and insecurity or ergonomic working conditions [8].

According to Gupta and Kundra (2012), in all manufacturing processes, there are two types of activities, namely value adding activities and non-value-adding activities. The non-value-adding activities are distributed in activities that can be eliminated, referring to those activities for which the client is not willing to pay, and the second category of the non-value-adding activities, which are necessary (these cannot be completely eliminated, but can be reduced by making major changes within the company) [9].

Lean manufacturing is a production system, which aim is continuous improvement of productivity, by identifying and reducing waste [10-11].

According to Azizi and Manoharan (2015), the implementation of the Lean Manufacturing production system involves five principles, as follows: specifying the value, identifying the value flow, creating the value flow, configuring the pull system by the customer and pursuing perfection through continuous improvement [12].

The implementation of the Lean manufacturing concept within a company contributes significantly to increasing productivity and sustainability, improving lead-time and improving quality of product [13-14].

Lead time reduction implicitly reduces the time to make the payment to the raw material suppliers and the time to collect the payment for the product manufactured and delivered to the customer, because the lead time represents the time between the order from the customer is received and the product is delivered to him [15-16].

Even if the transformation of a company based on traditional production principles into a company based on the Lean Manufacturing principles contributes to the increase of the productive efficiency and thereby generates higher profit, according to the study realized by Almanei et al, there are many challenges that the company must face [10].

Regarding the correlation between profitability and waste, Hamed and Soliman (2017) point out in their study that those companies that identify and eliminate waste, automatically increase their profit because the costs of waste are eliminated. Moreover, the savings created by eliminating that percentage of waste can be used to cover other operational expenses (employees' salaries, direct expenses, maintenance costs, etc.) [17].

The operational process analysis is performed using Value stream mapping, which is a visual management tool used in Lean production [18]. VSM is a method that helps to visualize the entire technological process, quickly identifying the existing waste and eliminate it, realizing a streamline flow of raw materials and information, removing non-operational times, respectively waiting times from the technological flow [19-20].

This tool can be automatically generated, in real time, by computer-assisted programming, using a system with wireless RFID monitoring, thus reducing the time to make the value stream mapping and at the same time significantly reducing the errors [21].

Within Lean production, there are certain techniques that once implemented can significantly contribute to the increase of the productive efficiency [22], for example the implementation of the SMED (Single minute exchange of die). This technique improves the production flexibility and the time required to change the manufacturing batch by 50% [15]. In some cases, by implementing the SMED and Kaizen, these times have been reduced by over 60% [12].

The replacement of the traditional production system with the Lean Manufacturing production system significantly contributes to increasing the quality and costs reduction [19].

The implementation of Lean techniques not only has an impact on increasing profitability, but it also has a major impact on the environment. For example the use of VSM helps to identify the production process impact on the environment, 5S helps to maintain cleanliness (oil leaks and a variety of toxic solutions) and a clean working space, Total Productive Maintenance helps prevent oil leaks, dust emissions, chemical vapors in the atmosphere [23].

The term of "leanness" represents the impact of a company to become lean, reaching its objectives, respectively elimination of waste [24].

Lean design in manufacturing on CNC machining centers, or the design process by lean machine tools, according to Gupta and Kundra (2012), have many advantages, such as increased operating time of the machine, less materials, reduced design cycle time, easier manufacture and assembly of machine tools, improves product quality and reliability, easy cleaning and maintenance of machine tools, improves loading and unloading system, fast loading of machined workpiece [9].

The occurrence of errors in the production process involves different challenges, which if not resolved in time cause significant waste, thus reducing the company's profit. Any errors in the production process can be prevented by Poka Yoke mechanisms [25]. Here are some of the causes of the occurrence of possible errors and their impact on productivity:

- human errors can cause quality problems in the operation of the automated equipment (for loading, unloading and configuration) [26];
- errors of the processed part because of tool [27];
- errors at the workplace can be caused by inappropriate planning, ineffective communication and lack of proper training [7];
- during the mechanical processing performed on CNC machining centers or conventional machine tools, thermal errors can occur, due to the increased temperature of the machine tool elements that cause a relative movement between the machined part and the tool, during the machining process [28].

