Laser Cladding and Joining of Metals : A Review

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Abstract: ***The Proper implementation of laser cladding process is widely used in the concerned aerospace industries. The principal aim of this review research paper is to make analysis of various parameters of laser cladding process as examined by several research for optimum output values. These parameters are cladding laser power, laser power, scanning speed, current power, laser beam, energy density, laser irradiance, mass flow of coating, particles, spot diameter, pulse duration, and many more all the research try to optimize this parameters according to the concerned requirement. In this review proper it was tried to consider different research paper containing the research and analysis made on input output parameters of laser cladding process.***

This paper also focused on analysis of some research papers containing heat input rates cooling rate of clad, microstructure of clad and heat affected *zone* ***and their effect on the performance of the coating. Total 18 research papers were selected for our consideration after a thorough investigation of several such papers after the analysis of the research papers the future scope of research was also suggested.***

Keywords: laser power, energy density, current, voltage, laser beam, scanning speed etc.

INTRODUCTION

Laser cladding a popular form of laser hard facing techniques. Is a processing method in which laser beam is used as the heating source to melt the alloy powder to be clad laser cladding provides good metallurgical bonds duration and low distortion of the work piece. And the accompanying microstructures with improved properties. There are several techniques to after properties of a solid material in order to increase its hardness or to make it wear or corrosion resistance. By using laser beam as the energy sources. It is possible to apply the treatment very accurately only on the final result of the treatment appears in various from.

A) A clad layer with low duration in substrate.

A surface layer of added material Alloyed with the substrate or a solution of solid added practical's in a re-melted surface layer of the substrate. In laser cladding, interest are generally draw to the relationship between the microstructures and properties, usually hardness of the clad layer with one or a series of hard facing powder are seldom reported therefore an investigation of cladding parameters in necessary for achieving an optimum properties of the hard facing alloy which will improves the wear resistance of the alloy to its fall extend.

Laser Cladding Process

Laser cladding is an interdisciplinary technique which combine the laser technology, the control system together. Laser cladding utilize a laser heat sources to deposit a thin layer of preplaced material on a moving substrate, as shown in fig. moving the substrate after laser cladding is usually divided into four parts-cladding zone(cz), Interfacing zone (IZ) heating affected zone (HAZ) and they substrate (SUB).

As mentioned in the introduction section, good metallurgical bonding between the coating and substrate can be obtained with laser cladding technique in order to promote the further application, more should be carried out in the laser cladding process on magnesium alloys micro morphological microstructures and properties of the cladding are tested and the results of them are taken as the criteria of the cladding process are summarized, including processing parameters, feeding way of the material the cladding material used in the method is placed by layer by layer before being machine to attain the final dimension until the necessary thickness is covered. Laser cladding is much better than other techniques. It provides the potential for developing such a technology for repairing. Mechanical sections have been repairing using the methods that consume more and energy but laser cladding is an option to techniques of diffusion. The laser cladding system is made up various parts shown fig the laser cladding has several process parameters. The main parameters are laser energy, laser beam spot, diameter, laser scanning velocity or comparative work. Place motion velocity pre-powder layer thickness powder feed rate, nozzle angle and stands off etc. fig represents the cause and effect diagram for laser cladding process which classified the process parameter into five major categories. Machining parameters, characterized of laser beam, characterized of product, laser clad characterized and characterized of cladding powder the process parameters should be legitimately controlled into order to optimize the process.

Laser cladding is applied not only for coating, but also for repair and rehabilitation as well as rapid prototyping.

STUDYS AND FINDINGS

Yongjian Li et al. Have conduction of welding process in shielded metal arc welding and gas tungsten arc welding in geometric. The input parameters consider for the experiments are laser powder, scanning speed, powder delivery velocity, spot diameter. It was observed that the process parameters has a micro hardness, ultimate tensile 502MPa strength, martensite structure and lamellar cementide structure were studied. Circular groove procedures were conductive. In Ni-cu alloy powder Aae used [1].

Alexandru Pascu al. Have conducted the laser cladding process using explosive welding method in titanium are used mechanical properties and microstructure of cladded surface were analysed. Their result several the application reconditioning of damage aeroplane engine blade manufactured from titanium alloy. Very good bonding with the substrate [2].

