CIRP Annals - Manufacturing Technology 65 (2016) 447–450

Contents lists available at ScienceDirect

CIRP Annals - Manufacturing Technology

journal homepage: http://ees.elsevier.com/cirp/default.asp

Exploring optimal timing for remanufacturing based on replacement theory

Zhichao Liu [a,b], Feri Afrinaldi [b,c], Hong-Chao Zhang (1)[a,b,*], Qiuhong Jiang [a]

[a] *School of Mechanical Engineering, Dalian University of Technology, Dalian, Liaoning, China*
[b] *Department of Industrial Engineering, Texas Tech University, Lubbock, TX, USA*
[c] *Department of Industrial Engineering, Andalas University, Indonesia*

ARTICLE INFO

Keywords:
Optimization
Fatigue failure
Remanufacturing

ABSTRACT

This paper presents a model to determine an optimal timing for remanufacturing from the environmental perspective. Long-run environmental impact per distance travelled $L(s_r)$ is defined based on the replacement theory. In the case study, the Weibull distribution function of crankshaft's time to failure is obtained. The $L(s_r)$ is calculated by dividing the total environmental impact with the distance travelled by the crankshaft. The minimum value of $L(s_r)$ indicates the best long-run environmental benefit. When climate change is selected as an environmental impact indicator, the result shows that the minimum value of $L(s_r)$ is achieved when the crankshaft reaches 1.53×10^5 km.

1. Introduction

The rapid development of building industry in China makes the demand for construction vehicles increase gradually and meanwhile, the quantity of scrapped trucks grows dramatically due to the high load operation. The manufacturing processes of large and expensive engine parts, such as the crankshaft, are energy intensive and generate large amounts of environmental emissions as well [1]. Therefore, it is essential to develop new technology to prolong the service life of high value added components.

Remanufacturing is a transformation process by which a previously failed product or component is recycled and refurbished through a series of rigorous processes, including disassembly, cleaning, inspection, repairing and reassembly, to ensure its performance meets or exceeds the new product [2]. Realizing the noticeable environmental and economic benefits, automobile products remanufacturing has become dominant in the field and occupies two-third of all remanufacturing in the US and the market has ballooned into the industry involving more than USD 100 billion worldwide [3]. Several reports have documented the overall benefits of engine components remanufacturing [4–6], all of which have indicated that remanufacturing could remarkably reduce the energy and resource consumptions and environmental emissions. However, the remanufacturing timing selection is rarely mentioned in these reports, and the benefits of remanufacturing might be quite different when it is remanufactured at a different point in time.

End-of-life (EoL) remanufacturing is regarded as a general ideology for remanufacturing as it can achieve the biggest product use value. Several models have been built to optimize the EoL remanufacturing system [7] and support the design for EoL remanufacturing [8]. Some researchers consider that the end-of-life product remanufacturing is a good idea and can reach the maximum value of the product [9]. However, when the product already reaches the end of its life and is completely obsolete, the remanufacturing process will consume more energy and produce much more pollution.

“Active remanufacturing” is proposed aiming to solve the uncertainties of cores in remanufacturing procedure, and prolong the product life cycle and eliminate the cost and environmental burdens during the components remanufacturing processes [10]. “Active remanufacturing” requires that the product be remanufactured once it has reached the prescribed time-point even though it has not been scrapped. Because the remanufacturing processes for the product at this point are relatively simple, it can reduce the energy of remanufacturing processes and improve the comprehensive efficiency along the product's entire life cycle [11].

A crankshaft is an important component of an engine and its repair or replacements is common because its surface would be easily worn due to the impurity of oil and uneven stress of the shaft neck. Traditionally, a crankshaft will be remanufactured at the same time as the engine's EoL remanufacturing takes place. This consumes more energy and produces more environmental emissions. This study aims to determine an optimal timing for the crankshaft remanufacturing from the environmental perspective. Also, the study tries to achieve the best environmental benefit and also provides an effective reference to guide engine remanufacturing practices.

---

[*] Corresponding author at: Department of Industrial Engineering, Texas Tech University, Lubbock, TX, USA.

E-mail address: hong-chao.zhang@ttu.edu (H.-C. Zhang).

http://dx.doi.org/10.1016/j.cirp.2016.04.064
0007-8506/© 2016 CIRP.

2. Materials and methods

2.1. Proposed model

A single component of a particular truck is considered during modelling. The policy of the remanufacturing process is that "the component will be remanufactured as soon as it fails or when it reaches a pre-specified distance travelled by the engine, whichever happens first." which is similar to the concept of age replacement model. Therefore the model is developed according to this concept [12]. It is also important to state that the model presented in this paper is dedicated for the continuous time to failure random variable. Graphically, the schematic diagram of the policy is presented in Fig. 1 (adapted from [12]).

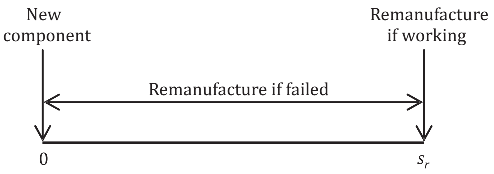


Fig. 1. Schematic diagram of the remanufacturing policy.

In Fig. 1, s_r is the remanufacturing distance such that if the component fails before s_r, it is remanufactured; if the component still works at s_r then it will be remanufactured immediately. s_r is acting as the decision variable. Since some components fail before s_r and other components still work at s_r then, based on [12], the expected total environmental impact is defined in Eq. (1):

$$E[\text{Total environmental impact for } s \le s_r] = l_r + l s_r \Pr\{S \le s_r\}$$
$$= l_r + l s_r F(s_r) \qquad (1)$$

In Eq. (1), S is a random variable denoting the distance travelled when the component fails (km) and its cumulative distribution function (CDF) is $F(s)$; l_r is the environmental impact from component remanufacturing processes (CO_2 equiv./component, MJ/component, kg CFC_{-11} equiv./component, etc.); l is the environmental impact produced during the component operation period (CO_2 equiv./km, MJ/km, kg CFC_{-11} equiv./km, etc.).

In Eq. (1), $\Pr\{S \le s_r\} = F(s_r)$ is the cumulative probability that the lifetime of the component will be less than or equal to s_r. It is easy to see that it is also the CDF of S with s_r as the upper limit.

