Literature Review Matrix

**Source 1:**

**Citation:** P. Walker, N. Zhang, " Active damping of transient vibration in dual clutch transmission equipped powertrains: A comparison of conventional and hybrid electric vehicles," *Mechanism and Machine Theory*, Vol. 77, pp. 1-12, 11 February 2014 [Accessed 2 February 2015]

**Purpose:** To investigate the active damping of automotive powertrains for suppression of gear shift related transient vibrations. This paper presents an approach for active suppression of transient responses utilizing only the current sensors available in the powertrain. An active control strategy for manipulating engine or electric machine output torque post gear change via a proportional-integral-derivative controller is developed and implemented.

**Why is this Study necessary?** The major trends in the automotive industry is to improve the overall efficiency of passenger vehicles. Majority of these losses in efficiency is through the powertrain, but this efficiency comes at a cost. The more efficient a powertrain is, the more uncomfortable the drive quality becomes. This study is used to make the more efficient duel-clutch transmission a more pleasurable driving experience, therefore more acceptable to be introduced to a wider market.

**Methods:** By studying the rotational speeds of the two clutches and vehicle speed with respect to time, the powertrain oscillations become very clear. The process is broken up into four parts; the shift preparation phase, the torque phase, inertia phase, and the post shift phase. By adjusting certain sensors, already incorporated into the transmission, and rewriting the throttle programming a smoother shift can occur. This experiment was performed on a standard duel-clutch transmission on a conventional internal combustion engine and a duel-clutch transmission installed on an electric/hybrid vehicle.

**Results:** Using the active vibration reduction control strategies discussed in this paper, the vibration reduction was significant. The electric motor of the hybrid motor was capable of faster response to varying torque demands, as the internal combustion engine was limited by the delay in piston firing and the ability to supply high torque variation while maintaining vehicle speed.

**Conclusion:** While powertrain vibration during gearshifts can never be eliminated, the suppression of this vibration can provide a dramatic difference in the overall driving experience. On the electric motors an inertia phase control motor was able to be greatly reduce powertrain vibration due to its ability to adjust torque almost instantaneously due to its motor feed-back loops. This reduction in vibration will provide the driver a more comfortable driving experience without sacrificing any performance.

**Project Integration:** While the focus of our project is to design a duel clutch transmission we must not overlook the importance of the control system. This paper will be referenced when it comes time to begin developing the control system. This paper has inspired me to try to develop, in its control system, a way to monitor engine torque and use this information and control to better time the clutch switching process. While developing an inertia phase controller is not possible for an internal combustion engine, the slight adjusting of throttle position during shifts could provide a smoother transmission system.

**Source 2:**

**Citation:** Y. Hu, L. Tian, B. Gao, H. Chen, ” Nonlinear gearshifts control of dual-clutch transmissions during inertia phase,” *ISA Transactions*, Vol. 53, pp 1320-1331, 31 March 2015 [Accessed 2 February 2015]

**Purpose:** To investigate the effects of a nonlinear gearshift controller by using the back stepping method to improve shift quality of vehicles with a duel-clutch transmission. The controller is rearranged into a concise structure which contains a forwarding control and a feedback control. This closed loop error system is then input to a state stability theory, to improve the overall effectiveness of the controller.

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**Methods:** Using simulation software, a complex car was designed using a model to simulate the engine, transmission, drivetrain, and road conditions. The proposed nonlinear controller was then used to calculate clutch response during the inertial stage of the gear shift. This experiment was then conducted at various speeds and different road conditions to track the error within the controller for different dynamic situations. An experiment rig was built with a hydraulic pump and was used to simulate the real responsiveness of the hydraulic actuated clutches.

**Results:** Using the nonlinear system controller the overall error within the back stepping and forwarding control was equal or reduced compared to the traditional controller. The nonlinear controller achieved this faster and required less computational power to achieve these results. The back stepping controller is robust enough to handle driving condition variations, and can obtain better control performance than the PID controller.