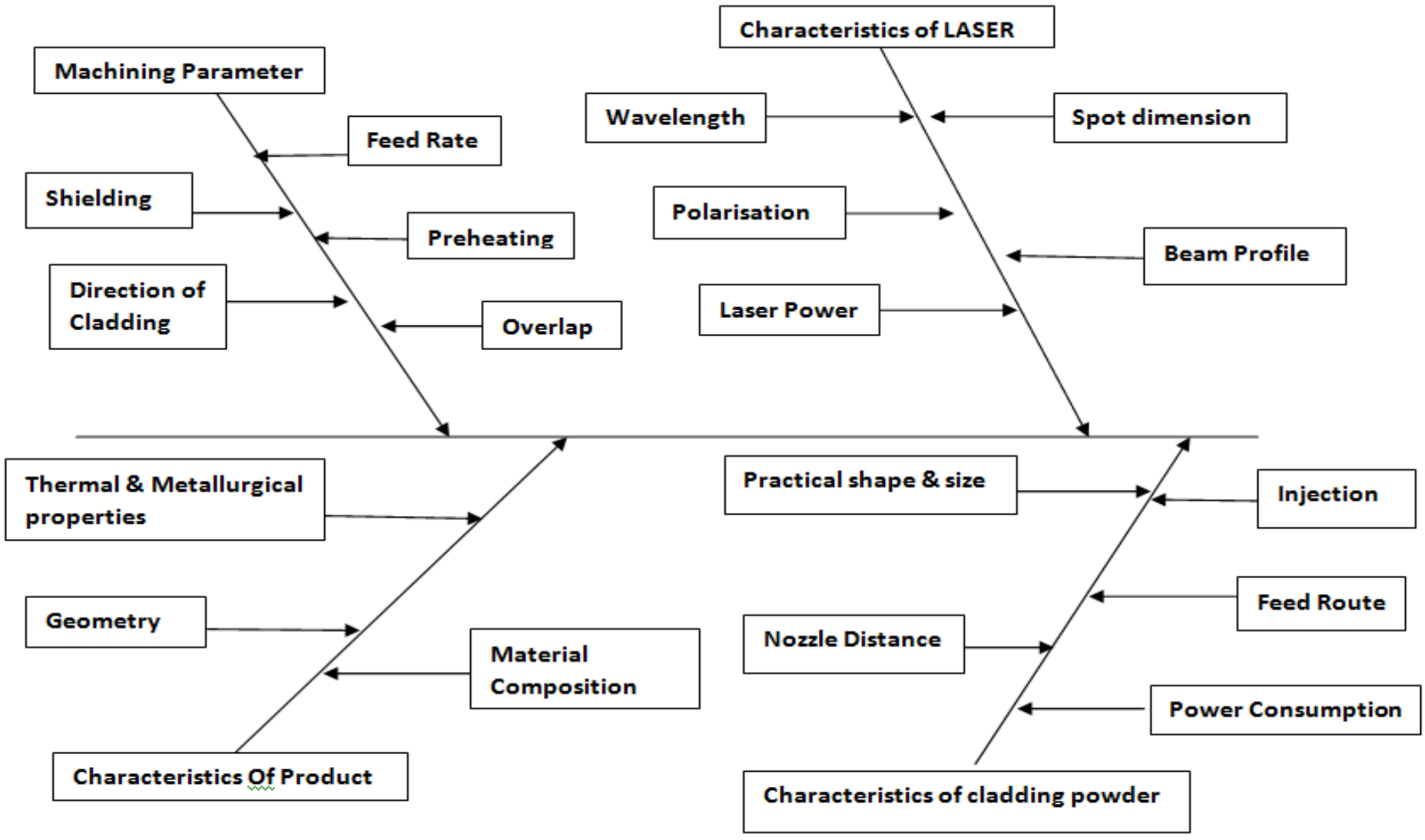

Fig:- Cause and Effect Diagram of Laser Cladding Procedure

Yongjian lia et al. Have discussed the temperature field and weld poor geometry by conducting the arc welding, plasma spying, oxy-acetylene welding of HT 200 gray cast iron. The microstructure weld was analysed by optical scanning electron probe microscope. The mechanical properties of the weld were evaluate by conducting residency strength test. And impact toughness test. It has been widely studied about remaining during laser cladding Ni based alloy. Their result several the application reconditioning of damage aeroplane engine blade manufactured from titanium alloy. Very good bonding with the substrate [3]