Given that the remanufacturing process will be conducted as soon as the component fails or as soon as it reaches s_r, whichever happens first, then, based on [12], the actual remanufacturing distance is given by Eq. (2). The CDF and the expected value of X are given by Eqs. (3) and (4), respectively [12].

$$X = \min\{S, s_r\} \qquad (2)$$

$$G(x) = \Pr\{X \le x\} = \begin{cases} F(x) & \text{if } x < s_r \\ 1 & \text{if } x \ge s_r \end{cases} \qquad (3)$$

$$E[X] = E[\min\{S, s_r\}] = \int_0^{\infty}(1-G(x))dx = \int_0^{s_r}(1-F(x))dx \qquad (4)$$

The objective function of the model is the long run average environmental impact per distance travelled (CO_2 equiv./km, MJ/km, kg CFC_{-11} equiv./km, etc.), denoted as $L(s_r)$, and it is modelled as the following equation.

$$L(s_r) = \frac{l_r + l s_r F(s_r)}{\int_0^{s_r}(1-F(x))dx} \qquad (5)$$

In order to find the value of s_r that will minimize $L(s_r)$, s_r^*, following [12], take the first derivative of $L(s_r)$ with respect to s_r and set it equal to zero, which yields $d(L(s_r))/ds_r = 0$.

Then, we have the following equation.

$$[l F(s_r) + l s_r f(s_r)]\int_0^{s_r}(1-F(x))dx = [l_r + l s_r F(s_r)][1-F(s_r)] \qquad (6)$$

where, $f(\cdot)$ is the probability density function (PDF) of the component's lifetime. By dividing both sides of Eq. (6) with $l s_r$ and $1-F(s_r)$ and then set l_r/l as the left-hand side, Eq. (7) is produced.

$$\frac{l_r}{l} = \left[\frac{F(s_r)}{1-F(s_r)} + s_r h(s_r)\right]\int_0^{s_r}(1-F(x))dx - s_r F(s_r) \qquad (7)$$

In Eq. (7), $h(s_r)$ is given by Eq. (8). In reliability theory, $h(\cdot)$ is known as the hazard function. Hazard function calculates the failure rate as the interval tends to zero. For this model, $h(s)$ computes the failure rate as $\Delta s \to 0$. It is assumed that the failure rate increases as s increases.

$$h(s_r) = \frac{f(s_r)}{1-F(s_r)} \qquad (8)$$

To see whether Eq. (7) has one or more than one solutions then the derivative of l_r/l with respect to s_r needs to be found and it is given by the following, Eq. (9).

$$\frac{d}{ds_r}\left(\frac{l_r}{l}\right) = \left[\frac{f(s_r)}{(1-F(s_r))^2} + h(s_r) + s_r\frac{dh(s_r)}{ds_r}\right]\int_0^{s_r}(1-F(x))dx \qquad (9)$$

Since it is assumed the failure rate increases as s increases then $h(\cdot)$ is an increasing function. Consequently, Eq. (9) is positive for all $s_r \ge 0$. This implies that Eq. (7) is also an increasing function. Using this fact, it is expected that, if the left-hand side of Eq. (7) (a constant) and the right-hand side of Eq. (7) are plotted then the result is presented in Fig. 2, which presents only one optimal solution.

This paper applies exponential and Weibull distributions on Eq. (7). This is done because their random variables could well describe the distribution model of product life.

(i) For an exponential distribution with the parameter λ, the CDF is $F(s_r) = 1 - e^{-\lambda s}$, and the hazard function is $h(s_r) = \lambda$. Substituting the CDF and hazard function into Eq. (7) yields,

$$\lambda\frac{l_r}{l} + 2 = e^{\lambda s_r} + e^{-\lambda s_r} \qquad (10)$$

(ii) For the Weibull distribution with shape parameter k and scale parameter λ, its CDF is $F(s_r) = 1 - \mathrm{EXP}[-(s_r/\lambda)^k]$, and hazard function is $h(s_r) = (k/\lambda)(s_r/\lambda)^{k-1}$. Substituting the CDF and hazard function into Eq. (7) yields,

$$\frac{l_r}{l} = \left[e^{(s_r/\lambda)^k} + s_0\frac{k}{\lambda}\left(\frac{s_r}{\lambda}\right)^{k-1} - 1\right]\int_0^{s_r} e^{-(x/\lambda)^k}dx + s_r e^{-(s_r/\lambda)^k} - s_r \qquad (11)$$

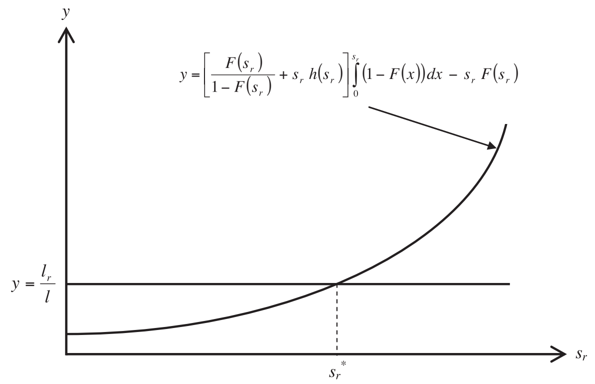


Fig. 2. Graphical solution of Eq. (7) where s_r^* is the optimal remanufacturing distance.

2.2. Sensitivity analysis

Fig. 3 shows that if s_r^* increases then the value of l_r/l will also increase and vice versa. There are several scenarios that can occur so that l_r/l increases or decreases and it is summarized in Table 1. The change in the value of l_r is due to the condition of the crankshaft to be remanufactured. A higher value of l_r means a crankshaft with a worse condition implied that it has been used for a longer driving distance.

Case 1. Since the environmental impact of the remanufacturing process increases then a longer value of s_r^* is needed so that the environmental impact per distance travelled is minimized.

Case 2. It is better to have a longer s_r^* because the component's environmental impact during use phase decreases but the environmental impact of the remanufacturing process is constant so that the total environmental impact per distance travelled is minimized.

Case 3. Since the environmental impact of the remanufacturing process decreases and the environmental impact during use phase is constant then increasing the frequency of remanufacturing process (by decreasing s_r^*) is a better option. Therefore, total environmental impact per distance travelled will be minimized.

Case 4. Since the use phase has more environmental impact then it is better to decrease s_r^*.

However, it is also essential to know the change in the magnitude of l_r/l if s_r changes. The general equation is given by Eq. (9). For exponential and Weibull distribution, the expression for $d(l_r/l)/ds_r$ is given by Eqs. (12) and (13), respectively. Those two equations confirm the conclusion made using Fig. 2, Eq. (7) is an increasing function.

$$\frac{d}{ds_r}\left(\frac{l_r}{l}\right) = e^{\lambda s_r} - \frac{1}{e^{\lambda s_r}} > 0 \tag{12}$$

$$\frac{d}{ds_r}\left(\frac{l_r}{l}\right) = \left(h(s_r)\int_0^{s_r} e^{-(x/\lambda)^k} dx\right)\left(e^{(s_r/\lambda)^k} + k\right) > 0 \tag{13}$$

Table 1
Scenarios for sensitivity analysis.