**Conclusion:** The back stepping technology integrated into the system controller allowed the controller to converge on the tracking error more quickly than the more conservative, current system controller. This improves the overall shift quality of the transmission while performing on various road conditions

**Project Integration:** The design and fabrication of a duel-clutch transmission is going to be no easy feat. I hope that we will get to the point of having to reference this paper to achieve a more effective and faster system controller. This paper can be referenced to aid in the setup of our own mat lab and Simulink experiments. The mathematical formulas noted in this paper will go a long way to helping us understand the intricacies of the whole simulation process.

**Source 3:**

**Citation:** P. Walker, N. Zhang, “Modelling of dual clutch transmission equipped powertrains for shift transient simulations," *Mechanism and Machine Theory*, Vol. 60, pp. 47-59, 13 September 2012 [Accessed 2 February 2015]

**Purpose:** To investigate the two main assumptions when vibration tests are performed on powertrain systems. The first assumption to be tested is the application of minimal degrees of freedom for the powertrain model and second, the use of a mean engine torque model to describe engine torque. These assumptions will be compared to a truer to life twelve degrees of freedom and a variable engine torque model that will better simulate the engine of an automobile.

**Why is this Study necessary?** With more and more research being conducted in the field of powertrain control and integration, the ability to properly analysis these new controllers needs to be as true to life as possible. Why perform research based on a simulated transmission that is perfectly machined with exact tolerances or perform these simulations on perfectly flat strait roads? None of these things exist. More true to life simulations need to be performed to aid in the research and development of these new technologies.

**Methods:** Using simulation software, a more accurate model was made to simulate the vibrations that occur within the engine, transmission, and clutches. These test were then compared to same tests used following the two basic assumptions listed above. They added ten new degrees of freedom within the transmission to accomplish a more thorough analysis. Simulations where performed on two different transmission designs with two different engines to achieve the most accurate results.

**Results:** The more accurate model indicated a more true to life representation of the vibrational analysis of the duel-clutch transmission. The added degrees of freedom allows for further analysis of different components of the transmission. Further vibration analysis of the clutches and clutch housing allow for more developments in further research. The more accurate model will provide a better baseline for further development.

**Conclusion:** The comparison of different modeling strategies were used to investigate two assumptions made for dynamic modelling and control of duel-clutch transmissions and the impact that the more accurate model had on vibration analysis and variations to system controllers. Simulation of the engine harmonics using the detailed model will allow for much more accurate results in future model testing.

**Project Integration:** Once we design our duel clutch transmission this paper will be referenced to aid in the setup and performance of our simulations. The higher degree of detail will further aid in indicating areas that need improvement and will result in an overall better product. This form of in-depth simulation will simulation will help us locate potential problems before we move on to the prototyping stage.

**Source 4:**

**Citation:** X. Lu, H. Chen, B. Gao, Z. Zhang, W. Jin, “Data-Driven Predictive Gearshift Control for Dual-Clutch Transmissions and FPGA Implementation,” *IEEE Transactions on Industrial Electronics*, Vol. 62, no. 1, pp. 599-610, 19 December 2014, [Accessed 2 February 2015]

**Purpose:** To investigate the effect on shift shock and shift quality using a data-driven predictive gearshift control. This controller will aim to pursue a real-time improvement of the hardware computing speed of the data-driven predictive controller based on a field-programmable gate array. This controller will rely on other sensors around the vehicle to predict the next gear that will be selected, allowing for even faster shifts into the next gear by pre-loading it.

**Why is this Study necessary?** The duel-clutch transmission is the perfect balance between efficiency and performance. This predictive transmission controller will increase the performance of an already very fast shifting transmission. This will entice the market share that still values the overall performance of their automobiles to transition to the duel-clutch transmission, which is more efficient than previous automatic transmissions. Since we are designing this transmission to go on a future Formula SAE competition racecar, the quicker our car can shift, the better we will be in competition

**Methods:** Using simulation software, a simulated engine, transmission, and rear tire set were used to analyze the vibrations and shift speeds of the duel-clutch transmission. Using a predictive algorithm based on throttle position, clutch speeds, and output torque to pre-load the next gear based upon the inputs to the control system. The system was tested on different driving conditions and under different engine loads.