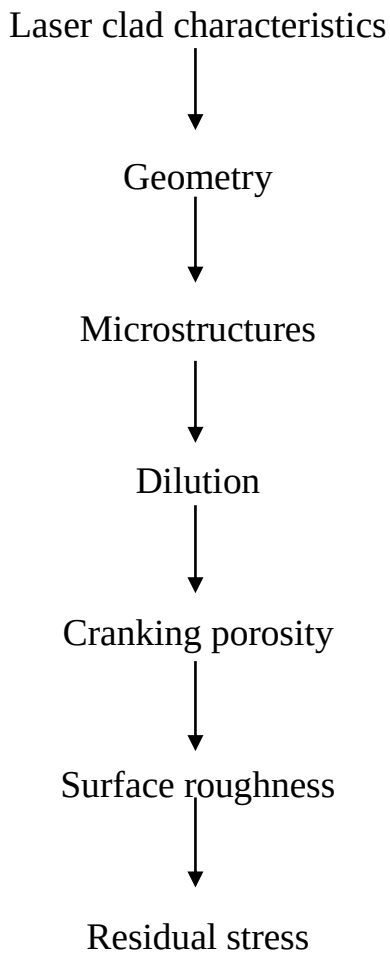

Fig: - Flow chart work piece properties

jing yu et al. Have investigated the various laser cladding process parameters HT-300 cast iron D=22mm H=100mm. The precipitation of borides and carbides in the coating is beneficial for increasing the hardness to abrasive and adhesive wear the interfacial region where as the Cr.CB gradually diffused and migrated into layer.

Their result reveal the stability of wear resistance of coating was better than that of the substrate. It can be concluded that the wear resistance of the substrate can be improved significantly by using the coating finding of elements precipitation of borides beneficial for increasing the hardness. The interfacing region whereas the Cr.C.B gradually diffused and deposition money alloy coating on gray cast iron has rarely been investigated [4].

Table:- properties of clad

Mechanical properties	Metallurgical properties	Geometrical properties	Qualitative properties
Residual stresses	Microstructures	Clad dimension	Porosity
Hardness distribution	Dilution	Roughness	Crank
wear distribution	Grain size	Dilution	
Tensile strength	Corrosion		

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F. arias- Gonzales et al. Have conducted electro Conductive loading by considering the fallowing process parameters like laser power, scan speed, and powder feed rate on clad bead quality characteristics for AISI 1040 steel substrate. The process parameters were optimised by using gray relational analysis of gray cast iron sample generally present higher dilution than the equivalent sample in ductile cast iron. The hard facing coating has been generated by fiber laser cladding. Greatest angles are obtained at the higher speed and laser irradiance. Suitable processing parameters to generate the Ni based alloy coating were determined, it has been widely studied the laser cladding of Ni-Cr-B-Si over carbon steel [5].

Zhikun Weng et al. have conduction electro conductive coating by considering the fallowing process parameters:- substrate material type of powder feeding arrangement, stagnation gas temperature, stagnation gas pressure, and stand-off distance. The significant process parameters were identified and their contribution to the response also analysed by employment of variance techniques. It was observed that the maximum contribution given to the response by the process parameters is stagnation

pressure. The laser power has significant effect to the quality of the interface between the clad and the substrate with the increase in the laser power higher value, high residual stress would cause cracking in the interfacial cracking (crack) the microstructure of repaired v-groove is fine of porosity and cranks [6].