Case	l_r	l	l_r/l	Effect on s_r^*
1	Increases	Constant	Increase	Increase
2	Constant	Decrease	Increase	Increase
3	Decrease	Constant	Decrease	Decrease
4	Constant	Increase	Decrease	Decrease

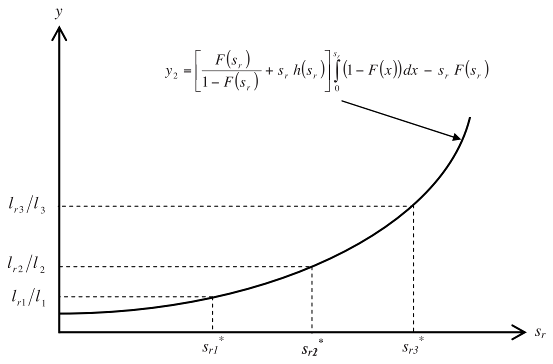


Fig. 3. The relationship between s_r and l_r/l.

3. Case study

3.1. Parameters of the model

In this study, a typical crankshaft (45#steel, 103 kg) from a WD615 Diesel Engine is chosen as a case to prove the applicability of the model. Life cycle assessment (LCA) method is conducted to calculate the environmental impact of the crankshaft remanufacturing and operation [13]. To simplify the modelling process, only Global Warming Potential (GWP) is considered. The crankshaft was remanufactured in SINOTRUK, Jinan Fuqiang power Co., LTD. The energy consumptions and additional materials required during the crankshaft remanufacturing processes are shown in Fig. 4.

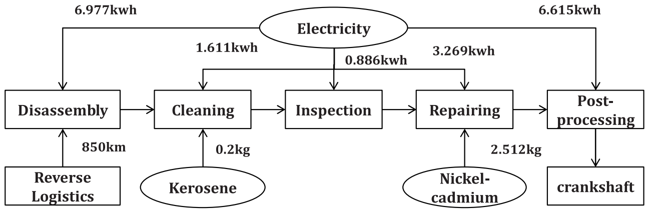


Fig. 4. Flow diagram of the crankshaft remanufacturing processes.

When the truck is in service, its fuel efficiency is 25 L/100 km. Given that the density of diesel fuel is 0.85 kg/L, then the amount of diesel fuel consumed is $0.85 \times 25/100 = 0.2125$ kg/km.

The direct contribution of each pollutant to GWP, such as CO_2, CH_4, N_2O, etc., generated in the production of materials and energy as well as scraped engine sending back is quantified according to the Chinese Life Cycle Database (CLCD) developed by IKE, China [14]; The input parameters are listed in Table 2 indicating that $l_r = 126.92$ kg CO_2 equiv. To estimate the contribution of the crankshaft to the GWP of the engine during use phase, weight to fuel economy correlation found in [15] is used and it is found that $l = 9.19\text{E}{-}05$ kg CO_2 equiv./km.

Statistical analysis of the fatigue failure rate of 100 crankshafts indicates that the rate fits Weibull distribution. The reliability curve of the crankshafts is showed in Fig. 5.

Table 2
Result of GWP during crankshaft use phase and remanufacturing process.

Items	Quantity (kg)		Characterization factor [16]	Result (kg CO_2 equiv.)	
	Reman.	Operation		Reman.	Operation
CO_2	111.65	0.226	1	126.92	0.23
CH_4	0.50	2.27E−04	25		
N_2O	0.0093	5.65E−06	298		

Resource: CLCD & Eco-invent 2.0.

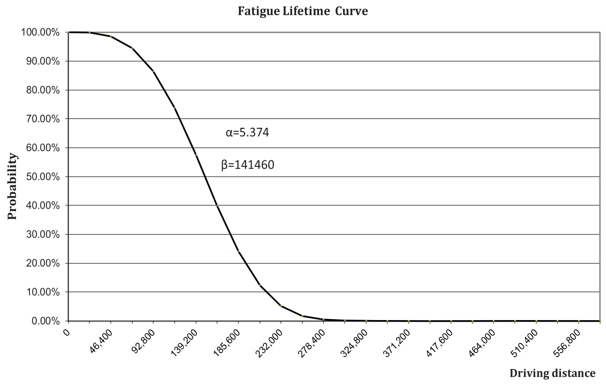


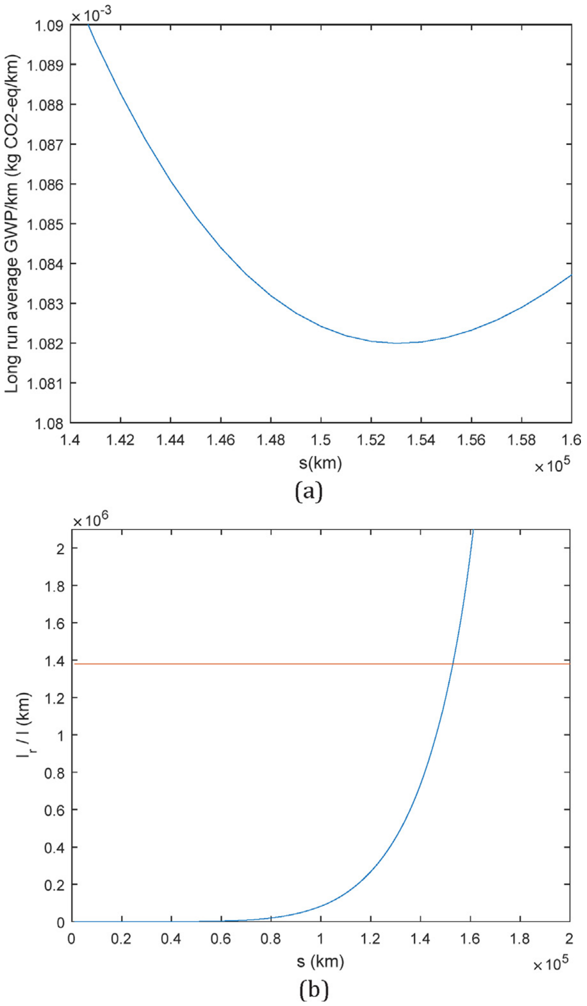
Fig. 5. Weibull Distribution for crankshafts.

3.2. Result and discussion

By substituting the value of l_r, l and the time to failure distribution function of the crankshaft into the Eqs. (5) and (7), we can draw the plot of objective function and l_r/l, as is shown in Fig. 6. From the figure it is concluded that the optimal timing for crankshaft remanufacturing is when it reaches 1.53×10^5 km of service. The minimum GWP over the whole life cycle is equal to 1.08×10^{-3} kg CO_2-equiv./km. The case study selects climate change as the environmental indicator. However, it is important to note that the model might produce other locations of optimal driving distance if other indicator, such as toxicity from metal emissions or particle effects on human health, is chosen.