**Results:** The comparison between a well-tuned standard controller and the predictive controller were much the same when it comes to shift speeds, but the predictive system had lower fluctuations and performed better under fluctuating loads. The predictive controller handles the varying input-output data more quickly and adapted to the road conditions in a faster manner.

**Conclusion:** Aiming to improve the overall shift quality of the duel-clutch transmission, the predictive control system tries to accommodate the conflicting control requirements of a faster shift time while minimizing vibrations felt within the drivetrain. The robustness of the predictive controller is proven by the simulations of various road conditions. Further analysis will be performed on a hardware-in-the-loop experiment along with a real vehicle test

**Project Integration:** Our group has discussed the possibility of using a somewhat predictive system by using the throttle position sensor and engine speed to preload the next gear to be used. This is a very complicated program and this study will be referenced when it comes time to start designing the control system.

**Source 5:**

**Citation:** M. Farish,“ Changing up a gear,” *Automotive Manufacturing Solutions*, Vol. 15, no. 3, pp. 53-55, March 2014, [Accessed 2 February 2015]

**Purpose:** To discuss the logistical and technological requirements to place a transmission manufacturer into operation. The 90,000 sq.m factory will produce 500,000 highly sophisticated nine speed transmissions. The paper covers the methodology for selecting the workforce and the need for two-way development between the engineers and the manufacturers.

**Why is this Study necessary?** The manufacture and production of the transmission is a highly complex undertaking. The need to have the proper machines and personnel to operate them efficiently and safely is paramount. This paper also explains that the necessity for engineers to work alongside there more hands on counterparts. A breakdown in communication could cause a plant to have to shut down or worse someone could be injured.

**Methods:** Using top of the line mills, lathes and CNC machines, the factory is able to produce top of line transmissions of very high quality. The plant plans to implement a certain degree of automation that will aid in the production process. By having properly trained machinists and engineers the product is of high enough quality to be sold to Aston Martin and Audi.

**Results:** The production floor of this plant in South Carolina is able to produce over 500,000 transmissions a year, with that number rising to 800,000 by the end of 2016. The skills and flexibility of the South Carolina workforce is a crucial asset for the operation of the plant. The two-way development in personnel has yielded an overall more powerful workforce that will be able to handle any situation safely and efficiently.

**Conclusion:** The advanced training and constant communication between the engineers and the shop floor have allowed the production plant to manage the mix of widely varying product volumes and identities. Then plant intends to increase its ability to handle the mechatronic capability of the plant to be able to build a complete assembly. This may very well dictate the final overall price of the vehicle and where it will be assembled and tested.

**Project Integration:** To me, the most important part of this article is the strategic operations between the engineers and machinists. Much in the same way as the factory, we have people within our group that may not be on the same level academically, but those people are generally better at the machining and manufacturing process. A balance must be reached between the two groups for this project to succeed, and as this paper points out, the way to bridge the gap between the two groups is to have constant and productive communication.

References

1. P. Walker, N. Zhang, " Active damping of transient vibration in dual clutch transmission equipped powertrains: A comparison of conventional and hybrid electric vehicles," *Mechanism and Machine Theory*, Vol. 77, pp. 1-12, 11 February 2014 [Accessed 2 February 2015]
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4. X. Lu, H. Chen, B. Gao, Z. Zhang, W. Jin, “Data-Driven Predictive Gearshift Control for Dual-Clutch Transmissions and FPGA Implementation,” *IEEE Transactions on Industrial Electronics*, Vol. 62, no. 1, pp. 599-610, 19 December 2014, [Accessed 2 February 2015]
5. M. Farish,“ Changing up a gear,” *Automotive Manufacturing Solutions*, Vol. 15, no. 3, pp. 53-55, March 2014, [Accessed 2 February 2015]