2. Research methodology

The study started from a human error, respectively inadequate assumptions and measurements were made. Consequently, the price offer was also incorrectly issued, the calculated price being lower than the cost of manufacturing the piece. The assumption for the price offer was made on the fact that the piece will be manufactured on a classic lathe SN 320.

As a result of this human error, the technological process was re-analyzed, reaching the conclusion that manufacturing the piece on a CNC lathe is more profitable than processing it on the classic one, provided in the tender.

The adoption of the production on CNC machining center was considered more cost-effective due to the reduced manufacturing time (considerably shorter than using the lathe SN 320 machine tool), which led to the shortening of the overall operational time, a significant increase of profit and higher product quality.

3. Case study

The present study analyzes the technological flow for the execution of a piece – knurled axle.

The number of pieces executed is 200. Figures 1 and 2 present the 2D, respectively the 3D drawings of the manufactured piece, produced on a CNC machining center - CNC Fanuc Oi Tc lathe. The final piece is shown in figure 3.

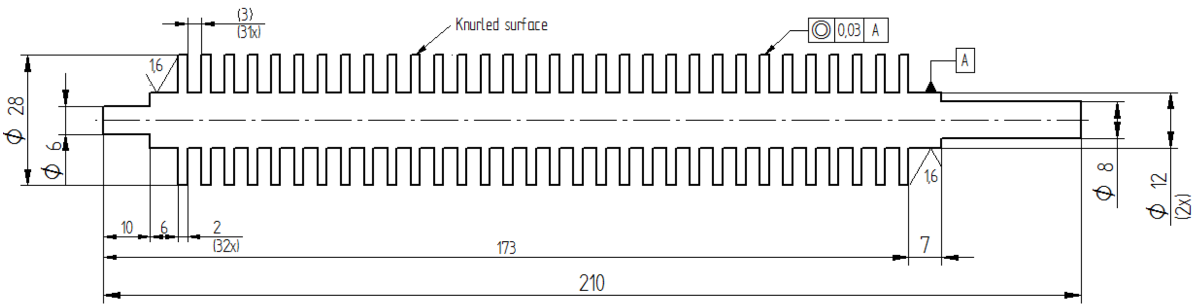

Figure 1. Knurled axle – 2D drawing.

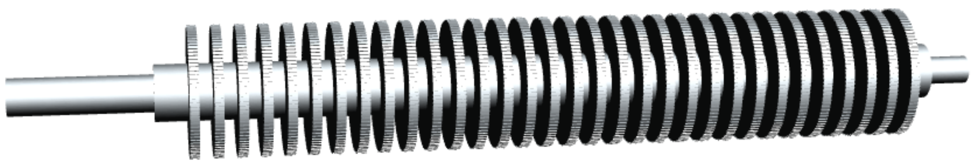

Figure 2. Knurled axle - 3D drawing.

Figure 3. Knurled axle - manufactured on CNC machining center Fanuc Oi Tc lathe.

Name of the piece: Knurled axle.
Material: 16MnCr11.
Manufacturing technology
The processing of this part requires 2 clamps:
Clamping 1.
Exterior turning Φ28 and Φ8x30 respectively Φ12x7;
Knurl Φ28x157, step 0.6, deepness 0.2 mm;
Turning 3 mm;
Cutting Φ28x210 mm.