The determination of an optimal remanufacturing timing for engine parts is complicated due to the difference in failure modes and service life of the components. Liu et al. analyzed the optimal timing of total engine remanufacturing by creating a model to reflect the average environmental impact over two life cycles [17]. However, the authors did not consider the reliability of the components being analyzed and excluded the effect of uncertainty in time to failure. The proposed model considers the specific failure rate the single part, and once the failure modes of all components are figured out, it could help to determine the best opportunity to each point without introducing any uncertainties, resolving the above-mentioned problem nicely.

Several aspects, such as environmental impact, economic benefit and current technology level, should be evaluated when formulating the strategy for formulating a strategy for sustainable engine parts manufacturing. Although the proposed methodology does not consider other factors except for the environmental impact, it provides a fundamental model which brings a high ability to realize the integration of all qualified aspects in the future.



(a)

(b)

Fig. 6. Objective function plot (a) and l_r/l plot (b).

4. Conclusions

Remanufacturing can retain the surplus added value of original manufactured components. It does not only improve the performance of specific part and prolong the service life cycle but also saves resources and energy and reduces the production cost. Choosing a different time for remanufacturing can result in a different amount of environmental benefits. This paper presented a model, based on the replacement model, to figure out an optimal remanufacturing timing. A case study using the crankshaft as an object showed that the proposed model can be used to identify the best opportunity for remanufacturing. The simulated result indicated that the best environmental benefit can be achieved when the crankshaft is remanufactured after being used to drive for 1.53×10^5 km.

However, the proposed model cannot be applied to all situations. There might be unusual damage to the crankshafts causing them to be inappropriate for repair under the present technical conditions. Therefore, a re-manufacturability assessment before making a decision for remanufacturing is indispensable. The method can be used as a basic tool to better inform the decision makers. It must be said, though, in order to simplify the calculation process, only environmental impact (GWP) is considered in the case study. A more comprehensive and well balanced decision should include other decision criteria, such as cost and technology. In this case, the preference of the decision makers will play an important role.

Acknowledgements

The authors gratefully acknowledge the support of SINOTRUK, Jinan Fuqiang Power Co., LTD. and the National Basic Research Program of China (Grant No. 2011CB013406).

References

[1] Afrinaldi F, Zhang HC (2014) A Fuzzy Logic Based Aggregation Method for Life Cycle Impact Assessment. *Journal of Cleaner Production* 67:159–172.
[2] Williams J, Shu LH, Fenton RG (2001) Analysis of Remanufacturer Waste Streams Across Product Sectors. *CIRP Annals – Manufacturing Technology* 50(1):101–104.
[3] Kim HJ, Severengiz S, Skerlos SJ, Seliger G (2008) Economic and Environmental Assessment of Remanufacturing in the Automotive Industry. *LCE 2008: 15th CIRP International Conference on Life Cycle Engineering: Conference Proceedings, CIRP*, 195–200.
[4] Sutherland JW, Adler DP, Haapala KR, Kumar V (2008) A Comparison of Manufacturing and Remanufacturing Energy Intensities with Application to Diesel Engine Production. *CIRP Annals – Manufacturing Technology* 57(1):5–8.
[5] Amaya J, Zwolinski P, Brissaud D (2010) Environmental Benefits of Parts Remanufacturing: The Truck Injector Case. *17th CIRP International Conference on Life Cycle Engineering: Conference Proceedings, CIRP*, 34–39.
[6] Liu Z, Li T, Jiang Q, Zhang H (2014) Life Cycle Assessment-Based Comparative Evaluation of Originally Manufactured and Remanufactured Diesel Engines. *Journal of Industrial Ecology* 18(4):567–576.
[7] Jin X, Ni J, Koren Y (2011) Optimal Control of Reassembly With Variable Quality Returns in a Product Remanufacturing System. *CIRP Annals – Manufacturing Technology* 60(1):25–28.
[8] Sherwood M, Shu LH, Fenton RG (2000) Supporting Design for Remanufacture Through Waste-Stream Analysis of Automotive Remanufacturers. *CIRP Annals – Manufacturing Technology* 49(1):87–90.
[9] Lee HB, Cho NW, Hong YS (2010) A Hierarchical End-of-Life Decision Model for Determining the Economic Levels of Remanufacturing and Disassembly Under Environmental Regulations. *Journal of Cleaner Production* 18(13):1276–1283.
[10] Liu G, Liu T, Ke Q, Song S, Zhou D (2013) Time Interval Decision-Making Methods for Active Remanufacturing Product Based on Game Theory and Neural Network. *Chinese Journal of Mechanical Engineering* 49(7):29–35.
[11] Zhu S, Yao JK (2009) *Theory and Application of Remanufacturing*, China Machine Express, Beijing81–83.
[12] Feldman RM, Valdez-Flores C (2010) Replacement Theory. *Applied Probability and Stochastic Processes*, Springer Berlin Heidelberg: 305–321.
[13] Westkämper E (2000) Life Cycle Management and Assessment: Approaches and Visions Towards Sustainable Manufacturing (Keynote Paper). *CIRP Annals – Manufacturing Technology* 49(2):501–526.
[14] Liu XL, Wang HT, Chen J (2010) Data Acquisition Method for LCA Database and Basic Life Cycle Model. *Journal of Environmental Science* 30(10):2136–2144.
[15] Broda R, Casadei A (2007) *Impact of Vehicle Weight Reduction on Fuel Economy for Various Vehicle Architecture*, The Aluminium Association, Inc.
[16] Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (2007) *Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change.*
[17] Liu Z, Jiang Q, Li T, Zhang H (2014) An Optimal Timing of Engine Remanufacturing – A Real Option Approach. *Procedia CIRP* 15:223–227.