C. M. lin et al. Have conducted the laser cladding process by considering a process parameters such as power, process speed, and powder feed rate to analyse the relationship between process parameters and response. It has also to be optimised from the results it was observe that optimised process parameters give better solution to improve and repair the working components. Their result reveal analysis the tensile properties pre-treatment increasing ductility with the notch position of the centre of the welded pre-treatment to eliminate graphite nodule at surface before lasing hence the weld ability of ductile cast iron during welding process the diffusion of the carbon can lead to the formation of hard brittle phase at the weld interface [7].

Table:- Process characteristics

Surface Modification process	**Process characteristics**
Laser	Low heat input thin laser low dilution and porosity high hardness, small HAZ, high initial equipment investment.
Welding	-MIG/TIG reasonable bond, medium heart input. -Sub merged arc -Oxyacetylene liquid/solid bond, high heart input, shielded metal arc. -Plasma arc – thick layer high deposition rates, low equipment cast, covers large area, high heat input and part distortion.
Spaying	-Flame powder no dilution -no deformation to base metal.
Physical vapour deposition	-spattering - vacuum coating

Satish R. More et al. Have received the laser cladding process parameters for one drop of spray to the base material. Section of pulse process Parameters. During laser welding is very important to maintain the arc bead geometry. The improve such as poor bead surface. Improper fusion of filler material burn backs stubbing in and undercuts. From the result related to erosion wear response.

Mainly erosion wear the characteristics of cladding material characteristics of laser beam and characteristics of product also focus on erosion wear. It was observed that the proper selection of laser process parameters ensure better performance during laser welding process [8].

Yancong Liu et al. Have studied the effect of manufacturing variable on the corrosion resistance of super duplex stainless steel. The manufacturing variable considered for the study were surface condition heart treatment and clod working.

Morphological characteristics of carbonic different region the specimens vary. The cladding layer is form by melting the Fe based powder graphite is not observed in region. Carbon atom in the substance affect the binding and bottom region of the cladding layer but do not diffuse into the cladding layer [9].