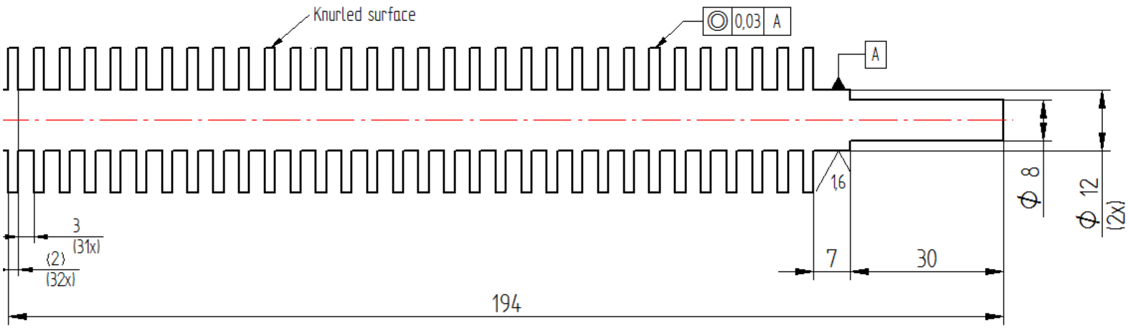

Figure 4. Knurled axle - clamping 1.

Clamping 2.
Exterior turning Φ12X16 and Φ6x10.
The cutting parameters:
speed: 2100 rpm;
feed rate: 400 mm/min (0.2mm/revolution).

The table 1 presents the cutting tools for each operation.

Table 1. Operations within the production process - CNC machining center.

No. crt.	Operation	Tool	Parameters

1	Exterior turning Φ28 and Φ8x30 respectively Φ12x7		Speed: 2000 rpm Feed: 0.1 mm/revolution Ap= 3 mm
2	Knurl Φ28x157, step 0.6, deepness 0.2 mm		Speed: 1000 rpm Feed: 0.5 mm/revolution Ap= 0.2 mm
3	Turning 3 mm		Speed: 2280 rpm Feed: 0.2 mm/revolution Ap= 8 mm
4	Cutting Φ28x210 mm		Speed: 2280 rpm Feed: 0.2 mm/revolution Ap= 14.5 mm
5	Exterior turning Φ12X16 and Φ6x10		Speed: 2000 rpm Feed: 0.1 mm/revolution Ap= 3 mm

In order to manufacture the knurled axle on CNC machining center (Fanuc oi-Tc), the below table presents the operations performed within the manufacturing process, with processing times related to each phase.

Table 2. Operations within the production process - CNC machining center.

No. crt	**Operation**	**Machine tools**	**Measuring device**	**Operations time**
		Clamping 1		
1	Exterior turning Φ28 and Φ8x30 respectively Φ12x7	FANUC 0I TC Lathe	Caliper	10 s - clamping aluminum bar 18 s - processing 5 s - measuring
2	Knurl Φ28x157, step 0.6, deepness 0.2 mm	FANUC 0I TC Lathe	Caliber	25 s - processing 5 s - measuring 7 s - time for cutting tool positioning
3	Turning 3 mm	FANUC 0I TC Lathe	Caliper	38 s - processing 5 s - measuring 10 s - time for cutting tool positioning
4	Cutting Φ28x210	FANUC 0I TC	Caliper	4 s - processing

	mm	Lathe		5 s - measuring 15 s - handling parts and time for cutting tool positioning
		Clamping 2		
1	Exterior turning Φ12X16 and Φ6x10	FANUC 0I TC Lathe	Caliper	10 s - clamping aluminum bar 14 s - processing 5 s - measuring 15 s - handling parts and time for cutting tool positioning
		Total time		**191 s** - Production lead time **99 s** - VAT - Value added time

With the help of Value Stream Mapping, the entire technological process and the operational flow was graphically exemplified. The operational time (CT - cycle time) from each operation separately and the nonoperational time (summing all the nonoperational activities from each operation separately - C / O - changeover time) is included in the VSM, shown in figure 5.

