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A Schematic Design Method and Analysis of Machine Elements Using Robust Design Apporach

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Abstract:

In this paper we are using robust design optimization (RDO) for the sensitivity-assisted Monte Carlo Simulation method is developed in this study. The purpose of this paper is to propose a multi-objective optimization algorithm, which can improve both the performance robustness and the constraint feasibility when the uncertainty in design variables is considered. The objective functions that have been considered are the mean and standard deviation of the difference between the maximum and minimum gripping forces and the transmission ratio of actuated and experienced for machine element. The finite element analysis (FEA) was performed for the element. This research work deals with the stress in the Spline shaft under various loading condition of given torque. Finite element method along with experimental technique of photo elasticity is used. The optimisation objectives in the proposed model are maximising the total reliability of machines in shops in the whole job shop system, maximising the total reliability of the spline and minimising the total repair cost in the system.

Key words: Spline shaft, Uncertainty, Robust optimization, Multi-objective optimization approach, FEA.

Introduction:

Due to the existence of variety of typical sources of uncertainties in real-world designing and manufacturing of mechanisms and machines, it is very desirable to use stochastic and probabilistic methods in order to reduce performance variation of the systems in noisy environments. Therefore, researchers have paid significant attentions to robust and reliability-based design algorithms. Reliability-based design optimization (RBDO) and robust design optimization (RDO) are the two well-known approaches for uncertainty consideration, which have attracted a great deal of research in the past decades. RBDO methods focus on guaranteeing constraints feasibility at a desired reliability level and RDO methods seek to optimize the objective functions and simultaneously to minimize its sensitivity with respect to random parameters. Based on the definitions of two methods, it is obvious that the RDO and RBDO can guarantee the desired performance robustness and constraints feasibility, respectively. In this regard, it has been shown that integrating the two approaches in a reliability-based robust design optimization (RBRDO) framework facilitates both robustness assessment and reliability calculations. Traditional manufacturing has relied on dedicated mass-production systems to achieve high production volumes at low costs. As living standards improve and the demands for new consumer goods rise, manufacturing flexibility gains prominence as a strategic tool for rapidly changing markets. Flexibility, however, cannot be properly incorporated in the decision-making process if it is not well defined and measured in a quantitative manner. Flexibility in its most rudimentary sense is the ability of a manufacturing system to respond to changes and uncertainties associated with the production process. Reliability-based design optimization (RBDO) methods are used to perform design optimization accounting for reliability metrics. The reliability analysis capabilities described in Section II provide a rich foundation for exploring a variety of RBDO formulations.

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Stress analysis is complete and comprehensive study of stress distribution in a component. As the spline shaft is used in many applications to transmit the torque while permitting the axial movement, it is necessary to know main cause of failure of the spline. The tooth engagement, tolerance and pressure distribution was studied. Very little information is found available on the stress concentration area on spline shaft.

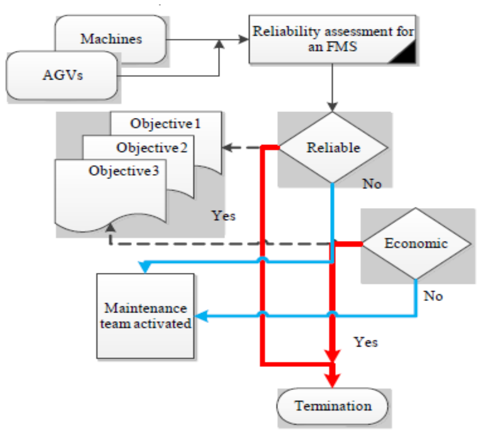
Literature review:

1. **Levitina and Abezgaouz (2017)** considered the case when loads were placed in flat pallets and each new picked up pallet was loaded on the top of batch of pallets already carried by the AGV. To avoid use of excessive space and time needed to reorder pallets in the batch, the loading–unloading procedures should be performed in accordance with last-in-first-out (LIFO) rule. The authors formulated the condition of existence of AGV routes in which, it visited each workstation only once and meets LIFO constraint.
2. **Corréa et al. (2016)** proposed a hybrid method designed to solve a problem of dispatching and conflict free routing of AGVs in a FMS. The problem consisted in the simultaneous assignment, scheduling and conflict free routing of the vehicles. The approach consisted in a decomposition method where the master problem (scheduling) was modelled with constraint programming and the sub problem (conflict free routing) with mixed integer programming. Logic cuts were generated by the sub problems and used in the master problem to prune optimal scheduling solutions whose routing plan exhibits conflicts. The hybrid method presented herein allowed solving instances with up to six AGVs.
3. **Sanchez-Salmeron et al. (2016)** the works which are is already made in the field of multi-objective optimization switched reluctance machine are numerous and different in the sense of improving the performance of these machines, the difference in this way is the choice of objective function, the algorithms and resolution method of a problem multi-objective optimization.
4. **Salehipour et al. (2015)** the authors used the PSO algorithm to optimize the stator and rotor pole arc of a 8/6 SRM calculated analytically with the machine dimensions in order to increase the average torque and minimize torque ripples
5. **Fazlollahtabar et al. (2014)** proposed a flexible jobshop automated manufacturing system to optimise the material flow. The flexibility was on the multi-shops of the same type and also multiple products that can be produced. An AGV was applied for material handling. The objective was to optimise the material flow regarding the demand fluctuations and machine specifications.
6. **Sridharan (2013)** the purpose was to prove that experimental design was an utilisable method not only for product development and process improvement but it can also be used effectively in the design of material handling–transfer systems and performance optimisation of automation technologies, which were to be integrated to the firms.