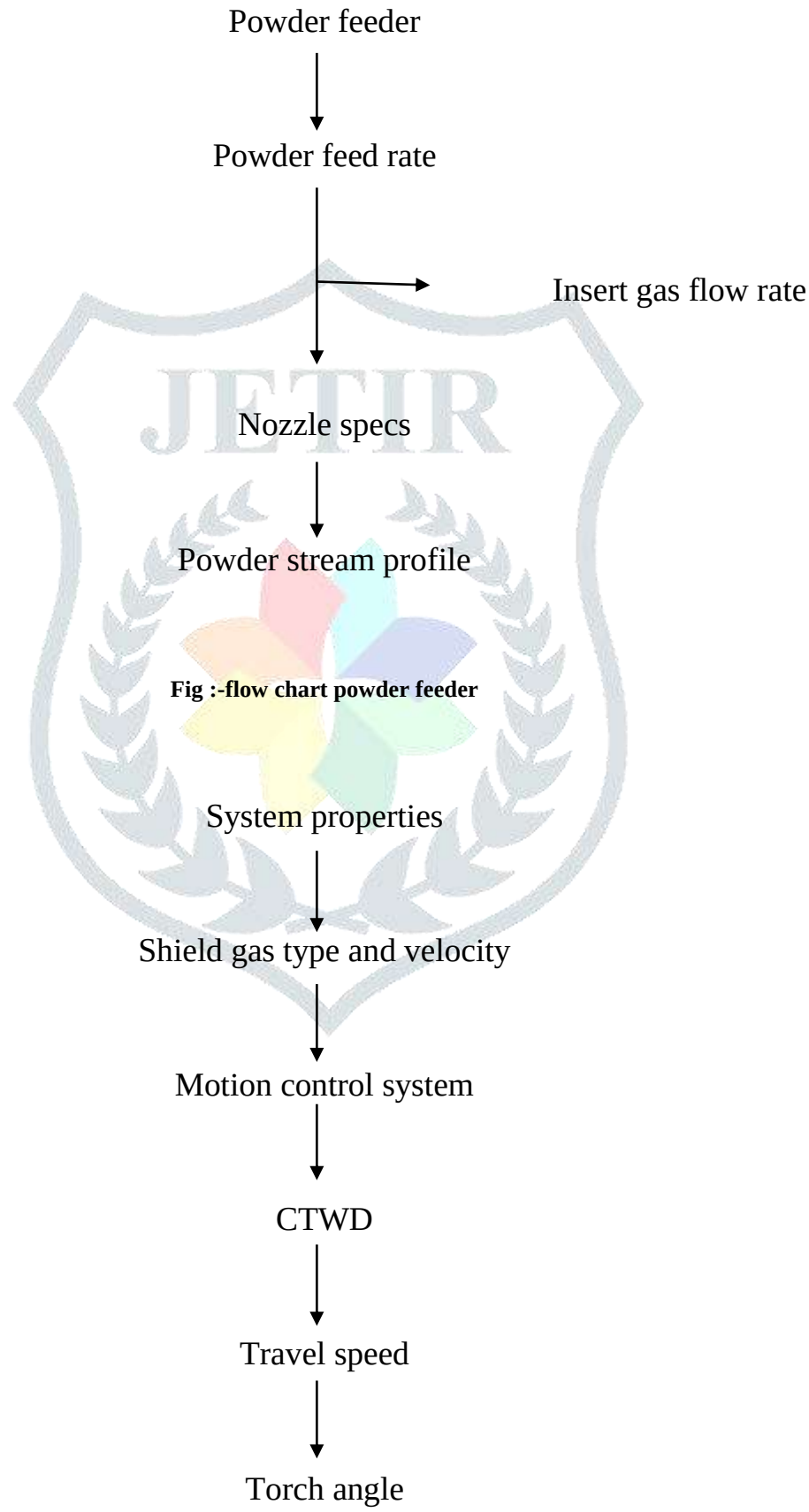

Fig :-flow chart powder feeder

Fig: - Flow chart system properties

Yongian Li et al. Have studied the optimisation of process parameters during flux tungsten inert gas welding. The optimisation characteristics were clad bead geometry. The coefficient of the shape of welds (internal and external) and percentage of dilution. The cracks always sprouted in the boundary of voids. The coating strongly depends on the combination of hardness and toughness. Their result reveals the top surface and cross section illustrate different growth orientation according to the XRD results typical phase (Fe Ni) 23C6 and Mn5Si were identified in SAD pattern in the interface zone. Micro hardness of the layer was little higher than that of the substrate decreased obviously in CGZ grain could be refined in the interface zone between two cladding layer [10].

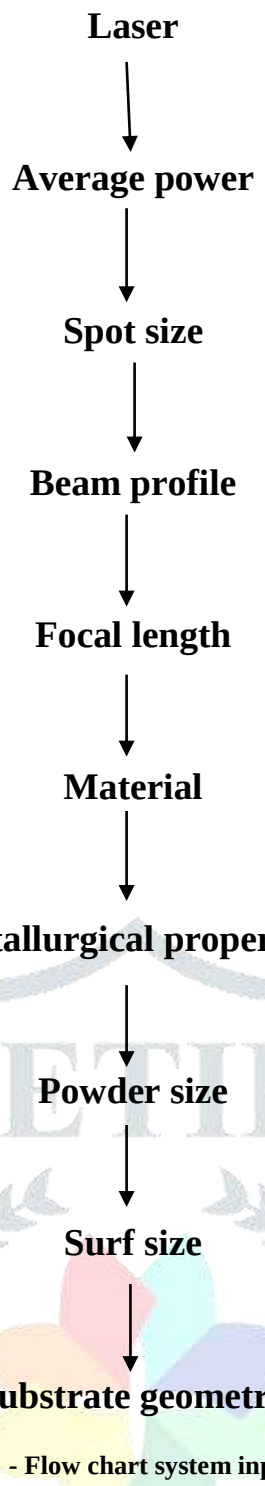

Fig: - Flow chart system inputs

Zhengian jing et al. Have investigate the influence of process parameters such as welding current and welding speed on microstructure and mechanical properties of high strength low alloy steel wed during the laser cladding. We process it was found that grain structure of the weld zone and heat affected zone is varied based on the heat supplied. The welding current is the predominant factor for deciding hardness of the material as compared to welding speed. The ductile fracture is occurred due to increase in heat input. Their result reveals herringbone carbide Fe3W3c formed in the laser cladding wc units, the microstructures of the changes due to increase growth and fracture. The micro hardness of all laser cladding re-melting one [11].