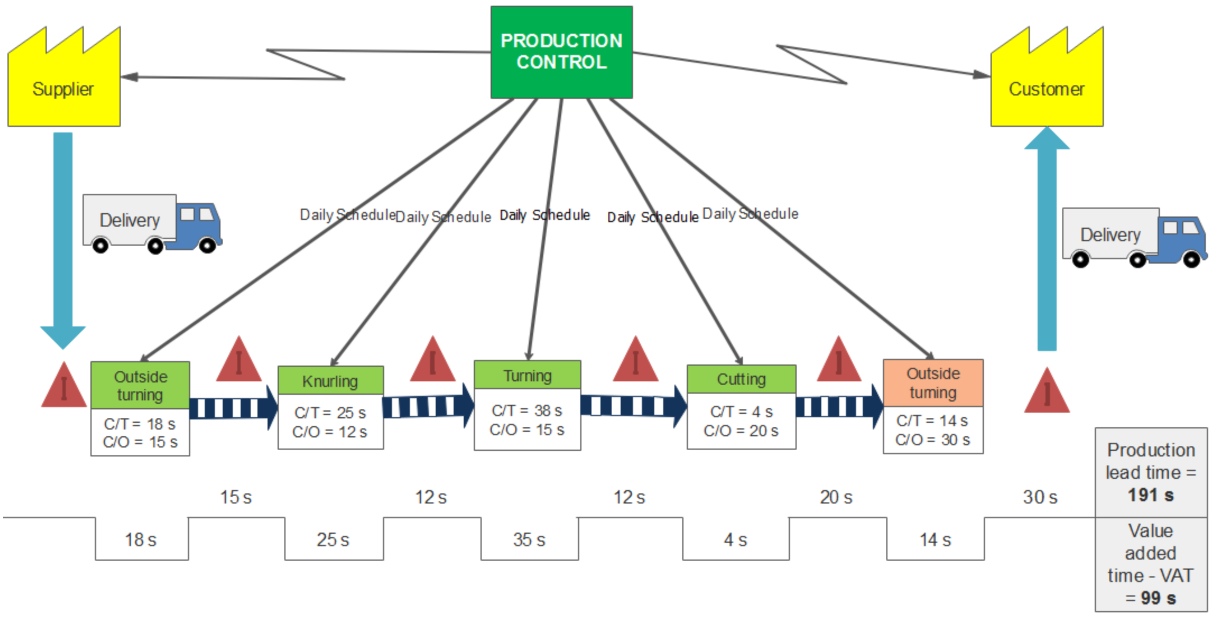

Figure 5. The VSM - manufacturing on CNC machining center

4. Results and discussions

The price offered for the manufacturing process of 200 pieces was Eur 27 per hour. Following the piece manufacturing on a SN 320 lathe, it took 35 minutes to manufacture a single piece, which means a production capacity of 1.71 pieces / hour.

Regarding the necessary manufacturing time for the first piece it was found that the time required to manufacture a single piece is much longer compared to the estimated time on which the price offer was made. Therefore, after analyzing the technological process, new solutions were sought to reduce this time significantly, which would solve human error.

A solution chosen to quickly fix the human error was the implementation of a manufacturing technology that shortens both the operational and non-operational times. As a solution in this regard was the proposal to manufacture these parts on a CNC machining center (Strung Fanuc OiTc). The manufacturing time of one piece in this case was 3.18 minutes, which means a production capacity of 18.86 pieces per hour.

Therefore, starting from the premise that for every working hour Eur 27 are charged, the production cost for a single piece in the case of CNC machining center is Eur 1.43, and in the case of manufacturing on the SN 320 lathe is Eur 15.78 for a single piece.

Regarding the difference between the manufacturing time and cost, respectively the revenues for each manufactured piece, there is a very big difference, reflected in figure 6.