Statement of the problem:

The significance of advanced manufacturing systems in cost efficiency viewpoints motivates decision makers (DMs) to consider the optimal design and maintenance as well. Despite adding flexibility and more accuracy via automation, availability of the system is crucial to get back the investments and obtain a confident benefit. An obvious concept for the availability is reliability consideration.

3.0 Methodology:



The flowchart of the work

Mathematical formulation:

Two policies are modelled mathematically using three objective functions with the corresponding constraints. As we employed the reliability merit to assess the availability of an FMS, and while reliability depends on machines and AGVs in the proposed FMS, it is significant to include the effective aspects of the system in mathematical modelling. Here, the mathematical optimisation model is given. As stated before we aim to maximise the total reliability of machines in shops in the whole jobshop system, maximise the total reliability of the AGVs, and minimise the total repair cost in the system.

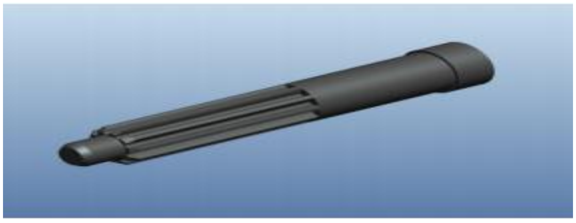
Maximising total reliability of machines:

Due to the sequence of the process plan, availability of the shops being dependent to the reliability of machines is significant to satisfy the demand constraint. Therefore, determining the machines that are more available is important to justify the jobshop FMS availability. The following mathematical notations are employed to model this maximisation problem. Note that, the model is looking for the more reliable machines such that the job plan is fulfilled**.**

Finite Element Analysis of Spline Shaft:

Modeling:

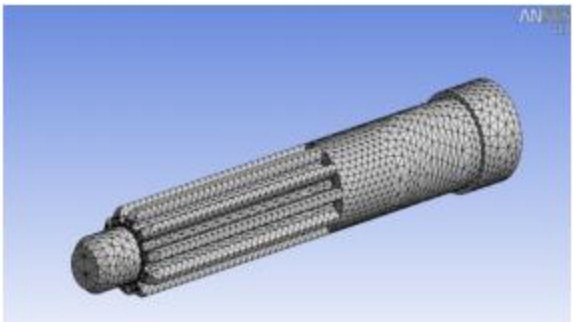
The Spline shaft of model was created in CATIA software as shown in figure by taking the dimension from table1 and exported to ANSYS12 using ".iges" format. Thin Shell 187 was considered as the element type and material properties were given for Structured Steel. Then meshing was done for areas using Quad meshing. After this the shaft is fixed at one end and torque is applied at other end. Then the model is solved and FEA results are plotted.



Model of Spline Shaft

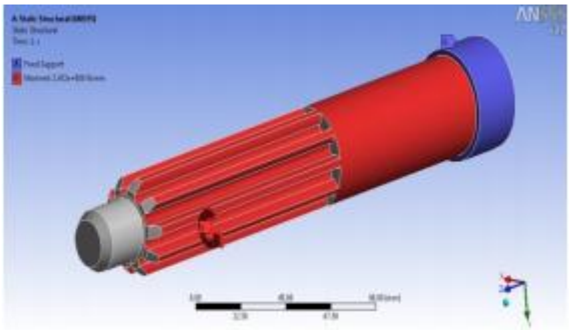
Meshing and Boundary Condition:

Finite element analysis is a numerical method in which a particular body is subdivided into discrete partitions (called elements) that are bound by nodes. Each element is connected to adjacent elements by the nodes.