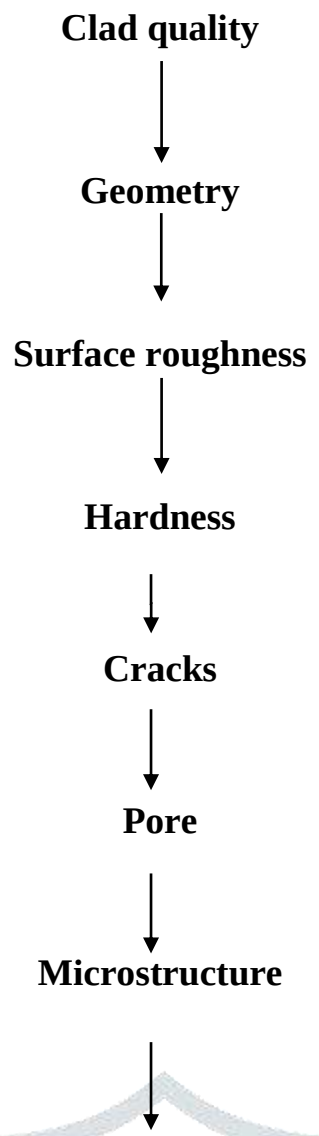

Fig: - Flow chart work piece properties

F.Abouda et al. Have investigate the surface morphology of stainless steel plate TRUMPEH when subjected to different grinding condition such as load spindle speed and fluid type it was observed well with the reduced valley depth of the surface while other roughness parameters including roughness average, root mean square roughness average, skewness, and other showed poor correlated with corrosion behaviour.

Their result reveal high chromium hard facing alloy (Fe-Cr-C-Ni-MO-Mn) was deposited on stainless steel of microstructure wear resistance of alloy coating. The structure like molybdenum carbide Cr.Tc3 and Cr23C6 then average micro hardness of the clad [12].

V.ocelik et al. The microstructure features of these coating were studied using optical microscopy, scanning electron microscopy (Philips XL30, FEG) EDS and XRD, mechanical properties were determined using micro hardness measurement scratch test analysis at room tribotesting. (CSM HT tribometer) at room and evaluated up to 25c temperature. They concluded that no substantial change in mechanical characteristically was observed in the overlap area of the tracks the microstructure of the satellite style coating near the interfacing with the cast iron substrates does not contain a sharp interface but it is formed by a gradual change in microstructure with a substantial number of micro voids formed during the melt shrinkage at the last stage of solidification [13].

Peng vi et al. Examined different speed and examined different depth the phase are changes. Speed performed main role in clad. During cooling stage, solidification starts from bottom of the melted layer. The energy density scanning speed and type of laser are key factor for the laser treatment. They concluded that microstructures composition and phase components of laser clad mainly composed of mg matrix ra[id solidification is worked due to microstructures and composition phase are decreased with increase depth [14].

Ligji zhu et al. A composite coating was designed and produced using cu-Ti-Ni blending powder on the surface of gray cast iron by fiber layer cladding system. The phase constituent and microstructures of the composite coating were investigate using x-ray diffraction and scanning electron micrograph micro hardness and wear resistance of the coating were evaluated. They concluded that surface properties of gray cast iron was improved by Tic rain forced composite coating. The micro hardness of the laser cladding zone was approximate 2 to 3 time that of the substrate and the wear resistance of the coating was significantly improved [15].

yongijian li et al. Have studied the optimization of process parameters on clad plasma beam welding SMAW TIGW geometry during of duplex ductile cast iron. By the tungsten inert gas welding process. Response surface methodology based central composite design matrix was used to perform the influences of process parameters on response.