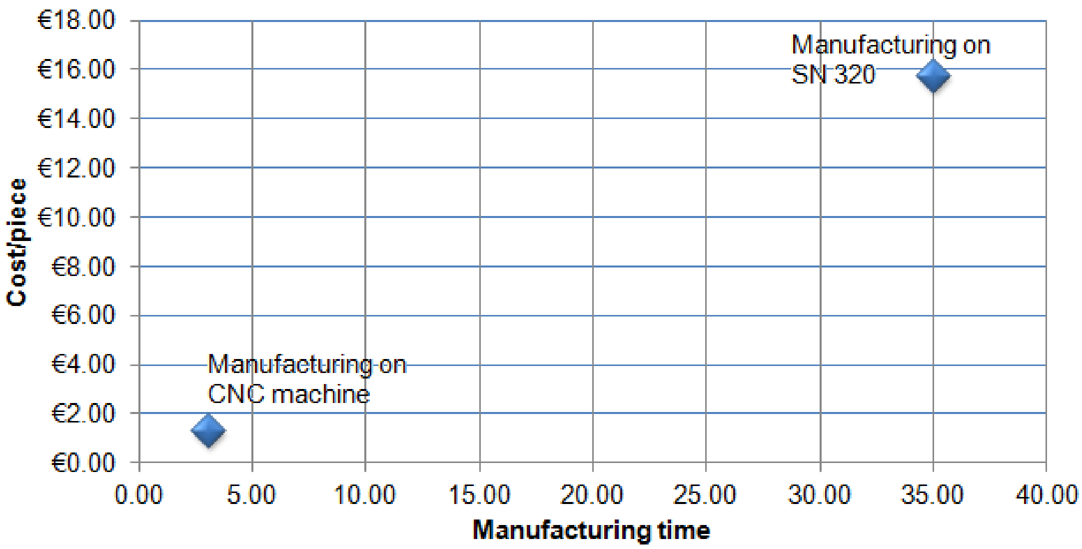

Figure 6. The impact of the manufacturing time on the production cost.

5. Conclusions

The adoption of the manufacturing technology on a CNC machining center led to the increase of the productive efficiency by 90.93%.

It took 15.60 days for the manufacturing of 200 pieces on the lathe SN 320, while in the case of producing the same quantity on the lathe Fanuc Oi Tc 1.41 days were required (working hour per day - 7 hours and 30 minutes - 30 minutes break).

In the time difference between the two presented cases, respectively in the remaining 14.19 days, continuing the production after the completion of the 200 pieces on CNC, an extra quantity of 2008 pieces can still be produced, which is equivalent of Eur 2871.4. This could be valued in case of contracting orders with larger amounts than the 200 parts.

By adopting the manufacturing technology using a CNC machining center, not only was the human error remedied, but it also significantly contributed to the elimination of non-operational times, which led to an increase in the percentage of value-creating activities.

In conclusion, the shorter the required time for a single piece manufacturing, the more it reduces the cost of production, in other words, more will be produced with less resources, which is one of the characteristics of Lean Manufacturing.

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References

[1] Bungau C, Blaga F, and Gherghea C 2014 Kaizen implementation for cost reduction in manufacturing process product " driver control board ", *Int. Conf. Prod. Res. – Africa, Eur. Middle East 3rd Int. Conf. Qual. Innov. Eng. Manag* 55–58.

[2] Csokmai L S, Bungău C, Ţarcă R C and Husi G 2015 A comprehensive approach to off-line advanced error troubleshooting in intelligent manufacturing systems, *Int. J. Comput. Commun. Control,* **10**, no. 1 30–37.

[3] Bungau C, Blaga F, and Gherghea C 2011 Method of analysis and audit, used to implement 5s in operational management, *Proceedings of the 2th RMEE Int. Mng. Conf.* (Cluj- Napoca) 36–47.

[4] Gherghea C, Bungau C, and Negrau D C 2019 Best Practices to Increase Manufacturing Productivity - Comparative study *Int. Manufact. Science and Ed. Conf.* MATEC Web of Conferences (Sibiu) **290** 1–9.

[5] Faur M and Bungau C 2019 Exploring the insights of a consignment stock program implementation in a leagile supply chain *Annual Sess. Scientific Papers- IMT Oradea* 291-295.

[6] Womack J P., Jones D T and Roos D 1990 *That Machine That changed the world*, Free Press.

[7] Arunagiri P and Gnanavelbabu A 2014 Identification of major lean production waste in automobile industries using weighted average method *Procedia Eng.,* **97** 2167–2175.

[8] Wyrwicka M K and Mrugalska B 2017 Mirages of Lean Manufacturing in Practice *Procedia Eng.,* **182** 780–785.

[9] Gupta A and Kundra T K 2012 A review of designing machine tool for leanness *Sadhana - Acad. Proc. Eng. Sci.,* **37**, no. 2 241–259.

