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Analysis of scheduling activities in the processes of improving surface characteristics of parts

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Abstract. In the framework of planning and scheduling process for improving surface characteristics the laser cladding process is one of the best solutions, due to the fact that it involves deposition of high-quality material layers by laser radiation. This process is efficient whenever there is the need of improving the surface characteristics of metallic parts, component of products that usually require high cost maintenance because of their severe wear while functioning. This paper presents a time- efficiency analysis of two types of surface properties improving techniques. One is laser cladding and the other is thermal spraying and there are envisaged the work in process time and the availability of capacity in each of the required manufacturing systems. In addition to the efficiency obtained by scheduling activities, the laser cladding process with nano powders ensures a reduction in the use of expensive materials, about 80% compared to traditionally manufacturing, higher productivity and lower energy consumption, about 20% reduction, compared to metallizing. So, compared to various existing solutions, laser nano-cladding technologies are versatile and applicable to various industrial sectors as energy, automotive, mining, food, etc.

1. Introduction

In order to reduce the cost of mechanical components with high surface properties, such as corrosion resistance, wear resistance and hardness, there is the issue of optimizing the production process through optimal planning and programming of production capacities [1] but also by using surface treatment advanced technologies to improve surface properties of metal components, to the detriment of the use of special alloys that are very expensive.

One of the efficient techniques for improving the surface properties of materials is laser processing, which by using the laser radiation modifies the structure and surface characteristics of materials. Laser surface treatments can be divided into direct processes, which need only the heat generated for hardening and melting (annealing, melting, solidification and hardening of the material in well-defined areas of the part) and thermo-chemical processes that need addition material for alloying and deposition [2, 3].

The objective of the research presented by this paper is to analyze the performance of the laser cladding process, compared to other classical process - thermal spraying, for improving the surfaces properties of metal parts (with intensive wearing in exploitation), in the context of optimization of production capacity. From a technological point of view, the analysis of researches conducted by specialists in the field, the laser cladding process enables a local deposition, on well-defined areas, of different types of materials (alloy steel powders, ceramic powders) and thus ensures improved mechanical characteristics (compared with the base material/substrate) such as: wear resistance, lubrication properties, corrosion resistance, etc.

2. Characteristics of the studied deposition techniques

One of the most important characteristics/properties of LC (Laser Cladding), according to the specialized literature, is the *wear resistance*.

In [4, 5] is presented an example of the use of the laser cladding process for the repairing and/or maintenance of parts, such as disc and wheels in the railway industry.

In [6] are presented aspects of determining the wear resistance of layers of Ni alloys, obtained from powders deposited by LC. The abrasion tests were performed with a specific equipment, according to the Brinell-Haworth scheme, where silicate granules with a particle size of 200-600 μm were introduced in the friction zone.

Another example of LC application is the laser deposition for laser and metal powder reconditioning of punches used in Abkant type bending presses [7]. The application in this case was made on a robotic cell, digitally controlled by a controller, and the laser beam is transmitted via fiber optics. The powder was distributed with a precise dosing device, with the possibility of drying and preheating the filler material.

Another important characteristic of the LC is the *hardness*. The determination of the hardness characteristics, for different types of high chromium alloy steel powders, deposited on 316L steel substrate, by the laser cladding process, with coaxial spray head, is presented in [8]. Also, in [7] is highlighted the way to determine the microhardness of the layers deposited by laser cladding, LC. The mechanical characteristics of the deposited layers were determined by analysing the microhardness in the fusion zone and in the heat affected zone.

According to [9], thermal spraying is a generic term for a group of metallic and non-metallic layers deposition processes. There are two basic types of thermal spray processes. The first type, called the "combustion process", is based on burning a mixture of hydrocarbons (acetylene, propane, kerosene) and oxygen (or air) to create the enthalpy and kinetic energy needed to plasticize and propel particles to the surface. In the second process type, the electric power (electric arc or plasma) is the energy source needed to spray the particles.

The essential feature of the layers deposited by thermal spraying is their wide applicability due, on the one hand, to the composition of the deposited material, which is almost unlimited, and on the other hand, to the temperature of the parts, which is kept low during the spraying process 100÷260°C, which considerably reduces the danger of deformation, oxidation and phase transformations.