Their results revel microstructure and mechanical properties were studied Ni-Cu alloy powder. Martensite structure and lamellar cementite structure were studied. Circular groove procedure were conductive [16].

zhang et al. At different speed and different depth the phase are changes speed perform main role in clad during cooling stage, solidification starts from bottom of the melted layer. The energy density, scanning speed and the type of laser are key factor for the laser treatment. They concluded laser alloyed layer are crank free with very fine structure metrological bonding with the substrate was good. No defects such as micro cranks or pits with homogenous structure. High cooling rate creates the fine cellular dendrite structure after layer alloying [17].

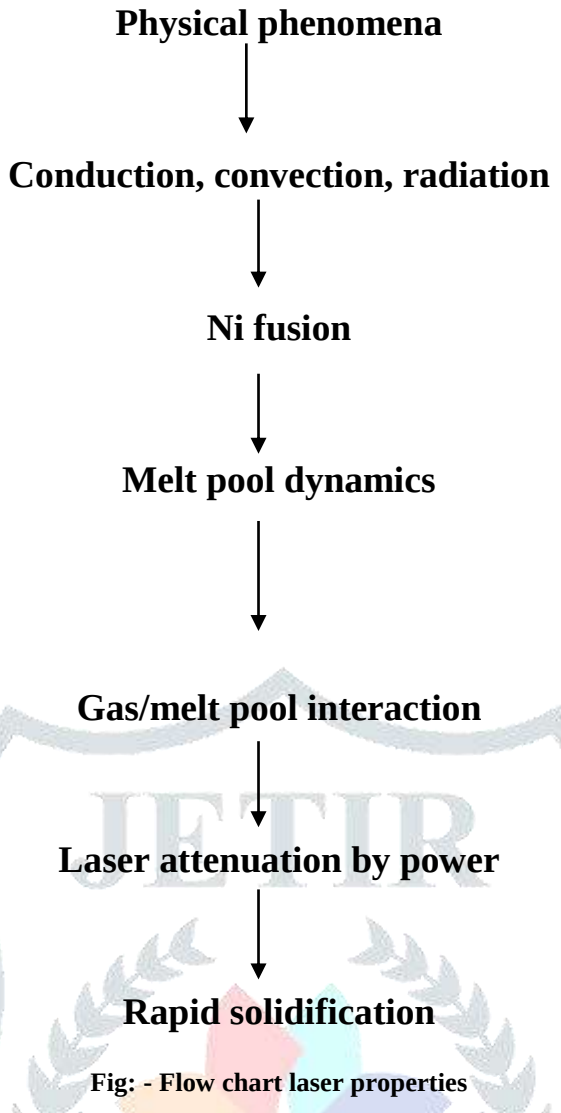

Fig: - Flow chart laser properties

N. jeyaprakash et al. Deposition techniques plasma spraying, laser cladding, thermal spraying laser alloying, physical and chemical vapour deposition. Only few research work was performed on study of abrasive wear on modular cast iron. Laser alloyed layer are crank free with very fine structure. Metrological bonding with the substrate was good defects such as micro cranks or pits with homogeneous structure. After laser alloying high cooling rate creates the fine cellular dendrite structure [18].

Conclusion: - The optimization means the best combustion of different parameters such as laser powder. Laser beam diameter and laser powder. Laser scanning speed with the help of numerical simulation, optimization of laser cladding process parameters will be easier surface flatness significantly affected by the over lapping ratio. For multi-track single layer cladding process long edge overlapping scanning with the same direction is optimal.

References:-

1. Yongjian Li, Shiyun Dong , Shixing Yan, Xiaoting Liu, Peng He, Binshi Xu , Surface remanufacturing of ductile cast iron by laser cladding Ni-Cu alloy coatings, surf. Coat. Technol. 374 (2018) 20-28

2. Alexandru pascu, Julia Mirza Rosca, Elena manuela stanciu ,Laser cladding: from experimental research to industrial applications, Mater. Process. 19 (2019) 59-65 .

3. Yongjian Lia, Shiyun Dongb, Shixing Yanb ,Xiaoting Liub, Enzhong Lib ,Peng Hea,Binshi Xua ,Elimination of voids by laser remelting during laser cladding Ni based alloy on gray cast iron, Opti. Laser Technol. 112 (2019) 30-38.