[10] Almanei M, Salonitis K and Xu Y 2017 Lean Implementation Frameworks: The Challenges for SMEs *Procedia CIRP,* **63** 750–755.

[11] Bungau C, Blaga F and Gherghea C 2012 Continuous improvement of processes in cutting operations *Proceedings of the 3th RMEE Int. Mng. Conf.* (Cluj- Napoca) 208–216.

[12] Azizi A and Manoharan T 2015 Designing a Future Value Stream Mapping to Reduce Lead Time Using SMED-A Case Study *Procedia Manuf.* **2**, no. February 153–158.

[13] Soliman M and Saurin T A 2017 Lean production in complex socio-technical systems: A systematic literature review *J. Manuf. Syst.,* **45** 135–148.

[14] Badulescu D, Bungau C and Badulescu A 2015 Sustainable development through sustainable businesses. An empirical research among master students *J. Environ. Prot. Ecol.,* **16**, no. 3 1101–1108.

[15] Kumar A and Rajenthirakumar D 2016 Reducing the Manufacturing Lead Time of Export Pump Components in an Indian Pump Industry *Natl. J. Technol.,* **12**, no. 2 July 23–31.

[16] Gherghea I C, Bungau C and Negrau D C 2019 Lead time reduction and increasing productivity by implementing lean manufacturing methods in cnc processing *center IOP Conf. Ser. Mater. Sci. Eng.,* **568**, no. 1.

[17] Hamed M and Soliman A 2017 A comprehensive review of manufacturing wastes: Toyota a comprehensive review of manufacturing wastes: Toyota Production System lean principles *Emirates J. Eng. Res.,* **22**, no. 2 April 1–10.

[18] Forno J D, Pereira F A, Forcellini F A and Kipper L M 2014 Value stream mapping: A study about the problems and challenges found in the literature from the past 15 years about application of Lean tools, *Int. J. Adv. Manuf. Technol.,* **72** no. 5–8 779–790.

[19] Manjunath M, Shivaprasad H C, Keerthesh K K S and Deepa P 2014 Value Stream Mapping as a Tool for Lean Manufacturing Implementation-A case study *Int. J. Innov. Res. Dev.,* **3**, no. 5 477–481.

[20] Bungau C, Gherghea I C and Prichici M 2010 Value Stream Mapping Analysis, Efficiency Methods of Operational Management *Proceedings of the 1th RMEE Int. Mng. Conf.* (Cluj-Napoca) 188-198.

[21] Chen J C and Chen K M 2014 Application of ORFPM system for lean implementation: An industrial case study *Int. J. Adv. Manuf. Technol,* **72** no. 5–8 839–852.

[22] Faur M and Bungau C 2018 Supply chain 'leagility' through adopting consignment stock strategy in manufacturing companies *Proceedings of the 6th RMEE Int. Mng. Conf*. (Cluj-Napoca) 623-632.
[23] Chiarini A 2014 Sustainable manufacturing-greening processes using specific Lean Production tools: an empirical observation from European motorcycle component manufacturers *J. Clean. Prod.,* **85** 226–233.
[24] Tekez E K and Taşdeviren G 2016 A Model to Assess Leanness Capability of Enterprises *Procedia Comput. Sci.,* **100** 776–781.
[25] Gherghea C and Bungau C 2018 Poka yoke application synthesis in manufacturing engineering *Proc. 6th Rev. Manag. Econ. Eng. Int. Manag. Conf.* **6** 564–571.
[26] Sundar R, Balaji A N and Satheesh K R M 2014 A review on lean manufacturing implementation techniques *Procedia Eng.,* **97** 1875–1885.
[27] Li X 2001 Real-Time Prediction of Workpiece Errors for a CNC Turning Centre, Part 4. Cutting-Force-Induced Errors Int*. J. Adv. Manuf. Technol*. **17** 665–669.
[28] Ruijun L, Wenhua Y and Zhang H H 2012 The thermal error optimization models for CNC machine tools *Int J Adv Manuf Technol* **63** 1167–1176.