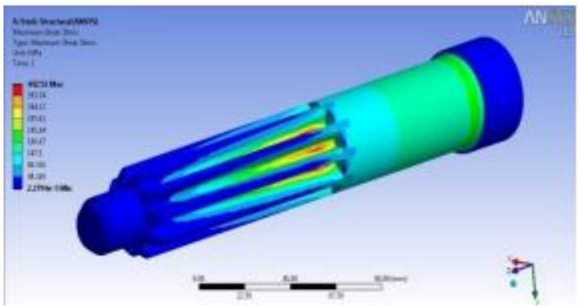
Meshing of Spline Shaft

4.0 Results and discussions:



Applying Torque

A Torque of 2472 N/mm2 is applied on spline shaft as indicated by circular arrow "B". The following procedure is adopted in ANSYS. Preference → Loads → Define load → Apply → Structural Force/Moment → On nodes → Define load → Apply → Moment= 2472 N/mm2.



Maximum Shear Stress

Displacement and stresses distribution:

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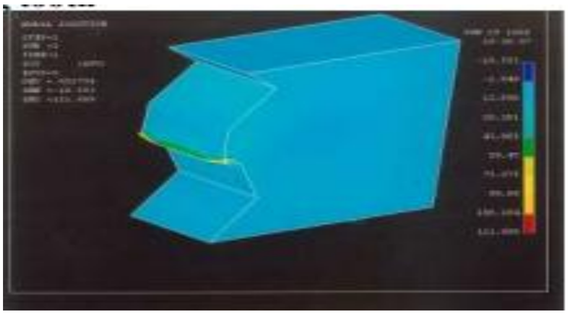
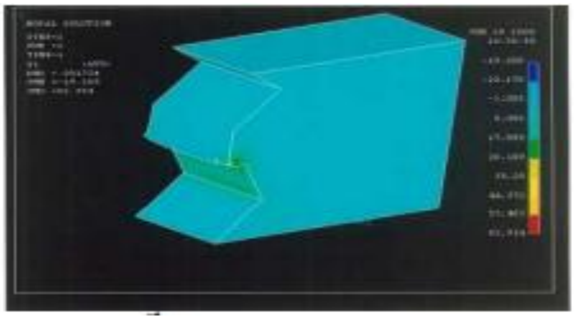
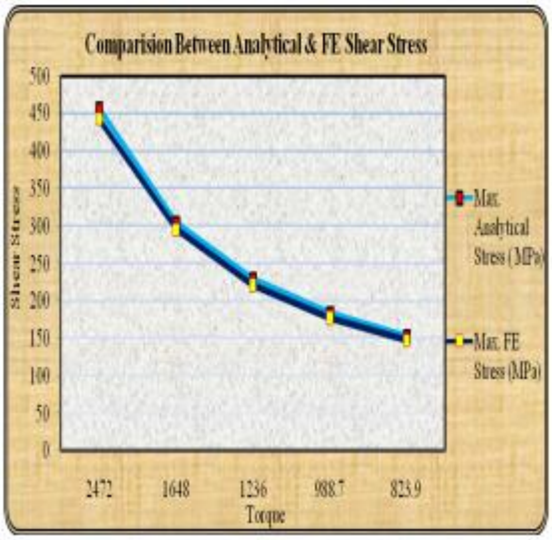