4. Jing Yu, Bo Song, Yanchuan Liu, Microstructure and wear behavior of Ni-based alloy coated auto gray cast iron using a multi-step induction cladding, Res. In Phys.10 (2018) 339-345.

5. F.Arias-Gonzales, J. del Val, R. Comesana, J. Penide, F. Lusquinos, F. Quintero, A. Riveriro, M. Boutinguiza, J. Pou, Fiber laser cladding of Ni- based alloy on cast iron, Appl. Surf. Sci. 374 (2016) 197-205.

6. Zhikun Weng, Aihua Wang, Yuying Wang, Dahui Xiong, Huiqun Tang, Diode laser cladding of Fe-based alloy on ductile cast iron and related interfacial behavior, Surf. Coat. Technol. 286 (2016) 64-71.

7. Satish R Morea*, Dhananjay. V. Bhatt, Jyoti. V. Menghani c.. Resent Research Status on Laser Cladding as Erosion Resistance Technique - An Overview Materials Today: Process. 4 (2017) 9902– 9908

8. C.-M. Lin*1,2,3, A. S. Chandra3, L. Morales-Rivas4, S.-Y. Huang1, H.-C. Wu5Y.-E. Wu3 and H.-L. Tsai3. Repair welding of ductile cast iron by laser cladding process: microstructure and mechanical properties. International journal of cast iron material. 27 (2014) 378-383.

9.Yancong, Liu a, b,⇑ Xianghua Zhan a, Peng Yi a, Tuo Liu a, Benliang Liu c,, Qiong Wu a, Research on the transformation mechanism of graphite phase and microstructure in the heated region of gray cast iron by laser cladding, Opti. Laser Technol. 100 (2018) 79–86

10. Yongjian Lia, Shiyun Dongb, Peng Hea, Shixing Yanb, Enzhong Lib, Xiaoting Liub, Binshi Xua, Microstructure characteristics and mechanical properties of new-type FeNiCr Laser caldding alloy coating on modular cast iron, J. Mater. Process. Technol. 269(2019) 163-171 .

11. Zhengjun Jing, Hong Zhou, , Peng Zhang, Chuanwei Wang, Chao Meng, Dalong Cong , Effect of thermal fatigue on the wear resistance of graphite cast iron with bionic units processed by Laser caldding WC, Appl. Surf. Sci. 271(2013) 329-336

12. E.Aboada ,M.Dal , P.Aubry, T.N. Tarafa, I. Demiric ,C.Gorny ,T.Malot, Effect of laser cladding parameters on the microstructure and properties of high chromium hardfacing alloys , Phys. Process.83(2016) 684-694

13. Peng yi, Yancong Liu, ChangFeng Fan, Xianghua Zhan, Pengyun Xu, Tuo Liu,Impact analysis of the thermal mechanical coupling characteristics of graphite marphologies during laser cladding of gray cast iron, Opti. Laser. Technol. 90 (2017) 52-64.

14. Lingjie Zhu, Yanhui Liu, Zhiwei Li, Lei Zhau, Yongjiu Li, Anhui Xiong, Microstructure and properties of CU-Ti-Ni composite coatings on gray cast iron Fabricated by laser cladding, Opti. Laser. Technol. 122 (2020) -105879.

15. V. Ocelik, u. de oliveira, M. de Boer, J. Th.M. de Hosson, Thick co-based coating on cast iron by side laser cladding : Analysis of processing conditions and coating properties, Surf. Coat.Technol. 201(2007) 5875- 5883.

16. Yongjian Li, shiyus dong. Shixing yan, xiaoying liu, peng He, Binshi Xu, Surface Remanufacturing of ductile cast iron by laser cladding Niku alloy coatings, Surf. Coat. technol. 347(2018) 20-28.

17. Erlei chen, kemon zhang, jianxin zou,. Laser cladding of a Mg based Mg-Gd-Y-Zr alloy with Al-Si powders, Appli. Surf. Sci. 367 (2016) 11-18

18. Microstructure and tribological evolution during laser alloying WC-12%Co and CrC2-25%Nicr powders on nodular iron surface, Res. In Phys. 12 (2019) 1610-1620