ScienceDirect

CIRP Annals

8.5
CiteScore

3.641
Impact Factor

Search in this journal

Submit your article ↗

Guide for authors ↗

Volume 65, Issue 1

Pages 1-548 (2016)

‹ Previous vol/issue

Next vol/issue ›

Receive an update when the latest issues in this journal are published

Sign in to set up alerts

Session on Life-Cycle Engineering and Assembly (A)

Research article Full text access

The Sustainability Cone – A holistic framework to integrate sustainability thinking into manufacturing

Jan-Markus Rödger, Niki Bey, Leo Alting

Pages 1-4

Download PDF Article preview

Research article Full text access

Sustainability Cockpit: An integrated tool for continuous assessment and improvement of sustainability in manufacturing

Wen Li, Samira Alvandi, Sami Kara, Sebastian Thiede, Christoph Herrmann

Pages 5-8

Download PDF Article preview

Research article Full text access

A hybrid group leader algorithm for green material selection with energy consideration in product design

Pages 37-40

Download PDF Article preview

Research article Full text access

A decision support system to manage the quality of End-of-Life products in disassembly systems

Marcello Colledani, Olga Battaïa

Pages 41-44

Download PDF Article preview

Research article *Open access*

High voltage fragmentation and mechanical recycling of glass fibre thermoset composite

Paul T. Mativenga, Norshah A. Shuaib, Jack Howarth, Fadri Pestalozzi, Jörg Woidasky

Pages 45-48

Download PDF Article preview

Research article Full text access

A new method for combining handling systems with passive orientation devices

Gunnar Borchert, Annika Raatz

Pages 49-52

Download PDF Article preview

Research article Full text access

Model based design of process-specific handling tools for workpieces with many variants in shape and material

Klaus Dröder, Franz Dietrich, Christian Löchte, Jürgen Hesselbach

Pages 53-56

Download PDF Article preview

Research article Full text access

A probabilistic approach to workspace sharing for human–robot cooperation in assembly tasks

Stefania Pellegrinelli, Federico Lorenzo Moro, Nicola Pedrocchi, Lorenzo Molinari Tosatti, Tullio Tolio

Pages 57-60

Download PDF Article preview

Research article Full text access

Augmented reality system for operator support in human–robot collaborative assembly

Sotiris Makris, Panagiotis Karagiannis, Spyridon Koukas, Aleksandros-Stereos Matthaiakis

Pages 61-64

Download PDF Article preview

Research article Full text access

Coil winding process modelling with deformation based wire tension analysis

Florian Sell-Le Blanc, Janna Hofmann, Rico Simmler, Juergen Fleischer

Pages 65-68

Pages 93-96

Download PDF Article preview

Research article Full text access

Reduction of built-up edge formation in machining Al- and cast iron hybrid components by internal cooling of cutting inserts

Friedrich Bleicher, Christoph Pollak, Jens Brier, Anton Siller

Pages 97-100

Download PDF Article preview

Research article Full text access

Effect of structure and residual stresses of diamond coated cemented carbide tools on the film adhesion and developed wear mechanisms in milling

G. Skordaris, K.-D. Bouzakis, P. Charalampous, T. Kotsanis, ... O. Lemmer

Pages 101-104

Download PDF Article preview

Research article Full text access

The influences of pulsed-laser-ablation and electro-discharge-grinding processes on the cutting performances of polycrystalline diamond micro-drills

Paul Butler-Smith, Maximilian Warhanek, Dragos Axinte, Michael Fay, ... Konrad Wegener

Pages 105-108

Download PDF Article preview

Research article Full text access

The mechanics of milling of germanium for IR applications

J.D. Owen, J.R. Troutman, T.A. Harriman, A. Zare, ... M.A. Davies

Pages 109-112

Download PDF Article preview

Research article Full text access

Critical depth of cut and asymptotic spindle speed for chatter in micro milling with process damping

J.J. Wang, E. Uhlmann, D. Oberschmidt, C.F. Sung, I. Perfilov

Pages 113-116

Download PDF Article preview

Research article Full text access

Deformation of thin parts in micromilling

Ismail Lazoglu, Ali Mamedov

Pages 117-120

Download PDF Article preview

Research article Full text access

Thermo-mechanical modeling of the third deformation zone in machining for prediction of cutting forces

Erhan Budak, Emre Ozlu, Hayri Bakioglu, Zahra Barzegar
Pages 121-124

Download PDF Article preview

Research article Full text access

Prediction of effect of helix angle on cutting force coefficients for design of new tools

E. Ozturk, O. Ozkirimli, T. Gibbons, M. Saibi, S. Turner
Pages 125-128

Download PDF Article preview

Research article Full text access

Design of irregular pitch end mills to attain robust suppression of regenerative chatter

N. Suzuki, R. Ishiguro, T. Kojima
Pages 129-132

Download PDF Article preview

Research article Full text access

Chip geometry and cutting forces in gear shaping

Kaan Erkorkmaz, Andrew Katz, Yasin Hosseinkhani, Denys Plakhotnik, ... Fathy Ismail
Pages 133-136

Download PDF Article preview

Research article Full text access

Comparison of conventional drilling and orbital drilling in machining carbon fibre reinforced plastics (CFRP)

Robert Voss, Marcel Henerichs, Friedrich Kuster
Pages 137-140

Download PDF Article preview

Research article Full text access

A new hybrid oscillatory orbital process for drilling of composites using superabrasive diamond tools

I. Sultana, Z. Shi, H. Attia, V. Thomson
Pages 141-144

Download PDF Article preview

Research article Full text access

New abrasive deburring method using suction for micro burrs at intersecting holes

B.C. Kwon, K.H. Kim, K.H. Kim, S.L. Ko
Pages 145-148

Download PDF Article preview

Session on Design (Dn)

Research article Full text access

Optimization and lifecycle engineering for design and manufacture of recycled aluminium parts

Julien Le Duigou, Sverre Gulbrandsen-Dahl, Flore Vallet, Rikard Söderberg, ... Nicolas Perry

Pages 149-152

Download PDF Article preview

Research article Full text access

A novel engineering process for spatial opto-mechatronic applications

Jörg Franke, Jochen Zeitler, Thomas Reitberger

Pages 153-156

Download PDF Article preview

Research article Full text access

New methodology to define roller geometry on power bearings

Emmanuel Mermoz, Douchane Fages, Laurent Zamponi, Jean-Marc Linares, Jean-Michel Sprauel

Pages 157-160

Download PDF Article preview

Research article Full text access

Online-simulation of fluidic processes in early design of plant development using SPH

Stefan Krotil, Christoph Richter, Gunther Reinhart

Pages 161-164

Download PDF Article preview

Research article Full text access

From reverse engineering to shape engineering in mechanical design

Nabil Anwer, Luc Mathieu

Pages 165-168

Download PDF Article preview

Research article Full text access

Management of product design complexity due to epistemic uncertainty via energy flow modelling based on CPM

Roozbeh Babaeizadeh Malmiry, Jérôme Pailhès, Ahmed Jawad Qureshi, Jean-François Antoine, Jean-Yves Dantan

Pages 169-172

Download PDF Article preview

Research article Full text access

Modeling the transition to a provider–customer relationship in servitization for expansion of customer activity cycles