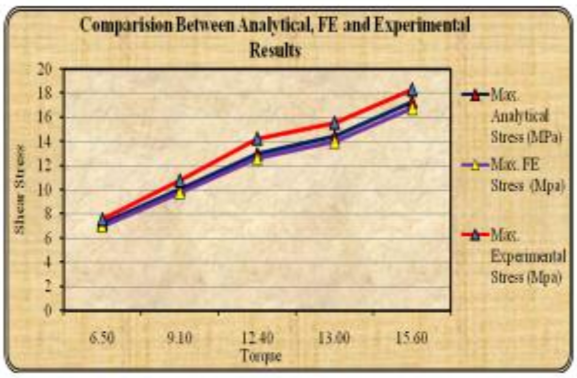
Stress with Finite elements



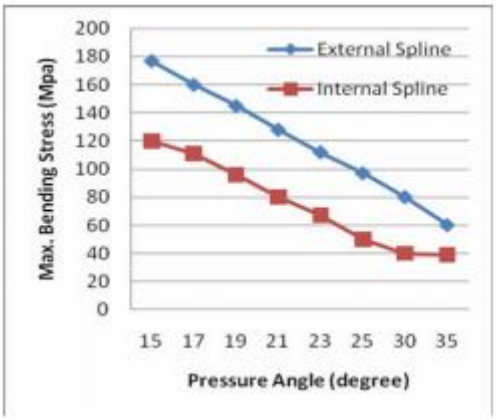
Principal stress distribution



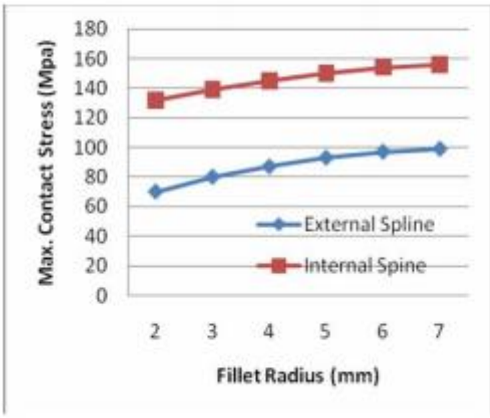
Comparison Between Analytical and FE Shear Stress



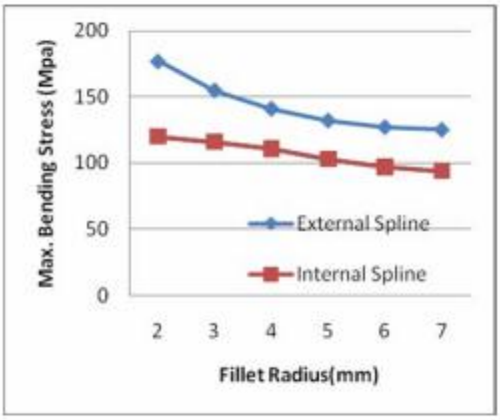
Comparison Between Analytical, FE and Experimental Shear Stress



Variation of bending stress for external and internal spline with pressure angle



Variation of bending stress for external and internal spline with pressure angle



Variation of bending stress for external and internal spline with pressure angle

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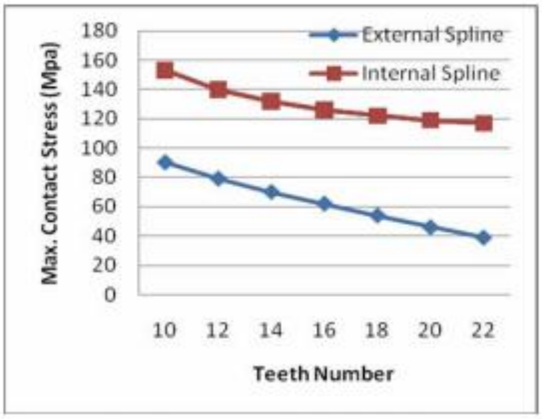

Variation of bending stress for external and internal spline with pressure angle

Multi-objective mathematical model was capable to function as a reliability assessment model. The numerical study illustrates an integrated determination of reliable AGVs and machines so that the repair cost is also considered. Clearly, more reliable system requires timely repair and maintenance operations incurring more costs. Therefore, the multi-objective aspect of the model provides a trade-off between the reliability, to be maximised, and the cost, to be minimised. The chosen AGVs and machines in shops need to be fortified to keep their confidence levels and availability and the ones not chosen should be analysed by the maintenance team for increasing their reliabilities.

Above figure shows that the principal stress distributes exponentially along the axial direction of the BFSC tooth and that the principal stresses induced in the spline shaft are higher than the principal stresses induced in the sleeve because of the difference between their geometry especially their root radiuses. They also shows that the principal stress distributes exponentially along the axial direction of the BBSC tooth and it distributes evenly due to the symmetric boundary conditions at its both ends. They said that the principal stresses induced due to applying cyclic impact load are higher than the principal stresses induced due to applying impact load with high different percentage depends on the number of cycles per unit time and the total loading time. The increasing in stresses results from accumulating the stresses induced at each cycle. It defines that increasing the amount of the applied load increases the induced principal stresses and the increasing is linear because the stresses are linearly related to the amount of applied load. It investigates the significant effect of the engagement length on the principal stresses where it shows that increasing the engagement length reduces the principal stresses with a high ratio due to increasing the area that carries the load

CONCLUSIONS:

The variations of cutting force per tooth are constant for different pitch values, for a given rake-angle. • The total Broaching force varies with pitch value for a given rake angle due to the variations in number of teeth in engagement. • The stress plot against depth of cut shows uniform increase of stresses, the stresses are increasing with decreasing of rake angles due to higher cutting forces. The stress analysis of spline shaft is carried out theoretically for various loading conditions and these results are verified by FE analysis and experimental analysis. From above discussion it is observed that maximum shear stress is found at the root section of spline. From the FE analysis of spline shaft it can be concluded that the shear stress is maximum at the root section of spline near the rigid end as compare to free end.

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