3. Research methodology

In any production process for obtaining parts with high characteristics, optimization results of the planning and scheduling working flow activities of each of the processes refer to decreases of production costs and of the costs related to the exploitation life of the product, by high corrosion resistance, wear resistance and hardness. Thus, the purpose of this paper is to study the way of optimizing the production process by using adequate technologies to improve the surface characteristics of parts, the results pointing toward application of high performance techniques like laser cladding, over the classical one, like thermal spraying (metallizing).

In table 1 are presented the process parameters, according [10], for two type of surface improving techniques: thermal spraying and laser cladding.

In order to establish the performance of laser cladding process, there will be analysed the process flow of both type of techniques (laser cladding and thermal spraying), only for a type of part. In table 2 are presented the flow process and time for work in process (WIP) for both types of the analysed techniques.

Table 1. Process parameters [10].

Type of process	Thermal Spray	Laser Cladding
Heat source	Electric arc	Laser beam
Coating thickness	0.5 -5 mm	0.2 -2 mm
Typical deposition rate	≤10 kg/hour	≤5 kg/hour
Dilution	5 – 15%	≤5%
Type of boding	Metallurgical	Metallurgical
Bond strength	≤800 MPa	≤800 MPa
Heat input	High	Low - medium
Porosity	≤0.1%	≤0.1%
Comparative capital cost	Low	High
Comparative running cost	Medium - low	Low

Table 2. Time for work in process and process flow.

Thermal Spraying				Laser cladding			
Process flow of thermal spaying	Processing Equipment	Machine code	WIP [min]	Process flow of cladding process	Processing Equipment	Machine code	WIP [min]
Surface cleaning (degreasing)	Manual / special enceinte	M1	3	Surface cleaning (degreasing)	Manual/ special enceinte	M1	3
Surface machining by turning	CNC center	M2	1.5	Cladding	MetcoClad system	M5	1.2
Surface roughening – by abrasive jet / metco method	Grit blasting equipment	M3	2	Post processing – seldom required-grinding	CNC center	M2	2
Metaling Spraying	METCO – Oerlikon system	M4	1.5				
Post processing by turning	CNC center	M2	2.5				

Table 3. Time for work in process and process flow for the Thermal Spraying technique.

Sequences activities, time [min]	Surface cleaning (degreasing)	Surface machining by turning	Surface roughening – by abrasive jet/METCO method	Metaling Spraying	Post processing by turning	Total time per each step of WIP [min]	Forecast production rate
Working station	M1	M2	M3	M4	M2		
Setup time	0.3	0.15	0.2	0.15	0.25	1.05	0.5
Process time	2.4	1.2	1.6	1.2	2	8.4	
Cleaning and removing time	0.3	0.15	0.2	0.15	0.25	1.05	
Total	3	1.5	2	1.5	2.5	10.5	

The time for each sequenced WIP is share per each step of WIP. The main processing steps for both studied techniques are: setup time, process time and cleaning/removing time. In tables 3 and 4 are presented the time per each step and calculated total time per each step and each working station.

Table 4. Time for work in process and process flow for the Laser Cladding technique.

Sequences activities, time [min]	Surface cleaning (degreasing)	Cladding	Post processing – seldom required-grinding	Total time per each step of WIP[min]	Forecast production rate
Working station	M1	M5	M2		
Setup time	0.3	0.1	0.4	0.8	0.5
Process time	2.4	1	2.4	5.8	
Cleaning and removing time	0.3	0.1	0.8	1.2	
Total	3	1.2	2	6.2	

For a rate of product planning in process by 0.5, the used capacity is presented in table 5, for each analysed process. The used capacity is calculated reporting the total planned time of each working station (resource) calculate considering the forecast of production rate at total available capacity of resources.

The used capacity for analysed case is presented in figure 1. If is necessary to do the planning of production process for different kind of parts, the used capacity will be higher and, in this case, it is necessary to do other analyses regarding the allocation of resources.

Table 5. Used capacity of resources for one type of part.