Tatsunori Hara, Keita Sato, Tamio Arai

Pages 173-176

Download PDF Article preview

Research article Full text access

A crowdsourcing design framework for concept generation

Ang Liu, Stephen C.-Y. Lu

Pages 177-180

Download PDF Article preview

Research article Full text access

Stakeholder integration for the successful product–process co-design for next-generation manufacturing technologies

Martina Flatscher, Andreas Riel

Pages 181-184

Download PDF Article preview

Research article Full text access

Semantic data management for the development and continuous reconfiguration of smart products and systems

Michael Abramovici, Jens Christian Göbel, Hoang Bao Dang

Pages 185-188

Download PDF Article preview

Research article Full text access

Accessing enterprise knowledge: A context-based approach

Florent Laroche, Mohamed Anis Dhuieb, Farouk Belkadi, Alain Bernard

Pages 189-192

Download PDF Article preview

Research article Full text access

Engineering design memory for design rationale and change management toward innovation

Lionel Roucoules, Esma Yahia, Widad Es Soufi, Serge Tichkiewitch

Pages 193-196

Download PDF Article preview

Research article Full text access

Recording the design thought process as time variation in parameter network

Shinsuke Kondoh, Yusuke Kishita

Pages 197-200

Download PDF Article preview

Session on Electro-Physical & Chemical Processes (E)

Research article Full text access

Porosity testing methods for the quality assessment of selective laser melted parts

Wessel W. Wits, Simone Carmignato, Filippo Zanini, Tom H.J. Vaneker

Pages 201-204

Download PDF Article preview

Research article Full text access

Using X-ray computed tomography to improve the porosity level of polyamide-12 laser sintered parts

Wim Dewulf, Michele Pavan, Tom Craeghs, Jean-Pierre Kruth

Pages 205-208

Download PDF Article preview

Research article Full text access

Influence of metal powder characteristics on product quality with directed energy deposition of Inconel 625

Yasuhiro Kakinuma, Masahiko Mori, Yohei Oda, Takanori Mori, ... Makoto Fujishima

Pages 209-212

Download PDF Article preview

Research article Full text access

Microstructure and mechanical properties of as-processed scandium-modified aluminium using selective laser melting

Adriaan B. Spierings, Karl Dawson, Mark Voegtlin, Frank Palm, Peter J. Uggowitzer

Pages 213-216

Download PDF Article preview

Research article Full text access

Fabrication of silicon-based porous nanocomposite films by focused infrared light sintering

Jiwang Yan, Kouga Okada

Pages 217-220

Download PDF Article preview

Research article Full text access

Development of peeling tools with sub-50 μm cores by zinc electroplating and their application to micro-EDM

Rie Tanabe, Yoshiro Ito, Naotake Mohri, Takahisa Masuzawa

Pages 221-224

Download PDF Article preview

Research article Full text access

Study on influences of bubbles on ECM gap phenomena using transparent electrode

Tomoyuki Shimasaki, Masanori Kunieda

Pages 225-228

Download PDF Article preview

Research article Full text access

Acoustic emission signatures of electrical discharge machining

Andreas Klink, Maximilian Holsten, Sebastian Schneider, Philip Koshy

Pages 229-232

Session on Forming (F)

Improvement of the wear resistance of hot forging dies using a locally selective deposition technology with transition layers

Dong-Gyu Ahn, Ho-Jin Lee, Jong-Rae Cho, Dae-Seon Guk

Pages 257-260

Download PDF Article preview

Research article Full text access

Modelling of real area of contact between tool and workpiece in metal forming processes including the influence of subsurface deformation

Chris V. Nielsen, Paulo A.F. Martins, Niels Bay

Pages 261-264

Download PDF Article preview

Research article Full text access

Effective forming strategy for double-sided incremental forming considering in-plane curvature and tool direction

Newell Moser, Zixuan Zhang, Huaqing Ren, Huan Zhang, ... Jian Cao

Pages 265-268

Download PDF Article preview

Research article Full text access

Influence of die geometry on performance in gradation extrusion using numerical simulation and analytical calculation

Dirk Landgrebe, Andreas Sterzing, Nadine Schubert, Markus Bergmann

Pages 269-272

Download PDF Article preview

Research article Full text access

Enhanced granular medium-based tube and hollow profile press hardening

Hui Chen, Sigrid Hess, Jan Haeberle, Sebastian Pitikaris, ... A. Erman Tekkaya

Pages 273-276

Download PDF Article preview

Research article Full text access

A rotary reduction of fine wires/tubes of a wide range of diameters using a pair of concave rolls

Takashi Kuboki, Shohei Kajikawa

Pages 277-280

Download PDF Article preview

Research article Full text access

Ring rolling with variable wall thickness

Christopher J. Cleaver, Matthew R. Arthington, Sharareh Mortazavi, Julian M. Allwood

Pages 281-284

Download PDF Article preview

Research article Full text access

New method for the manufacturing of curved workpieces by open-die forging

Martin Wolfgarten, Gerhard Hirt

Pages 285-288

Download PDF Article preview

Research article Full text access

Design and optimization of stamping process of ultra-thin stainless sheet into bidirectionally corrugated shape for finless high-efficiency heat exchanger

Jun Yanagimoto, Yasuhito Wake, Pascal Zeise, Hung Mao, Naoki Shikazono

Pages 289-292

Download PDF Article preview

Research article Full text access

Forming of light-weight gear wheel by plate forging

Z.G. Wang, K. Hirasawa, Y. Yoshikawa, K. Osakada

Pages 293-296

Download PDF Article preview

Research article Full text access

Die motion control for die-quench forging process of AA6061 aluminum alloys

Hiroshi Utsunomiya, Koki Tada, Ryo Matsumoto

Pages 297-300

Download PDF Article preview

Research article Full text access

Metastable material conditions for forming of sheet metal parts combined with thermomechanical treatment

Verena Kräusel, Peter Birnbaum, Andreas Kunke, Rafael Wertheim

Pages 301-304

Download PDF Article preview

Research article Full text access

Material flow control in tailor welded blanks by a combination of heat treatment and warm forming

Tobias Gnibl, Marion Merklein

Pages 305-308

Download PDF Article preview

Research article Full text access

A hybrid mixed double-sided incremental forming method for forming Ti6Al4V alloy

Beatrice Valoppi, Antonio J. Sánchez Egea, Zixuan Zhang, Hernán A. González Rojas, ... Jian Cao

Pages 309-312

Download PDF Article preview

Session on Abrasive Process (G)

Research article *Open access*

Influence of metalworking fluid additives on the thermal conditions in grinding

Daniel Meyer, André Wagner

Pages 313-316

Download PDF Article preview

Research article Full text access

Drastic reduction of grinding fluid flow in cylindrical plunge grinding by means of contact-type flexible brush-nozzle

Akira Hosokawa, Keita Tokunaga, Takashi Ueda, Takahiro Kiwata, Tomohiro Koyano

Pages 317-320

Download PDF Article preview

Research article Full text access

Modelling and simulation of thermal effects in internal traverse grinding of hardened bearing steel

D. Biermann, R. Holtermann, A. Menzel, S. Schumann

Pages 321-324

Download PDF Article preview

Research article Full text access

Modeling of material removal mechanism in vibratory finishing process

Fukuo Hashimoto, Stephen P. Johnson, Rahul G. Chaudhari

Pages 325-328

Download PDF Article preview

Research article Full text access

Cutting edge preparation with elastic bonded superabrasive grinding wheels

Jan C. Aurich, Christian Effgen, Benjamin Kirsch

Pages 329-332

Download PDF Article preview

Research article Full text access

Design of bronze-bonded grinding wheel properties

Berend Denkena, Thilo Grove, Imke Bremer, Leif Behrens

Pages 333-336

Download PDF Article preview

Research article Full text access

Grinding process for profiled texturing

Eraldo Jannone da Silva, Alex Camilli Bottene, João Fernando Gomes de Oliveira, Almir Atoatte, Alex de Souza Rodrigues

Pages 337-340

Download PDF Article preview

Research article Full text access

Grinding with controlled kinematics and chip removal

D. Barrenetxea, J. Alvarez, J.I. Marquinez, J.A. Sanchez

Pages 341-344

Download PDF Article preview

Research article Full text access

Grinding wheel motion, force, temperature, and material removal in rotational atherectomy of calcified plaque

Albert J. Shih, Yao Liu, Yihao Zheng

Pages 345-348

Download PDF Article preview

Session on Machines (M)

Research article Full text access

Trajectory generation and control of a 9 axis CNC micromachining center

A. Yuen, Y. Altintas

Pages 349-352

Download PDF Article preview

Research article Full text access

Sliding bearing with adjustable friction properties

T. Engel, A. Lechler, A. Verl

Pages 353-356

Download PDF Article preview

Research article Full text access

Enhancement of feed drive dynamics using additional table speed feedback

Zheng Sun, Günter Pritschow, Armin Lechler

Pages 357-360

Download PDF Article preview

Research article Full text access

Polymeric carbon nanotube nanocomposite-based force sensors

S.S. Park, K. Parmar, S. Shajari, M. Sanati

Pages 361-364

Download PDF Article preview

Research article Full text access

Analytic tuning of robust multi-mass dampers

Christian Brecher, Simo Schmidt, Marcel Fey

Pages 365-368

Download PDF Article preview

Research article Full text access

Mechanism and suppression of frictional chatter in high-efficiency elliptical vibration cutting

Hongjin Jung, Takehiro Hayasaka, Eiji Shamoto

Pages 369-372

Download PDF Article preview

Research article Full text access

A trajectory optimization method for improved tracking of motion commands using CNC machines that experience unwanted vibration

C. Okwudire, K. Ramani, M. Duan

Pages 373-376

Download PDF Article preview

Research article Full text access

Diagnostics for geometric performance of machine tool linear axes

Gregory W. Vogl, M. Alkan Donmez, Andreas Archenti

Pages 377-380

Download PDF Article preview

Research article Full text access

Process simulation integrated tool axis selection for 5-axis tool path generation

Lutfi Taner Tunc, Erhan Budak, Samet Bilgen, Mikel Zatarain

Pages 381-384

Download PDF Article preview

Research article Full text access

A sensorless approach for tool fracture detection in milling by integrating multi-axial servo information

Ryo Koike, Kouhei Ohnishi, Tojiro Aoyama

Pages 385-388

Download PDF Article preview

Research article Full text access

Design of self-tuneable mass damper for modular fixturing systems

Jokin Munoa, Alex Iglesias, Aitor Olarra, Zoltan Dombovari, ... Gabor Stepan

Pages 389-392

Download PDF Article preview

Research article Full text access

Adaptronic approach for modular long projecting boring tools

E. Abele, M. Haydn, T. Grosch

Pages 393-396

Download PDF Article preview

Session on Production Systems and Organizations (O)

Research article Full text access

Enhancing products and services using smart appliance networks

Takeshi Takenaka, Yoshinobu Yamamoto, Ken Fukuda, Ayaka Kimura, Kanji Ueda

Pages 397-400

Download PDF Article preview

page 1 of 2

Previous vol/issue Next vol/issue

ISSN: 0007-8506

ScienceDirect

CIRP Annals

8.5
CiteScore

3.641
Impact Factor

Search in this journal

Submit your article ↗

Guide for authors ↗

Volume 65, Issue 1

Pages 1-548 (2016)

Previous vol/issue

Next vol/issue

Session on Production Systems and Organizations (O)

Research article Full text access

Opportunistic maintenance based on multi-dependent components of manufacturing system

Benoit Iung, Phuc Do, Eric Levrat, Alexandre Voisin

Pages 401-404

Download PDF Article preview

Research article Full text access

Assessment of mathematical programming and agent-based modelling for off-line scheduling: Application to energy aware manufacturing

F. Tonelli, A.A.G. Bruzzone, M. Paolucci, E. Carpanzano, ... D. Trentesaux

Pages 405-408

Download PDF Article preview

Research article Full text access

Design for energy sustainability in manufacturing systems

Tarek AlGeddawy, Hoda ElMaraghy
Pages 409-412

Download PDF Article preview

Research article Full text access

The impact of corporate culture on manufacturing system design

Yoram Koren, Xi Gu, Theodor Freiheit
Pages 413-416

Download PDF Article preview

Research article Full text access

Design of deep convolutional neural network architectures for automated feature extraction in industrial inspection

Daniel Weimer, Bernd Scholz-Reiter, Moshe Shpitalni
Pages 417-420

Download PDF Article preview

Research article Full text access

Performance modelling and simulation of metal powder bed fusion production system

Simon Mounsey, Bernard Hon, Chris Sutcliffe
Pages 421-424

Download PDF Article preview

Research article Full text access

Multimodal speech and gesture control of AGVs, including EEG-based measurements of cognitive workload

Ludger Overmeyer, Florian Podszus, Lars Dohrmann
Pages 425-428

Download PDF Article preview

Research article Full text access

Multi-objective allocation of customized orders to production-line networks

Robert H. Schmitt, Max Ellerich, Sean Humphrey
Pages 429-432

Download PDF Article preview

Research article Full text access

Automatic design of scheduling rules for complex manufacturing systems by multi-objective simulation-based optimization