Working station	Production capacity	Thermal spraying	Capacity using for thermal spraying process	Cladding Process	Capacity using for cladding process	Working hours per day	Forecast production rate
M1	1	1.5	18.75%	1.5	18.75%	8	0.5
M2	1	2	25.00%	1	12.50%		
M3	1	1	12.50%	-	-		
M4	1	0.75	9.38%	-	-		
M5	1	-	-	0.6	7.50%		
Operator	1	1.05	13.13%	1	15.50%		

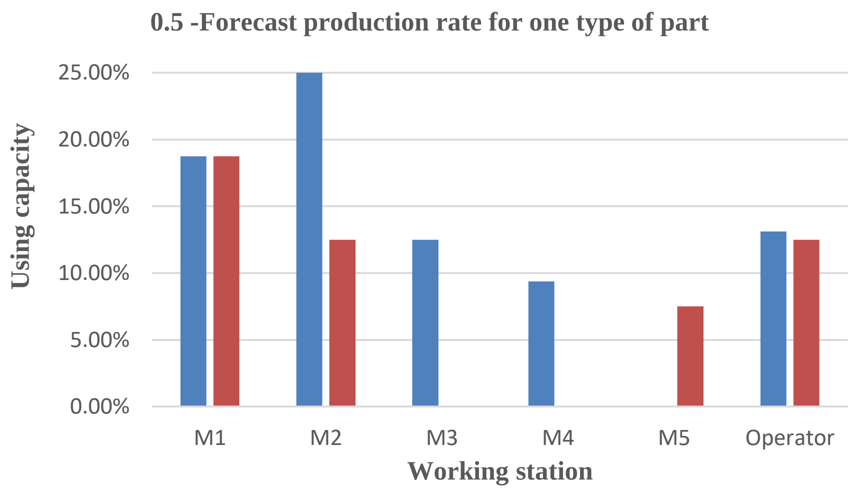

Figure 1. Used capacity.

Doing the simulation for different production rate forecast and for different type of parts, resulted in the values presented in table 6.

Table 6. Used capacity of resources for different type of parts.

Working station	Total time thermal spraying	Part 1 0.5	Part 2 0.35	Part 3 0.3	Part 4 0.25	Part 5 0.43	Part 6 0.47	Total using capacity
M1	3	18.75%	13.13%	11.25%	9.38%	16.13%	17.63%	86.25%
M2	4	25.00%	17.50%	15.00%	12.50%	21.50%	23.50%	**115.00%**
M3	2	12.50%	8.75%	7.50%	6.25%	10.75%	11.75%	57.50%
M4	1.5	9.38%	6.56%	5.63%	4.69%	8.06%	8.81%	43.13%
Operator	2.1	13.13%	9.19%	7.88%	6.56%	11.29%	12.34%	60.38%
Working station	Total time laser cladding	Part 1 0.5	Part 2 0.35	Part 3 0.3	Part 4 0.25	Part 5 0.43	Part 6 0.47	Total using capacity
M1	3	18.75%	13.13%	11.25%	9.38%	16.13%	17.63%	86.25%
M2	2	12.50%	8.75%	7.50%	6.25%	10.75%	11.75%	57.50%
M5	1.2	7.50%	5.25%	4.50%	3.75%	6.45%	7.05%	34.50%
Operator	2	12.50%	8.75%	7.50%	6.25%	10.75%	11.75%	57.50%

As is shown in table 6, the used capacity for working station M2 is overall located; in this case it is necessary to have available two resources for thermal spaying process. This scenario involves additional cost with fixed asset, and additional space in production workshop.

4. Results

In the framework of these complex processes for improving surface characteristics, the process specific parameters (power, speed, quantity of powders etc.) must to be correlated with planning and scheduling parameters for obtaining quality mechanical components at the client ordering.

As can be seen in the simulation performed to determine the capacity utilization in for two studied techniques, the LC ensures a lower capacity utilization comparing with the case of thermal spaying, which leads to the conclusion that in terms of planning and scheduling the production process, the laser cladding process is more efficient, ensuring shorter processing times and less production capacity utilization. Also, considering the process parameters, the LC process is characterized by a low heating/cooling time of molten metal baths.

5. Conclusion

The new laser cladding technologies will ensure a reduction in the use of expensive materials (additional material is deposited accurately where is necessary) higher productivity and lower energy consumption (about 20% reduction, compared to metallizing).

There can be used a very wide range of materials and additional material completely merge with the base material. The material is not excessively heated, which reduces the distortion of the substrate that would require further corrective processing by machining, the process can be fully automated and integrated into production lines.

Compared to existing solutions, LC technologies are versatile and applicable to several industrial sectors (energy, automotive, mining, food, etc.) also, these improve the durability and mechanical and chemical resistance of industrial parts (due to special nano-powders mixes).

One disadvantage of the LC technique could stand in the relatively large initial investment that must be made to purchase the equipment and training of the staff.

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