Michael Freitag, Torsten Hildebrandt
Pages 433-436

Download PDF Article preview

Research article Full text access

Lead time instability and its mitigation in production work systems
Neil Duffie, Julia Bendul, Katja Windt, Mathias Knollmann
Pages 437-440

Download PDF Article preview

Research article Full text access
Design and management of reconfigurable assembly lines in the automotive industry
Marcello Colledani, Dávid Gyulai, László Monostori, Marcello Urgo, ... Fred Van Houten
Pages 441-446

Download PDF Article preview

Research article Full text access
Exploring optimal timing for remanufacturing based on replacement theory
Zhichao Liu, Feri Afrinaldi, Hong-Chao Zhang, Qiuhong Jiang
Pages 447-450

Download PDF Article preview

Research article Full text access
Optimized joint motion planning for redundant industrial robots
Gábor Erdős, András Kovács, József Váncza
Pages 451-454

Download PDF Article preview

Research article Full text access
A novel manufacturing architecture for sustainable value creation
Pinar Bilge, Fazleena Badurdeen, Günther Seliger, I.S. Jawahir
Pages 455-458

Download PDF Article preview

Research article Full text access
An approach for process control of responsive service processes
Andy Bruntsch, Mitchell M. Tseng
Pages 459-462

Download PDF Article preview

Research article Full text access
Performance measurement in flow lines – Key to performance improvement
Nicole Stricker, András Pfeiffer, Emanuel Moser, Botond Kádár, Gisela Lanza
Pages 463-466

Download PDF Article preview

Session on Precision Engineering & Metrology (P)

Research article Full text access

Measurement of a tool wear profile using confocal fluorescence microscopy of the cutting fluid layer

Yasuhiro Takaya, Kenji Maruno, Masaki Michihata, Yasuhiro Mizutani

Pages 467-470

Download PDF Article preview

Research article Full text access

An imaging system with a large depth of field based on an overlapped micro-lens array

Kuo Pang, Le Song, Fengzhou Fang, Yue Zhang, Haoyang Zhang

Pages 471-474

Download PDF Article preview

Research article Full text access

Virtual spindle based tool servo diamond turning of discontinuously structured microoptics arrays

Suet To, Zhiwei Zhu, Haitao Wang

Pages 475-478

Download PDF Article preview

Research article Full text access

Automated thermal main spindle & *B*-axis error compensation of 5-axis machine tools

Josef Mayr, Michael Müller, Sascha Weikert

Pages 479-482

Download PDF Article preview

Research article Full text access

Measurement of thermal influence on a two-dimensional motion trajectory using a tracking interferometer

S. Ibaraki, P. Blaser, M. Shimoike, N. Takayama, ... Y. Ido

Pages 483-486

Download PDF Article preview

Research article Full text access

Gaussian process based multi-scale modelling for precision measurement of complex surfaces

Yuehong Yin, Ming Jun Ren, Lijian Sun, Lingbao Kong

Pages 487-490

Download PDF Article preview

Research article Full text access

Uncertainty evaluation of distributed Large-Scale-Metrology systems by a Monte Carlo approach

Maurizio Galetto, Luca Mastrogiacomo, Domenico Maisano, Fiorenzo Franceschini

Pages 491-494

Download PDF Article preview

Research article Full text access

Economic benefits of metrology in manufacturing

E. Savio, L. De Chiffre, S. Carmignato, J. Meinertz

Pages 495-498

Download PDF Article preview

Research article Full text access

3D artefact for concurrent scale calibration in Computed Tomography

A. Stolfi, L. De Chiffre

Pages 499-502

Download PDF Article preview

Research article Full text access

Self-Calibration Method for a Ball Plate Artefact on a CMM

Anke Guenther, Dirk Stöbener, Gert Goch

Pages 503-506

Download PDF Article preview

Research article Full text access

Implementation of straightness measurements at the Nanometer Comparator

Christoph Weichert, Harald Bosse, Jens Flügge, Rainer Köning, ... Horst Kunzmann

Pages 507-510

Download PDF Article preview

Session on Surfaces (S)

Research article Full text access

Nano/microcomposite surface fabricated by chemical treatment/microembossing for control of bubbles in boiling heat transfer

Keisuke Nagato, Shumpei Miyazaki, Shuhei Yamada, Masayuki Nakao

Pages 511-514

Download PDF Article preview

Research article Full text access

Effects of carbon contaminations on Y_2O_3-stabilized ZrO_2 thin film electrolyte prepared by atomic layer deposition for thin film solid oxide fuel cells

Suk Won Cha, Gu Young Cho, Yeageun Lee, Taehyun Park, ... Jang-moo Lee

Pages 515-518

Download PDF Article preview

Research article Full text access

Fast fabrication of superhydrophobic metallic surface using nanosecond laser texturing and low-temperature annealing

Doo-Man Chun, Chi-Vinh Ngo, Kyong-Min Lee

Pages 519-522

Download PDF Article preview

Research article Full text access

The effect of surface and subsurface condition on the fatigue life of Ti–25V–15Cr–2Al–0.2C %wt alloy

Donka Novovic, David K. Aspinwall, Richard C. Dewes, Paul Bowen, Brian Griffiths

Pages 523-528

Download PDF Article preview

Research article Full text access

An international comparison of surface texture parameters quantification on polymer artefacts using optical instruments

G. Tosello, H. Haitjema, R.K. Leach, D. Quagliotti, ... H.N. Hansen

Pages 529-532

Download PDF Article preview

Research article Full text access

Assessment of uncertainty in structured surfaces using metrological characteristics

Gavin D. MacAulay, Claudiu L. Giusca

Pages 533-536

Download PDF Article preview

Research article Full text access

Effects of different mould coatings on polymer filling flow in thin-wall injection moulding

G. Lucchetta, D. Masato, M. Sorgato, L. Crema, E. Savio

Pages 537-540

Download PDF Article preview

Research article Full text access

Surface topography and dielectric properties of polished PMN-PT single crystals

Hideaki Takahashi, Hirofumi Suzuki, Yoshiharu Namba

Pages 541-544

Download PDF Article preview

Research article Full text access

Antifouling coatings made with Cold Spray onto polymers: Process characterization

R. Lupoi, C. Stenson, K.A. McDonnell, D.P. Dowling, E. Ahearne

Pages 545-548

Download PDF Article preview

page 2 of 2

Previous vol/issue

Next vol/issue

ISSN: 0007-8506

ScienceDirect

CIRP Annals

8.5 CiteScore

3.641 Impact Factor

Menu

Search in this journal

Submit your article

Guide for authors

About the journal

Aims and scope

Editorial board

Abstracting and indexing

Editorial Committee

Society

ISSN: 0007-8506